## RETS <br> Practical Guide Book Series

# 5ㅂNEERNE DRAW/NB AND ESTIWAIES 

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RETS

## PRACTICAL GUIDE BOOK SERIES

## ENGINEERING DRAWING AND ESTIMATES

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## PREFACE

The success of any project / work in engineering field depends largely on the planning prior to taking up the work. In civil engineering this is even more important as the variables are many more than in any other discipline. Attempts are made by most big organizations for standardization in design, material specifications and working practices yet this can not replace the importance of understanding planning and design process at the field level. On Indian Railways, all planning starts at the level of Field supervisors and is to be translated into proposals by the Draftsmen and Estimators in the Drawing office. The present book on "Engineering Drawing and Estimates" is an attempt to compile the good practices prevalent in the Indian Railways for several decades.

One of the first steps for preparing the drawing and estimate is fixing specifications of work, materials and workmanship. This aspect has largely been covered under RETS's earlier publications in the 'Practical Guide Book Series'. The present book focuses on the specific requirements of preparing Engineering Drawings and Estimates. The idea of the book is to give sufficient confidence, even to a fresh JE (Drawing), JE (Works), JE (Bridge) and JE (P.Way) in understanding the requirements and taking up any planning assignment and carrying it out independently. It is also expected to be of great help to experienced and seasoned Section Engineers, as large amount of information which is scattered in several files, codes, manuals and above all the wisdom of old stalwarts in the Railway would be available at one place.

The book has been divided into 3 parts. Part 1, deals with Engineering drawings starting from the basics like using properly the drawing instruments to detailed drawings including reinforcement detailing and Yard Plan. Chapter on Planning of stations is sure to open new visions to planners. Part 2, deals with basics of estimation of quantities, adopting unit rates of items and finally preparing estimates and tender schedules. Part 3, has been made to give some useful data and information which are required by SE (Drg) in day to day use. The treatment on various subjects has been kept simple, precise and the bias is towards practice rather than theory, to be of use to a practicing engineer.

To my knowledge there is no written material available in one place on the subject, specially catering to the needs of Railway Engineers. The material has been collected from various sources like W.Railway (HQ), BCT division, Manmad Bridge Workshop, SBI Engineering workshop, Pune division, Construction offices of Pune, BB etc to name a few. I would like to place on record the help given by Shri. V.S.Wadekar, DyCE(C), PA who has enthusiastically supplied the various inputs, Sh V.N.Sohoni, SE(Br)/IRICEN, Sh.N.K.Khare, AP(W)/IRICEN and Sh.K. Narayan PS/I/IRICEN for assisting in preparing the material for the book. Last but not the least Shri Naresh Lalwani, Senior Professor, IRICEN apart from contributing to several chapters has gone through the script and given several valuable suggestions.

I hope this book will meet the objective to act as a Guide Book, and help draftsmen, estimators and field engineers in doing their work more efficiently and with confidence. This by no means is all exhaustive and can be further improved with the suggestion from the readers including the constructive criticism, which is welcome.

(A.K.Goel)

President, Railway Engineering Technical Society and

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## CHAPTER - I

## DRAWING INSTRUMENTS AND MATERIALS

### 1.0 Drawing Instruments:

A person required to draw any engineering drawing must have good knowledge of drawing instruments and their uses. Proper instrument should be used for different functions in drawing. The drawing instruments should be of good quality as any error in the instrument would affect accuracy of the drawing.

Commonly used instruments by draughtsman as under,
i. Drawing board
ii. T-square
iii. set-square
iv. mini drafter
v. scales
vi. Protractor
vii. French curves
viii. Drawing Instrument box
ix. Pencils
$x$. Drawing Pens

### 1.1 Drawing board :

Drawing board is used to support drawing sheet. It has plain surface on top. The left edge is used to support T -square is called as working edge. This edge is made up of hard material like Ebonite. The board is always in perfectly right angle at all the corners. Drawing board is made of strips of well seasoned soft wood about 25 mm thick. These strips are joined together with two battens, perpendicular to these strips, from back side. These battens are screwed to the strips.

Drawing boards are available in the following sizes:

| Board | Size |
| :--- | :--- |
| B0 | $1000 \times 1500$ |
| B1 | $700 \times 1000$ |
| B2 | $500 \times 700$ |
| B3 | $350 \times 500$ |



### 1.2 T-square:

T-square is used to draw horizontal lines, to support the set-square when drawing perpendicular or angular lines and it supports the stencils while lettering. It is made of two strips of hard wood joined together at right angle with screws. The short strip is called as stock and long strip is called as blade. Now the T-squares are also available in transparent plastic material. The edge of the stock is placed in contact
of working edge of the drawing board and blade lies on the drawing sheet. The top edge of the blade is chamfered and it is smooth edge perfectly at right angle to the working edge of the drawing board.


### 1.3 Set-Square :

Set-squares are used to draw perpendicular lines, inclined lines in $30^{\circ}, 45^{\circ}$ and $60^{\circ}$. It is also used for drawing parallel lines. The setsquares are made of transparent plastic. They are available in two shapes one is $30^{\circ}-60^{\circ}$ setsquare, another is $45^{\circ}-45^{\circ}$ set-square.


### 1.4. Ruler :

The ruler is used to draw straight lines with specific length and to measure distances. It is made of plastic or stainless steel. Generally one foot ( 300 mm ) long scale is used for drawing. It has two working edges and both are tapered or beveled. Both the edges are marked with divisions one side marked
 with metric system i.e. centimeters and subdivided into millimeters; other side is marked with inches. While inking the drawing scale should be used from opposite side i.e. the beveled edge towards paper. It makes gap between paper and scale at beveled edge so that the ink does not spread.

### 1.5 Protractor :

The protractor is used to measure angles. It is made of transparent plastic. The
 protractors are available in semi circular and circular shape but the semi circular is commonly used. It has straight edge at bottom called as base of protractor. This base is marked with horizontal line marked with $0^{0}$ and a small mark on the centre of line. The circumference of semi circular edge is gradually marked with angles of $1^{\circ}$ and $10^{\circ}$ starting from $0^{\circ}$ to $180^{\circ}$, each section of 10 degree divided in two parts, on circumference it is divided into 10 parts for convenience of measuring one degree.

### 1.6 Mini drafter :

It is a small machine having two scales perpendicular to each other and a protractor at their junction. It has two arms with mechanism which keeps scales always in parallel to their original position. It is used for drawing straight lines parallel to each other, horizontal lines, vertical lines, perpendicular lines, inclined lines in particular angle and particular length.
 It combines the functions of T-square, set-squares, scales and protractor.

### 1.7 French curves:

French curve is a template made out of plastic, composed of many different curves. It is used in manual drafting to draw smooth curves of varying radiuses which can not be drawn with compass.

The French curve is placed on the drawing sheet and a pencil or pen is traced around its curves to produce the desired curve. Three most common French curves are shown in figure. The one on the far left side is most commonly used for hyperbolas; the smaller one on the far right side is suited for ellipses. The large one below is used most for parabolas. The French curve is used to draw a smooth line through predetermined points. After the points are plotted, a light pencil line should be sketched to connect the points in a smooth flowing line. To draw the finished line over the freehand line, match the various parts of the French curve to various segments of the freehand
 curve. Avoid abrupt changes in curvature by placing the short radius of the French curve toward the short radius portion of the line to be drawn. Change your position around the drawing board when necessary so that you can work on the side of the French curve that is away from you. You should avoid working on the "under" side of the French curve. Place the French curve so that it intersects at least two points of the line. When drawing the line along the edge of the French curve, stop short of the last point intersected. Then move the French curve along to intersect two or three more points and make sure that the edge of the curve connects smoothly with the line already drawn. When using the irregular curve, you can draw a perfectly smooth curved line by plotting enough points.

In the Railways the curves of $1^{0}, 1^{1 / 2} 2^{0}, 13 / 4^{0}, 2^{0}, 3^{0}, 4^{0}, 5^{0}, 6^{0}, 7^{0}, 8^{0}$ etc. are used with different scale.

### 1.8 Drawing instrument box :

The drawing instrument box consist of compass, divider both in set of large and small size with different attachments.

## a) Compass :

Circles and circular curves of relatively short radius are drawn with COMPASSES. The large compass is satisfactory for drawing circles of 20 mm . to about 250 mm in diameter without an extension bar. One of the legs is equipped with a setscrew for mounting either a pen or a pencil attachment on the compass. There is also an extension bar which can be inserted to increase the radius of the circle drawn. The other type of compass found in the drawing instrument
 set is the bow compass. Many experienced draftsmen prefer the bow compass over the normal compass. The bow compass is much sturdier and is capable of taking the heavy pressure necessary to produce opaque pencil lines without losing the radius setting. There are two types of bow compasses. The location of the adjustment screw determines the type. The bow pen and bow pencil are the center adjustment type, whereas other bow instruments are the side adjustment type. Each type comes in two sizes: large and small. Large bow compasses are usually of the center adjustment type, although the side adjustment type is available. The large bow compasses are usually about 150mm long; the small, approximately 100 mm long. Extension bars are available for large bow compasses. Bow compasses are available as separate instruments, or as combination instruments with pen and pencil attachments.
b) Spring/Bow compass :

For drawing circles of small diameter and arcs of comparatively smaller radius, small spring compass is used. This has a spring on top which make tension on legs to remain opened outside at bottom end. An adjustable screw is provided at the centre. This screw gives precision in adjusting the radius.

## c) Divider :

Dividers are used to transfer measurements, to step off a series of equal distances, and to divide lines into a number of equal parts. DIVIDERS are similar to compasses, except that both legs are provided with needle points. The instrument set contains two different types and sizes of dividers: large 150 mm hairspring dividers and small center adjustment bow dividers. The large compass may also be used as dividers. As with compasses, dividers are available in large and small sizes, and in pivot joint, center adjustment bow, and side adjustment bow types. Normal dividers are used for measurements of approximately 20 mm or more. For measurements of less than 20 mm , bow dividers should be used. When setting the compass to a given radius or when setting divider points, never place the sharp points of these instruments on the scale. Lay out the desired radius or distance on a straight pencil line by using the scale in the manner described below. Then adjust the compass or dividers to the indicated length by using the measured line. A scale
surface marred by pinpricks is difficult to read and is unsuitable for accurate work. In making successive measurements along the same line, make as many measurements as possible without moving the scale. If a number of distances are to be laid out end to end, hold the scale in one position and add each successive measurement to the preceding one. If the scale is moved to a new position each time, slight error in measurement may accumulate. For example, four successive measurements of $15 / 8 \mathrm{in}$. each should give an overall length of $61 / 2 \mathrm{in}$., not 6-9/ 16 in. Therefore, make as many measurements as you can without changing the reference point. This will avoid cumulative errors in the use of the scale. Note that your pencil touches the scale only for the purpose of marking a point on the paper. Never use a scale as a straightedge for drawing lines. A typical office ruler has a metal edge; it is a scale and straightedge combined. But a draftsman's measuring scale is for measuring only; it is not a ruler. A scale properly used will last for decades, but a scale used as a straightedge will soon have the graduations worn away.

## d) Lengthening bar :

Some other attachments are also available in the instrument box like lengthening bar, which is used for drawing bigger radius circles or arcs. This is attached to the compass by removing the pencil point of a leg.
e) Another attachment is pen holder. This can be placed in one leg of compass by removing pencil point of a leg.

### 2.0 Drawing Pencils and Pens :

### 2.1 Drawing Pencils :

Drawing pencils are different from the ordinary pencils. The drawing pencils are available in series of grades. In the series of grade H stands for Hard and B stands for soft, the number in front of the letter stands for grade of hardness or softness. In the series of $B$, softness of pencil increases from $B$ to $6 B$. On the other hand hardness increases from H to 6 H in the series. The HB grade stands in the middle of these grades.


For the average drafting assignment, three or four pencils are usually sufficient. A hard pencil, 4 H or 5 H , should be used to lay out the drawing in light construction and projection lines. A medium pencil, H or HB , is then used to darken the required lines and to make arrowheads and lettering. The grade of drawing paper you use will also determine which pencil you choose for making a drawing. A soft, roughtextured paper usually requires a softer pencil for layout work, since a hard pencil would leave indentations in the paper and thus spoil the appearance of the drawing. One way to find out if you are using the proper pencils on a drawing is to make a blueprint (reproduction) of the drawing. If the reproduced lines do not appear, or

appear too light, use a softer pencil. If, on the other hand, lines appear too dark in relation to other lines, use a harder pencil. You may be able to vary the weight of lines by the amount of pressure exerted on the pencil, but this should not be attempted without experience. Bearing down on a hard pencil to produce darker lines may cause grooves in the paper. Another way to find out if you are using the proper pencil is to hold your drawing up to a light and view it from the back side. Pencil adjustment is the same as in the previous method. Of course, both methods apply only when transparent drawing paper is used. To sharpen a pencil, cut the wood away from the unlettered end with a draftsman's pencil sharpener or a penknife. The lettered end should be left intact so that the grade of pencil can always be identified. The cut should be started about $11 / 2 \mathrm{in}$. from the end, leaving a half inch of lead exposed. To produce a conical or needlepoint (view B), which is best for general use, tate the pencil between the fingers at the same time as the exposed lead is rubbed back and forth across the full length of the sandpaper pad (view C). The resulting needlepoint should be dulled slightly by drawing it lightly across a piece of scrap paper several times. Avoid sharpening pencils near your drawing. Graphite particles will cause smudges that are difficult to erase. A cloth or tissue should be used to wipe away graphite particles that cling to the pencil after it is sharpened. A wedge point (view D) will aid an experienced draftsman in the extensive drawing of straight lines. This point is produced by sharpening a pencil to the conical point just described, then flattening both sides on the sandpaper pad. For an elliptical point, hold the pencil firmly with thumb and fingers and cut the lead on the sand- paper pad by a back-and-forth motion, keeping the pencil at an angle of about 25 degrees to the pad. Continue until a flat ellipse is formed, as shown in (view E). A good draftsman never uses a dull pencil.

### 2.2 Ink Pen :

Ink pens are numbered depending upon the thickness of line they draw and these numbers are used for identification of pen size. These pens are available either as individual fountain pen units, resembling a typical fountain pen, or as a set, having a common handle and interchangeable pen units. The pen shown below is a part of a set of technical fountain pens.


B


These pens may also be used for any work that a regular technical fountain pen is used for.

### 2.3 Processes of Using the Technical Fountain Pen :

One must hold the technical fountain pen so that it is perpendicular to the drawing surface at all times. If you don't hold the pen in the correct manner, the point will bevel or wear unevenly and eventually form an elliptical point. With the point in this condition, the pen will produce lines of inconsistent widths. To fill the reservoir of a fountain pen, use the knob located on the barrel opposite the point. When you turn the knob counterclockwise, a plunger is forced down into the barrel forcing out any ink remaining in the reservoir. Place the point end of the pen into the ink and turn the knob clockwise to pull the plunger up. As the plunger is pulled up, ink is drawn through the point, filling the reservoir. To fill the ink cartridge type of pen, remove the cartridge from the body and insert the ink bottle dropper all the way into the reservoir cartridge. Place the dropper in contact with the bottom of the reservoir cartridge to prevent the ink from forming air bubbles. Fill the cartridge to approximately three-eighths of an inch from the top, then replace the cartridge and clamp ring.

### 2.4 Drawing with a technical fountain pen/ Care and Cleaning of the Technical Fountain Pen :

The feed tube of the pen point is threaded .Along this threaded portion is an inclined channel that allows air to enter the ink reservoir. This channel must be free of dried ink or foreign particles to ensure correct ink flow. When cleaning the pen, scrub the threads and channel with a brush, such as a toothbrush, wetted with a cleaning solution of soap and water. A cleaning pin (a tiny weighted needle) is made so that it fits into the feed tube and point. This cleaning pin assures a clear passage of ink from the reservoir to the point. Usually, a light shake of the pen will set the cleaning pin in motion, removing any particles that settle in the tube when not in use. (Do not shake the pen over your drawing board.) If the pen is not used frequently, the
ink will dry, clogging the point and feed tube. When the pen becomes clogged, soak the pen in pen cleaner or ammonia water until it will unscrew with little or no resistance. A better practice is to clean the pen before you put it away if you know in advance that you will not be using it for several days. The cleaning pin must be handled with care, especially the smaller sizes. A bent or damaged cleaning pin will never fit properly into the feed tube and point.

### 2.5 Drawing Ink :

A draftsman's drawing ink is commonly called INDIA INK. Drawing ink consists of a pigment (usually powdered carbon) suspended in an ammonia-water solution. Ink that has thickened by age or evaporation maybe thinned slightly by adding a few drops of solution of four parts aqua ammonia to one part distilled water. After the ink dries on paper, it is waterproof. Drawing ink is available in many different colors, but for construction and engineering drawings, black ink is preferred for reproduction and clarity.

### 3.0. Drafting templates/stencils :

DRAFTING TEMPLATES are timesaving devices that are used for drawing various shapes and standard symbols. They are especially useful when shapes and symbols must appear on the drawing a number of times. Templates are usually made of transparent green or clear plastic. They are available in a wide variety of shapes, including circles, ellipses, hexagons, triangles, rectangles, and arcs. Special templates are available for symbols used on architectural drawings, mechanical drawings, and maps. Templates for almost every purpose are available from the well-known drafting supply companies.

### 4.0 Drawing Medium :

### 4.1 Drawing Sheets:

The drawing sheets used for all the technical drawings in any field of engineering should be of standard size, including those produced through computer. It maintains similarity among all the drawings and easy to store. The drawing sheets, computer prints of drawings and blue-print sizes recommended by the Bureau of Indian Standards (B.I.S.) as per SP-46 (1988) are given below:

| Sheet Designation | Sheet Size( mm ) |
| :--- | :--- |
| A0 | $841 \times 1189$ |
| A1 | $594 \times 841$ |
| A2 | $420 \times 594$ |
| A3 | $297 \times 420$ |
| A4 | $210 \times 297$ |

The drawing sheets are available in two qualities one is off-white and other is super white, both are available in 180 GSM and 240 GSM.

### 4.2 Tracing paper :

Tracing paper is a translucent paper which is used for making drawing. The drawings on this paper are more durable than the normal drawing sheet. More copies and Ammonia Prints are possible for the drawings on tracing paper.

Tracing papers are available in 80, 90,100,130 GSM. We can take computer printouts on the tracing paper. For printing with inkjet printer special type of tracing paper is to be used. It is available in cut-sheets of size A4, A3, A2 etc. The rolls of tracing paper are also available in the width of $610 \mathrm{~mm}, 914 \mathrm{~mm}$ and 1016 mm and the length of the roll is 18.2 m .

Most of the drawings that one prepares will be drawn on tracing paper. One will use tracing paper to copy or trace drawings either in pencil or in ink and also prepare most of original pencil drawings on tracing paper. This type of paper is especially suited for reproduction of blueprints. However, it tears easily and becomes soiled after repeated handling. When making a drawing directly on tracing paper, you should place a smooth sheet of white paper below it. The whiteness of this sheet (called a platen sheet) gives better line visibility, and its hard surface makes it possible to draw good pencil lines without grooving the tracing paper. Do not use gritty erasers on tracing paper, especially when ink is to be applied. If at all erasures to be used, use a green or red ruby eraser, which is only slightly abrasive. Abrasive erasers wear away the surface. Erase carefully so you don't tear the drawing. A light back-and-forth motion works best. If the surface of the drawing becomes scratched by erasing, it can be partially smoothed by burnishing the damaged area with a hard, smooth object or your thumbnail. Water, perspiration, or graphite from your pencil will ruin drawing paper. In order to keep moist hands or arms from marring the drawing, use a clean sheet of paper as a mask to protect the drawing surface next to the work area. Between drawing sessions you should protect unfinished drawings by covering them. Tracing paper must not be folded. The crease marks will damage the lines on the drawing and cause blurred prints when the drawing is reproduced. For that matter, no drawing should ever be folded. Drawings and tracings should be either stored flat or rolled and placed in cylindrical containers. Prints or drawings larger than 8-1/2 inches by 11 inches may be folded so that they can be filed in standard filing cabinets.

### 4.3 Tracing cloth :

The drawings which are to be stored for longer periods should be made on tracing cloth. It has lot more inherent qualities compared to tracing paper. Drawings on tracing cloth do not lose clarity or colour even after storing them for years. It has better handling characteristics than ordinary tracing paper. It rarely crumples or form wrinkles. It is unaffected by harmful pests like white ants. Tracing cloth has better dimensional stability than tracing paper. Tracing cloth rolls are available in width of $100 / 102 \mathrm{cms}$ and the length of roll is 18 meters.

### 4.4 Reproducible Tracing Film :

(Ferro-print Film): Reproducible Film - RTF (Reproducible Tracing Film) is used to take print of original drawing on the tracing film, with this process as many numbers of copies as required may be obtained at any time. The copies will be appreciably clear. The correction/alteration/ additions can be made on RTF Copy with water proof ink by using rottering pens. It becomes a new tracing drawing with required changes and it can be used for taking ferro-prints like normal drawing. The RTF film is available in the market in roll of width 914 mm and 1016 mm .

### 5.0 Attachment of paper to the board :

The sheet should be placed close to the left edge of the drafting board. Working in this area makes the T square easier to handle and reduces the likelihood of error because of $T$ square "swing." The drafting sheet should be far enough from the bottom of the board (about 75mm) to ensure firm support for the head of the Tsquare when you are drawing at the lower part of the sheet. After aligning the drawing sheet, smooth out any wrinkles and fasten the four corners with short strips of drafting tape (Cello Tape serves equally well). If one is attaching large sheets, place additional strips of tape at the top and bottom edges of the sheet. Drafting tape has a lighter coating of adhesive than does masking tape. Consequently, it will hold the drawing firmly, yet can be removed without tearing or marring the drawing. Avoid the use of thumbtacks; they will eventually ruin the drafting board. If you are using a parallel straightedge or drafting machine instead of a T -square, the procedure just described is the same with one exception. Instead of placing the paper close to the left edge of the board, you should place it approximately at the midpoint of the length of the parallel straightedge or in the center of the drawing board surface when you are using a drafting machine.

### 6.0 Size of drawing sheets and tracing sheets :

$X$ and $y$ are the sides of the sheet.
Two sheets of smaller size can be obtained by folding the bigger sheet along the length. The areas of two sizes are in the ratio 1:2 i.e. $2-\mathrm{A} 1$ sheets can be cut from A 0 sheet, two-A2 sheets can be cut from 1-A1 sheet and so on. This
 is shown in the sketch below.
The basic principle involved in arriving of sheet sizes $x: y=1: \sqrt{2}$ where $x$ is the length and $y$ is the width.


Sizes of the trimmed sheets of all drawings, except yard plans, should be as given in Table below. All plans required to be of longer length will be in the form of a roll, keeping the width as specified. The size to be used would depend on the extent of details required; the IRWM (Para 903) stipulates the sizes of various drawings as under.

| No. | Sheet <br> Designation | Trimmed Size <br> $(\mathbf{m m})($ WxL) | Purpose |
| :--- | :--- | :--- | :--- |$|$| 1. | A0 | Index Plan and Section. General <br> arrangement and detailed drawings for <br> road over bridges, major/ important bridge <br> works \& important structures, building <br> (steel and concrete) etc. |  |
| :--- | :--- | :--- | :--- |
| 2. | A1 | $594 \times 841$ | General arrangement. |
| 3. | A2 | $420 \times 594$ | Temporary arrangement \& detailed <br> drawing for bridge works, steel structures, <br> building and temporary arrangement <br> drawings for Sr. No.1 above. |
| 4. | A3 | Site plans for road over/road under <br> bridges, passenger platform coverings, <br> buildings etc. and drawings for minor <br> detailing. |  |
| 5. | A4 | Alans for inclusion in Works Programme <br> booklets for handy reference, PERT <br> charts of works of limited activities etc. |  |
| 6. | Depending on the size of a yard, yard plans should be prepared in the <br> trimmed widths of 841 mm or 420 mm or 210 mm. The length of the yard <br> plans should not be more than 1189 mm when they are not intended to be <br> kept as a roll. Yard plans can be in parts, if necessary, maintaining the <br> scale for the drawing. |  |  |

### 7.0 Scale of Drawings:

One could, if necessary, determine the dimensions of the drawing by arithmetical calculation; for example, on a half-scale drawing, you divide each of the actual dimensions of the object by 2 . However, this might be a time- consuming process if you were drawing a map of a certain area to a scale of $1 \mathrm{~cm}=50 \mathrm{~m}$ or $1 / 5000$. Consequently, you will usually scale a drawing up or down by the use of one or another of a variety of scales. This sense of the term scales refers to a graduated, ruler like instrument on which scale dimensions for a drawing can be determined by inspection. Scales vary in types of material, shapes, style of division, and scale graduations. Good quality scales are made of high-grade boxwood or plastic, while
inexpensive scales are sometimes made of yellow hardwood. The boxwood scales have white plastic scale faces that are permanently bonded to the boxwood. The graduation lines on the boxwood scales are cut by a highly accurate machine. Plastic scales, while less expensive than boxwood scales, have clear graduations and are reasonably accurate. Scales are generally available in four different shapes, as shown in figure 2-23. The numbers in the figure indicate the location of the scale face. The triangular scale provides six scale faces on one rule. The two-bevel flat scale provides two scale faces on one side of the rule only. The opposite-bevel flat scale provides two scale faces, one on each side of the rule. And the four-bevel flat scale provides four scale faces, two on each side of the rule.

The scale is an important factor of the drawing. To represent a bigger size objects on the drawing, proper scale should be used. Scale is the ratio of the dimension taken in the drawing and actual size of object, means one unit shown in the drawing shows how many units of the actual object.

### 7.1 Types of Scales :

The scale are represented or expressed on the drawing in either of the following manner.

## i) Engineering scale :

The scale is represented as the relation between measurement taken in the drawing and the actual dimension of the object. It is shown numerically with unit of measurement like $1 \mathrm{~cm}=15 \mathrm{~m}$.

## ii) Representative fraction :

The ratio of measurement taken in the drawing and the actual dimension of the object is represented in fraction.

$$
\text { R.F. }=\frac{\text { Length onthe drawing }}{\text { Actual length of object }}
$$

For example 1 cm on the drawing represents 15 m of the object, Then the R.F. $=1 \mathrm{~cm} /(15 \times 100 \mathrm{~cm})$ i.e. R.F. $=1 / 1500$. This is usually represented as $1: 1500$.

## i) Graphical scale :

Now-a-days the drawings are prepared on computers. While taking printouts we have various choices of paper size, in this case scale given in the numerical value or units will be not applicable. In such cases graphical scale is generally used which changes with the change of size of print and stands correct for drawing. This scale is drawn on the drawing itself with showing measurement units on it.


Scale

The scale chosen for a drawing will depend upon the complexity of the object to be shown and the purpose of the representation. In all cases, the selected scale shall be large enough to permit easy and clear interpretation of the information depicted. Some times details are too small and can not get clear in the main drawing, dimensioning is also difficult in such view so a detail view should be shown separately in larger scale near main drawing.

Following are the standard scales readily available material in the market: (Adopted as per B.I.S.: SP-46)

| Designation | Description | Scale |
| :--- | :--- | :--- |
| M 1 | Full size | $1: 1$ |
|  | 50 cm to 1 m | $1: 2$ |
| M 2 | 40 cm to 1 m | $1: 2.5$ |
|  | 20 cm to 1 m | $1: 5$ |
| M 3 | 10 cm to 1 m | $1: 10$ |
|  | 5 cm to 1 m | $1: 20$ |
| M 4 | 2 cm to 1 m | $1: 50$ |
|  | 1 cm to 1 m | $1: 100$ |
| M 5 | 5 mm to 1 m | $1: 200$ |
|  | 2 mm to 1 m | $1: 500$ |
| M 6 | 3.3 mm to 1 m | $1: 300$ |
|  | 1.66 mm to 1 m | $1: 600$ |
| M 7 | 2.5 mm to 1 m | $1: 400$ |
|  | 1.25 mm to 1 m | $1: 800$ |
| M 8 | 1 mm to 1 m | $1: 1000$ |
|  | 0.5 mm to 1 m | $1: 2000$ |

### 7.2 Recommended scale for Engineering Department drawings:

The drawings should be prepared as per recommended scales (as per IRPWM Para 211) and are reproduced below.

| S. No. | Type of Drawing | Scale |
| :--- | :--- | :--- |
| 1. | Index plan \& sections |  |
|  | a. Horizontal | $1: 50,000$ |
|  | b. Vertical | $1: 1000$ |
|  | Detailed plan \& sections |  |
|  | a. Horizontal | $1: 5000$ |
|  | b. Vertical | $1: 500$ |
| 3. | Land plans |  |
|  | a. Normal | $1: 5000$ |


|  | b. Where normal scale does not admit sufficient <br> details with clarity |  |
| :--- | :--- | :--- |
|  | c. For congested areas in large towns as special use | $1: 1000$ |
|  | Station yard plans |  |
|  | a. Normal | $1: 1000$ |
|  | b. Enlarged | $1: 500$ |
| 5. | Block plans of properties \& site plan | $1: 1000$ |
|  | Bridge drawings |  |
|  | a. Working drawings | $1: 100$ |
|  | b. Detailed drawings | Scale as <br> convenient |
|  | Building drawings |  |
|  | a. Plans of buildings | $1: 100$ |
|  | b. Detailed drawings | Scale as <br> convenient |

All drawings except sketch plans should be drawn to scale. The scale or scales of a drawing should be indicated at the appropriate place in the title block. Where different scales are used for details, the corresponding scales should be shown under each relevant detail.

Details those are too small for complete dimensioning in the main representation should be shown adjacent to the main representation in a separate detail view or section which is drawn to a larger scale, normally done in a balloon or a block. Recommended scales for details are 1:2, 1:5, 1:10, 1:20 and 1:50.

## CHAPTER - II

## BASIC SKILLS OF DRAWING

### 1.0 Drawing Lines:

(a) The draftsman's horizontal line is constructed drawing from left to right along the working edge of a T square, This working edge, when true, is perpendicular to the working edge of the drafting board. When you draw horizontal lines, keep the working edge of the T-square head in firm contact with the working edge of the drafting board. The pencil should be inclined to the right at an angle of about 60 degrees, with the point close to the junction of the working edge and the paper. Hold the pencil lightly and, if it was sharpened with a conical point, rotate it slowly while drawing the line to achieve a uniform line width and preserve the shape of the point. Normally, when a series of horizontal lines is being drawn, the sequence of drawing is from the top down.
(b) Vertical lines are produced parallel to the working edge of the drafting board by using set-squares in combination with a T-square. One leg of a set-square is placed against the working edge of the blade and the other faces the working edge of the board to prevent the draftsman from casting a shadow over his work. Lines are drawn from the bottom up. The pencil is inclined toward the top of the working sheet at an angle of approximately 60 degrees, with the point as close as possible to the junction of the triangle and the drafting paper. Sequence in drawing a series of vertical lines is from left to right. At no time should the lower edge of the Tsquare blade be used as a base for set-squares.
(c) The direction or angle of inclination of an inclined line on a drafting sheet is measured by reference to the base line from which it is drawn. Inclined lines at standard angles are constructed with the T-square as a base for set-squares used either or in combination. Used in combination with the T-square as a base, the setsquares serve as guides for producing lines at intervals of 15 degrees. Used singly, the 45-degree triangle will divide a circle into 8 equal parts; the $30^{\circ} / 60^{\circ}$ triangle will divide a circle into 12 equal parts. For drawing lines at angles other than those described above, you should use a protractor.

To measure an angle, place the center mark of the protractor at the vertex of the angle, with the 0-degree line along one side. Then note the degree mark that falls on the side. To lay off an angle, position the protractor as above and use a needlepoint or a sharp-pointed pencil to mark the desired values. Then project lines from the vertex to these marks.

To draw a line parallel to a given line adjust the hypotenuse of a set-square in combination with a straightedge (T-square or set-square) to the given line; then,
holding the straightedge firmly in position, slip the set-square to the desired position and draw the parallel line along the hypotenuse. To construct a line perpendicular to an existing line, use the set-square and straightedge in combination, with the hypotenuse of the set-square resting against the upper edge of the straightedge. Adjust one leg of the set-square to a given line. Then slide the set-square along the supporting straightedge to the desired position and draw the line along the leg, perpendicular to leg that was adjusted to the given line. In the same manner, angles with multiples of 15 degrees may be drawn, using the triangle combinations.

## (d) Curved lines:

Basically there are two types of curved lines: circles and segments of circles, called arcs, which are drawn with a compass; and noncircular curves, which are usually drawn with French curves. For drawing of curves one grade softer pencil is selected. For dim construction lines, use 4 H leads. Avoid using leads that are too short. The compass lead should be sharpened with a single elliptical face. A sandpaper pad works best for sharpening compass leads. The elliptical face of the lead is normally placed in the compass so that it faces outward from the other compass leg. Adjust the shoulder-end needlepoint so that the point extends slightly farther than the lead. With the needlepoint pressed lightly in the paper, the compass should be centered vertically when the legs are brought together. Bow compasses and normal compasses are used in the same manner. To draw a circle with a compass, lightly press the needlepoint into the drawing paper and rotate the marking leg around it. Always rotate the compass clockwise. As you rotate, lean the compass slightly forward. With a little practice, you will find that you can easily draw smooth circles using only the thumb and forefinger of one hand. It is important that you use an even pressure as you rotate the compass. You may find it necessary to rotate the compass several times to produce a circle with a uniform dense black line. When you wish to set the compass to draw a circle of a given diameter, use a piece of scratch paper and follow the steps listed below.
a) Draw a horizontal line with a straightedge.
b) With the straightedge as a base, use a set-square and draw a vertical line intersecting the horizontal line.
c) Measure the radius of the circle with a scale and draw a second vertical line from this point.
d) Set the needlepoint at the intersection of the first vertical line and the horizontal line. This is the center of the circle.
e) Set the marking leg to fall on the intersection of the second vertical line and the horizontal line.
f) Draw a half circle with the compass.
g) Check your diameter established work by measuring the by this half circle with a scale. Once you have set the compass to the exact radius of the
circle, handle it very carefully so that you don't disturb the setting. Set the needlepoint at the center of the circle and carefully rotate the compass to draw a line describing the circumference of the circle.
When you are using the pencil leg to draw circles smaller than 25 mm in radius, keep the adjustable pencil and needle legs straight. For larger circles, both legs should be adjusted so that they are perpendicular to the paper. On the other hand, when you are using the compass with the pen leg, you MUST adjust it at the hinge joint to keep it perpendicular to the paper for all sizes.

If the pen is not perpendicular to the paper, ink will not flow properly. To draw large circles, insert the extension bar in the pen or pencil leg. When the extension bar is used to draw large circles, the process of using the compass with only one hand becomes awkward hence both hands should be used.

### 2.0 Order of penciling a drawing.

The recommended step-by-step procedures, is as follows:
a) Draw all center lines.
b) Draw the principal circles, arcs, fillets, rounds, and other compass-drawn lines. A fillet is a small arc that indicates a rounded concave joint between two surfaces. A round is a small arc that indicates a rounded convex joint between two surfaces.
c) Draw the horizontal and vertical outlines, visible lines, and hidden lines.
d) Draw the non-horizontal and non-vertical outlines, visible lines, and hidden lines.
e) Clean up the drawing, erasing all excess lines and construction lines. A construction line is a light line used as a drawing guide only.
f) Draw extension lines, dimension lines, section lines, and any other lines required.
g) Inscribe the dimensions and lettering. To a limited extent you can vary the thickness of a pencil line by varying the extent to which you bear down on the pencil. However, you can't bear down very hard without troughing the paper. Therefore, you can't get much variety in line weight with a pencil. For a drawing that will be inked over, this doesn't make any difference. However, for one that will not be reproduced, or which will be reproduced directly from the pencil original, you must follow, as nearly as you can the line conventions.

### 2.1 Order of Inking :

Nowadays, draftsmen prefer the reservoir pen or rapidograph to the ruling pen for inking straight and curved lines and even for lettering. On the other hand, the ruling pen should NEVER be used to ink freehand lines. One good way to avoid smeared ink lines is by using SPACE BLOCKS. These strips of tape or thin pieces of plastic, when fastened to both faces of the set-squares, French curves, or templates,
raise their edges from the surface of the drafting paper and prevent ink from running under the edge. When you use a rapidograph or reservoir pen with a T-square or parallel straightedge, make long lines with a whole arm movement and short lines with a finger movement. Draw horizontal lines from left to right, starting at the top of the drawing and working down. (If you are left-handed, you will, of course, draw these lines from right to left, and similarly reverse many of the directions given here.)

Vertical lines are usually drawn in an upward direction, moving from left to right across the drawing. However, when you have to draw a number of vertical lines or lines slanted in the same direction, the way you draw them will be governed by the source of your light and the way you have found that you can draw vertical lines with greatest control. Let the first lines dry before starting to draw any intersecting lines. Watch carefully when you draw one line across another line. You vary the thickness of ink lines by selecting a pen unit that matches your desired application and/or line convention.

The order generally recommended for inking is as follows:
a) Inking of a drawing must start from the top of the paper and progress toward the bottom.
b) Start inking all arcs of circles, fillets, rounds, small circles, large circles, and other compass-drawn lines.
c) Ink all irregular curves, using a French curve or a spline as a guide.
d) Ink all thick horizontal lines, then all medium and thin lines.
e) Start at the left edge and ink the thick first, the medium next, and finally the thin vertical lines from left to right.
f) Follow the same procedure described in (d) and (e) for slanting.
g) Ink section lines, dimensions, and arrowheads.
h) Ink notes and title, meridian symbol, and graphic scales.
i) Ink borders and check inked drawing for completeness.
j) Use an art gum or a kneaded eraser to erase pencil marks or for final cleanup of the drawing.

### 3.0 Lines:

Normally only sketching is done with pencils. The correct grade pencil should be used for different lines. H grade pencil should be used for object lines or out lines. H grade pencil is also used for lettering on drawing. H 2 grade pencil should be used for all other thin lines like dimension lines, hatching lines, centre lines, hidden lines etc.

When drawings are drawn with rotring pens -0.3 or 0.4 pen should be used for object lines or out lines and for lettering on drawing. The 0.2 pen should be used for all other thin lines like dimension lines, hatching lines, centre lines, hidden lines etc. Border lines of sheet should be drawn with 0.5 pens.

### 3.1 Convention of Lines:

Various types of lines are used in engineering drawing. Each line has specific indication and to be used for specific purpose.
Following table shows some of the lines and their use in drawing:

| S. <br> No. | Line | Description | Application |
| :---: | :---: | :---: | :---: |
| 1. |  | Continuous Thick line | Visible outlines of object, Object Lines |
| 2. | - | Continuous Thin line | Imaginary lines of intersection, Dimension lines, Projection lines, Leader lines, Hatching lines, Section lines, Extension lines |
| 3. | ~~~ | Continuous thin freehand line | Cutting of small objects.Cutting of objects when proportion length is not possible to show in drawing. Limits of partial or interrupted views and sections, if the limit is not a chain thin line. |
| 4. | $\sim \sim$ | Continuous thin straight with zigzags | Long-break line |
| 5. | - - - - | Dashed line | Hidden linesHidden edges |
| 6. | -------------. | Centre line | Centre line, Lines of symmetry |
| 7. | -"-.--.-.- | Chain thin, thick at ends If direction is changed then thick at change of direction | Cutting Plain lines, Alternate position of moving part. |

### 3.2 Types of lines:

a. Object line or out line :

It is a continuous thick line. Object line is drawn to represent edges and surface boundaries of the object or structure which are visible in the particular view. This line is prominent form all other lines in drawing of the object. To draw the object line H grade pencil should be used, whereas in case of ink drawing 0.5 or 0.3 mm rotring pen should be used.
b. Section lines:

Various sectional views are prepared, in those views cut surface area is shown by hatching angular thin lines. Section lines are drawn in the area to which cutting plane is touching or cutting. For section lines 2 H grade pencil should be used and in ink drawing 0.3 or 0.2 mm rotring pen should be used for section lines except for the object line.

## c. Hatching line :

These are also thin lines but not necessary it should be continuous. The specific objects are indicated by particular type of hatching. All the lines used in this regard should be thin hatching lines. The standard patterns of hatching lines are also available for specific indication like masonry wall, UCR etc.

## d. Centre line :

This is a line made of alternate long dash and small dash with pattern. This is also a thin line than the object line. This line shows the centre of the particular object and items like circle, arc, building, column, wall etc. This line is also used to indicate axes of cylinder, sphere, cone etc. The centre line should be extended for short distance beyond the object.
e. Dimension line :

It is a continuous thin line with pointed arrows on both the ends. This line terminates at the perpendicular extension line, centre line etc.
f. Extension lines:

This is a line extended to facilitate the dimension and to mark exact ends of the distance. This line is generally used in pairs. There should be slight gap between the object and the start of the extension line, in other word extension line should not touch the object. The extension line should be slightly extended beyond the dimension line.

## g. Leader lines :

This is also a continuous thin line with an arrow at one end. On the other end reference note or number should be written.
h. Cutting plane lines:

It is a line made with the pattern of a long dash and two small dashes. The end dash and corner dashes are thick dashes. This line indicates the location of cutting plane of the section.

## i. Hidden line :

This line is made of small dashes. This is also a thinner than the object line. This line indicates inner and hidden edges of the object which are not visible from this side of view.

## j. Border line :

This line is used to drawing border of drawing sheet. This line is thicker than all other lines. To draw this line HB or B pencil should be used and in ink drawing 0.6 to 1 mm rotring pen should be used.


Use of different lines

### 4.0 Lettering :

Lettering is a very important part of engineering drawing. It is used to show dimensions, labels, important particulars, titles, notes etc. The lettering on the drawing should be done clear, neat and uniform. Stencils help to obtain uniformity, especially where different people are working on same set of drawings. Use of stencils for lettering takes considerable time, hence careful free hand lettering is preferable. Efficiency in the art of lettering can be achieved by careful and continuous practice.

Lettering is to be done on the drawing in such a manner that it may be read when the drawing is viewed form bottom edge. When lettering is required to be written in a direction at right angles to the bottom edge of drawing, it is so written as to be read when viewed from the right hand edge of the drawing.

The text is identified by a nominal outside height size (h). The preferred text sizes used are (in millimeters) $2.5,3.5,5,7,10,14$, and 20 . Stencils are available as per description of height of letters.

Lettering is generally done in capital letters. Lowercase letters are never used on construction drawings, although it is acceptable to use them for notes on maps or similar drawings. Different sizes of letters are used for different purposes. The main titles are generally written in 6 mm to 8 mm size, sub-titles in 3 to 6 mm size, while notes, dimension figures etc. in 3 mm to 5 mm size. The drawing number in the title block is written in 10 to 12 mm size.

### 4.1 Single Stroke lettering :

Normally single stroke lettering is used for engineering drawing. This is very simple
lettering and easy to do free hand. The thickness of the line of the letter should be uniform. The horizontal lines of letters should be drawn left to right and vertical or inclined lines from top to bottom. Single stoke letters are of two types i) vertical and ii) inclined. The vertical letters are perpendicular to the horizontal where as inclined letters leaned to the right and the slope is $75^{\circ}$ with the horizontal.

### 4.2 Gothic letters :

These letters are thicker than the single stroke letters. In computers these are the bold letters. These are mostly used in main titles in the drawing. The outline of the letter is drawn first and then the gap between the out lines is filled. The thickness of the stem may vary from $1 / 5$ to $1 / 10$ of the


Fig. Gothic letters height of the letters.

### 5.0 Dimensioning :

All the sizes of the object are to be indicated by dimensioning. It should never be required of the user of the drawing to measure and scale down the measurement.
 Dimension represents actual size of object. A dimensioned drawing should provide all the information necessary for a finished product or object. A numerical value expressed in appropriate units of measurement and indicated graphically on technical drawings with lines, symbols and notes. There are generally following conventions to show dimensions on the drawing. (a) By arrowheads (b) By intersecting lines and (c) by solid dots at end of line Dimension line is a thin continuous line with arrows on both the ends. Sometimes it may have dots or inclined lines at the end. This is associated with two Extension or projection lines perpendicular to it. The arrow head is approx. 3 mm long and 1 mm wide i.e. the length is about 3 times the width.
 The extension lines should not touch the object i.e. there should be gap between object and extension line. This line also extended beyond the dimension line. There should be gap between the dimension line and figure of the dimension as shown below.

Centre lines are used for symmetric objects and also used for showing centre of the circles and holes. Dimensions should generally be done directly on the centre line.


Leader line with Arrow Leader line with Dot

Leader line is a part of dimension used to give labels or additional information, note about the object. It is a thin line has a arrow at one end and text on the other side. Sometimes it may have dot instead of arrow. If arrow is used it should touch the edge of object and if dot is used it should go within the object.

While preparing drawing in Auto CAD we have to set dimension style according to our requirement and drawing size. The parameters to be set are Arrow size, letter size, gap between object and extension line, extension of extension line beyond dimension line, gap between text and dimension line etc.

### 5.1 Features of Dimensions:

a) Dimension figures shall be placed near the centre either in the space of broken line or immediately above the unbroken dimension line.
b) Normally the dimension shall be placed outside the object or at the best suitable location.
c) All dimensions should be so arranged that they may read either from the bottom or from right hand edge of the drawing.
d) A drawing shall use the same unit for all the dimensions within it. Dimensions should show units with the figure of measurement or there should be note at the bottom like 'All dimensions are in mm'. In general, units can be omitted from dimensions if a statement of the units is included on the drawing. The general convention is to write dimension in millimeters.
e) All dimensions less than 1 should have a leading zero. i.e. 45 should be written as 0.45 . A zero must always precede the decimal point when the dimension is less than zero.
f) Each feature shall be dimensioned once only on a drawing.
g) Dimension shall be placed on the view that most clearly shows the corresponding features.
h) Functional and measurable dimensions should be shown directly on the drawing.
i) The extension lines or dimension lines should not cross each other unless it is unavoidable.
j) A dimension line shall be shown unbroken where the feature to which it refers is shown broken.
k) Dimensioning should be done so completely that one need not to do calculation or assumption for any required dimension.

### 5.2 Systems of Dimension :

On the basis of direction of measurement figure are
a) Unidirectional system :

In this system dimension figures or numerical are so placed that they can be read from only one direction, normally the bottom edge of the drawing sheet. The dimension lines are broken near the

middle for inserting the dimensions. This system is mainly used on large drawings where it is inconvenient to read dimensions from the right-hand side. In this system the dimension is not placed above the dimension line.
b) Aligned system :

In the aligned system the dimension figure or numerical are placed perpendicular to the dimension line in such a way that are rotation according to the dimension line. In this system the dimension can be placed above the dimension line.

### 5.3 Common Practices of Dimensioning :

a. Continuous dimensions :

All dimensions of a face are arranged in one line. An overall dimension is placed below small dimensions. Sometimes one small dimension is omitted.


Continuous Dimension


Progressive Dimension
b. Progressive dimensions:

The dimensions are placed with reference to common point or common base line. Cumulative error is avoided by this method but it takes more space for dimensioning.
c. Small distance dimensions :

When small distance is to be dimensioned arrow heads can be taken outside the extension line as shown in the figure leaving a gap between the extension lines. When two or more small dimensions to be shown contiguously, a dot must be put in between two dimensions instead of an arrow.


Fig. Small dimensions

## d. Angular Dimensions:

Angular dimensioning is different than the linear dimensioning. Type of angular dimensioning is depending on size of angle and space available for dimensioning. When there is less space available inside the angle and more space on the outside then arrows should be taken outside the angle. For small angles lettering shall also be taken outside
 of angle.

### 6.0 Layout of drawing sheet :

The layout of the drawing on the drawing sheet should be done in such a manner as to make its reading easy and speedy.

### 6.1 Margin, frame and Grid Reference :

Frame is a line limiting the drawing space and shall be drawn all around at specific distance from edge of sheet. The frame should be thick line about 0.5 mm and prominent on drawing. The recommended size for border or frame is 20 mm wide for sheet sizes $A_{0}$ and $A_{1}$ and 10 mm for sheet sizes $A_{2}, A_{3}$ and $A_{4}$.

It is good practice to use drawing space in the sheet by leaving 20 mm space to the left side and 10 mm form all other side inside the frame. The rectangles of the grid should be referred by means of capital letters A, B, C, $D$ etc. along one edge and numerals 1, 2, 3, 4 along the other edge. The numbering direction may start at the sheet corner opposite to the title block and be repeated on the opposite sides. (Ref. BIS: SP-46 - 1988)


The provision of Grid reference system is recommended for all sizes of sheet to locate particular part of drawing on the sheet for giving reference while additions, alterations, modifications etc. The drawing sheet should be divided into parts and the number of divisions should be divisible by two. It is recommended that the length of any side of the rectangles comprising the grid shall not be less than 25 mm and not more than 75 mm . This is particularly useful, while drawing details of small parts of a bigger assembly drawing. In civil engineering drawings however, grid reference system is not used.

### 6.2 Title Block :

The title block should be provided in the bottom-right corner of the drawing sheet. The size of the title block recommended by the B.I.S. (SP-46) is 170 mm wide maximum and height 65 mm which can be changed if required for accommodating more details. In the plans, as per Works manual also, size more than A3 the title

block should be of size $170 \mathrm{~mm} \times 65 \mathrm{~mm}$. following basic information should be given in the title block. Title block should preferably consist of one or more adjoining rectangles. These may be divided sub-divided into separate boxes for specific information. The direction of the viewing of the title block should correspond with that of the drawing.

The title block should contain following information:
i. Name of the Railway
ii. Name of Division/Construction organization
iii. Name of work
iv. Title of the drawing
v. Reference to sanction particulars
vi. Scale of drawing and reference to standard drawing, if any
vii. Drawing number
viii. Completion drawing number / main drawing no.
ix. Dated initials of the concerned officials
$x$. Alterations, if any, with full particulars (alteration block is normally a separate block, abutting the title block).

Signature part of the title block will be increased or decreased as per number of officials signing the drawings. The title of the drawing should be clear and self explanatory.
6.3 Drawing number: Drawing number should be unique.
i) The record of the old drawings should be maintained. For the purpose of maintaining records and numbering of the drawings in a methodical manner, a register, book or a master file should be used for the systematic allocation of drawing numbers with a Card Index for ready reference. A system of straight consecutive numbering should be adopted. It will be advantageous to indicate the year of the drawing (the last two digit only) along with the drawing number and separated by a stroke. For example a drawing may be numbered as CE's Drg. No.25642/99 or CE's Drg. No. 25642/2000 or CE's Drg. No. 25642/01 and so on.
ii) When a drawing covers several sheets for convenience in handling, as in the case of a longitudinal section of a railway or road project, the same CE's Drawing number should be given to all the sheets in the series with the consecutive sheet number given within brackets after the CE's Drawing number. For example, a sheet should be designated as CE's Drg. No. 223344 (4 of 10) which will indicate that the drawing is the $4^{\text {th }}$ of 10 sheets of as CE's Drg. No. 223344. All such sheets should be of the same size.
iii) A key diagram showing the index of sheets should be given, where necessary, at the bottom of the sheet to indicate at a glance all the drawing sheets contiguous to the sheet under consideration.

No. of sheet and total number of sheets of the set, in case of multiple drawing sheets marked with the same number should be indicated by means of a sequential sheet number on the total number of sheets in the following manner Sheet No. = n/p
Where $\mathrm{n}=$ sheet number and
$p=$ total number of sheets
(iv) If a drawing is cancelled or it supersedes a previous one, a note to this effect and the number of cancelled drawing should be recorded on the drawing. Correspondingly, the cancelled drawing should have an appropriate endorsement.

### 7.0 Revision / Alterations of drawings:

The revisions like alterations, additions or correction should be recorded and the same should be documented. Every change in the drawing shall be assigned with a revision number, letter or identification mark. The changes should be marked in the drawing and small description of changes should be mentioned in the revision block. The revision in the drawing should be made in the drawing in such a manner that it may be easily found. All changes shall be carried out preferably by putting as identification mark, so that the original version is also available in the drawing for information. If the drawing is completely revised then the revised drawing should be indicate the reference of the original drawing.
Revision or Alteration panel may be arranged in columns with headings (i) Revision/ Alteration No., (ii) Description or Brief record, (iii) Drawing and (iv) Approving Authority.

The heading of the column at bottom of column and the revision should be recorded in the relevant columns in horizontal rows. The next revision should be made in the next upper row likewise the revisions should be recorded from bottom to upwards as shown in para 6. The 'reference number' column shows the relevant revision number/letter or identification mark. The 'description' or 'Brief record' column shows the brief record of changes on the drawing. The 'drawn' column shows the dated initials of the person who carried out the changes in the drawing. The 'approving authority' column shows the dated initials of the approving authority.
The revision panel can also contain other information necessary for clarity regarding changes/revisions in the drawing. Such as what was the problem in the previous drawing and how it is solved by this alteration? Normally this can be shown in details brief record also.

### 8.0 Folding of drawings:

| $\begin{gathered} \text { SHEET } \\ \text { DESIGNATION } \\ \hline \end{gathered}$ | FOLDING DIAGRAM | LENGTHWISE FOLDING | CROSSWISE FOLDING |
| :---: | :---: | :---: | :---: |
| $\begin{gathered} \text { A0 } \\ 841 \times 1189 \end{gathered}$ |  |  |  |
| $\begin{gathered} \text { A1 } \\ 594 \times 841 \end{gathered}$ |  |  |  |
| $\begin{gathered} \text { A2 } \\ 420 \times 594 \end{gathered}$ |  |  |  |
| $\begin{array}{\|c\|} \text { A3 } \\ 297 \times 420 \end{array}$ |  |  | - |

Folding of the drawing or print should be made properly. It helps to fold or unfold the drawing without getting torn. It also helps to enhance the life of drawing. The folding marks are made in the drawing sheet as shown in the figure. All the large prints of sizes higher than the A4 size are folded to A4 sizes. The title block of all the folded prints appear in topmost position and visible on top after folding. The bottom most right corner shall be visible and have width not less than 190 mm . When prints are rolled for dispatch, they should be rolled with the title head outward i.e. the drawing should be rolled from left. The recommended folding is indicated below.
9.0 Geometrical Constructions: In the engineering drawing several geometrical constructions are required to be used for getting desire drawing. The draftsman must know these geometrical construction methods.

### 9.1 Bisecting a line:

Steps:
i) $\quad \mathrm{AB}$ is a given line.
ii) Take a compass, put the pointed needle on the point A
iii) Take the radius more than $A B / 2$ and draw arcs on either sides of the line $A B$.
iv) With the same radius put needle point on the point $B$ and draw arcs on either side of line $A B$ cutting the previous arcs at point PQ.

v) Draw the line $P Q$ by joining the points of intersection of arcs.
vi) The line $P Q$ is bisecting given line $A B$ at right angle.

### 9.2 Divide a line in equal number of parts:

Steps:
i) $\quad \mathrm{AB}$ is the given line. We have to divide it in (say) 5 equal parts.
ii) Draw a additional line from point $A$, with an acute angle with $A B$
iii) Take some distance in the two legs of compass. Put the pin on the point $A$ and mark an arc on line AC. Put the pin on point of junction of arc and line AC.
iv) Similarly draw 5 arcs on the line $A C$
v) Join the point $B$ and the last or 5th point on line AC
vi) Now draw the lines parallel to this line $B-5$, form each marking to intersect line
 AB.
vii) Thus the points on line $A B$ are dividing this in 5 equal parts.
viii) We can divide a line into any number of equal parts.

### 9.3.1 Bisecting an angle :

Steps:
i) Let the given angle is $\angle \mathrm{CAB}$ which we have to divide equally.
ii) Take some distance in compass, put pin point of compass at point A, draw an arc cutting the line $A C$ and $A B$ intersecting the lines $A B$ and $A C$ at point $D$ and $E$.
iii) Put the pin of compass on point $D$ take some distance in compass and draw an arc.

iv) Then put the compass with same radius at point $E$ and draw an arc cutting the previous arc. We will get intersecting point $F$.
v) Draw a line AF. This line is bisecting the given angle $C A B$

### 9.4 Tangential Arc to a line and a arc from inside: <br> Steps:

i) Let $A B$ is the given line and $C D$ is the given curve with radius R1 and centre O.
ii) We have to draw curve with radius $R_{2}$, tangential to the given line and an arc from inside. Take distance equal to $R_{2}$ in the compass. Put the pin of compass at any random point on the line $A B$ and draw a small arc above $A B$. Put the pin point of compass with same radius at another location on the line $A B$ and
 draw an arc as shown in figure.
iii) Draw a line $P Q$ tangential to both the arcs.
iv) Take distance in the compass $\left(R_{1}-R_{2}\right)$, put the pin point at point $O$. Draw an arc EF cutting the line PQ.
v) Take distance $R_{2}$ in the compass, put the pin point on the intersection of arc EF and line PQ. Draw the arc which is tangent to the given arc CD and the line $A B$.

### 9.5 Tangential arc to a line and given curve from outside: <br> Steps:

i) Let $A B$ is the given line and $C D$ is the given curve with radius R1 and centre O.
ii) We have to draw curve with radius $R_{2}$, tangential to the given line and the
arc from out side. Take distance equal to $R_{2}$ in the compass. Put the pin of compass on the line $A B$ at any random point and draw a small arc above $A B$. Put the pin point of compass at another location on the line $A B$ and draw arc as shown in figure.
iii) Draw a line PQ tangential to both the arcs.
iv) Take distance in the compass $\left(R_{1}+R_{2}\right)$,
 put the pin point at point O. Draw a arc EF cutting the line PQ.
v) Take distance $R_{2}$ in the compass, put the pin point on the intersection of arc EF and line PQ. Draw the arc which is tangent to the given arc CD and the line $A B$.

### 10.0 Engineering Curves:

When a solid like cone is sectioned/ cut, the surface produced at the cut face is one of the 3 Engineering curves. The 3 cases are as under.

Case 1: When the cutting plane is inclined to the axis and cuts only the generators on the apex side and is not cutting the base of the cone, the section made is an ellipse.
Case 2: If the cutting plane is inclined to the axis and is parallel to one of the generators, which is cutting the base and vertical axis of the cone,
 the section made is parabola.
Case 3: If the cutting plane parallel to the axis cuts the cone at one side of axis, means it cut the base but not cutting the axis of cone, the section made is called hyperbola.
10.1 Ellipse: Ellipse is symmetrical curve about its centre. There are two axis called major axis (AB) and minor axis (CD). The shape of ellipse depends on the measurement of these two axes. There are two points on the major axis on either side of the centre on the distance of half of the major axis from the end of minor axis. These are called focal or focus points. In figure shown as $F_{1}$ and $F_{2}$. The sum of the distances from any

point of the curve of ellipse to those two points is constant. Suppose $T$ is any point on the curve, then the distance TF1 + TF2 = constant.
Elliptical curves find use in concrete arches, stone bridges, dams, man holes etc. The ellipse has an important property which is used in the reflection of light and sound waves. Any wave that starts at one focus point will be reflected and pass through the other focus point. This principle is used in many structures for construction of whispering galleries. When a person whispers near one focus, it is heard at the other focus.

The eccentricity of an ellipse is denoted by e. It is the ratio of the distance between the focus points to the length of major axis. The eccentricity is necessarily between 0 and 1. Ellipse revolving on its axis gives ellipsoid. Ellipsoids are used for assumption of the shape of the earth and entire GPS system is based on that..

## Method of construction:

## Method 1:

1. The major and minor axes are given and we have to draw ellipse according to it. Draw a horizontal line $A B$ equal to major axis. Draw a perpendicular bisector line to $A B$ and mark point $C$ and $D$ at half of the minor axis distance on this vertical line.
2. Take distance $O B$ i.e. half of the
 major axis in the compass. Put the pin point at point C and draw arcs on both sides of minor axis cutting the major axis AB. We will get point F1 and F2. These are the focal points of the ellipse. The sum of distances of any point of the ellipse from these F1 and F2 is constant.
3. Mark some points on axis AB at any equal distances as shown 1, 2, 3, 4 etc. With the same distance mark points on other side of axis like 1', 2', 3', 4' etc.
4. Take radius of $A 1$ in the compass, put the pin point at $F 1$ i.e. centre at $F 1$ and mark arcs on both the sides of axis AB.
5. Take distance B1 with centre F2 mark the arcs cutting to the previous arcs.
6. With same manner mark points by arcs with centers $F_{1}$ and $F_{2}$, radius of distances of A2-B2, A3-B3, A4-B4 etc.
7. Repeat the procedure for other side of the ellipse for points $1^{\prime}, 2^{\prime}, 3^{\prime}$ and $4^{\prime}$. It is better to draw arcs simultaneously on both the sides.
8. Draw a smooth curve passing through the intersecting points. The achieved curve will be the ellipse with given major and minor axis.

Method 2: Concentric circle method:

1. We have given the major and minor axis of ellipse. Draw two circles of same centre point i.e. O, with radius half of the major and minor axis.
2. Mark the axis $A B$ and $C D$ in the figure which are perpendicular bisector of each other.
3. Divide the bigger circle into 12 equal parts. Mark the points as 1, 2,
 3...... 12.
4. Draw the lines joining these points with centre $O$ and cutting the small circle. Mark the intersecting points of small circle as 1', 2', 3' etc.
5. From point 1 draw perpendicular line to axis $C D$, similarly draw a line from point 1' parallel to axis $A B$.
6. Both the line will meet at point P1. Mark the point.
7. Similarly draw a line from point 2 parallel to axis $C D$ and a line parallel to axis AB from point 2'.
8. Mark the meeting point P2.
9. Repeat the procedure for all the 12 points.
10. Connect all the points P1, P2 etc with a smooth curve.

### 10.2 Parabola :

The curve parabola is a set of points in a plane that is equidistant from a fixed line and a fixed point in the same plane. Parabola is an open curve. The parabola curve is used in arch bridges. The mathematical equation of parabola is $y^{2}=4 a x$.

One of the nature's best known approximations to parabola is the path taken by a body projected upwards and obliquely to the pull of gravity, as in the parabolic projection of golf ball. Many bridge designs use parabolic supports, like Golden Gate Bridge in USA and Howrah Bridge in Calcutta.

If light or sound waves are placed at focus of a parabolic mirror or dish, the light will be reflected in rays parallel to axis. This is now used in head lamps, torches and reverse is used in audiences.

Parabola revolving on its axis gives paraboloid. Paraboloids are used for design of vehicle headlights etc.

## Method of construction:

## Method 1:

1. We have the given distance of the focus from the line is 60 mm . This line is called directrix.
2. Draw a vertical line $A B$ i.e. directrix. Draw a line CD perpendicular to line $A B$.
3. Mark the point $F$ at distance of 60 mm from point C .
4. As we want eccentricity $=1$, bisect the distance CF and get the point V which is vertex of the curve.
5. Draw some equidistance points on the line CD, like 1, 2, 3 etc.
6. Draw perpendicular vertical lines through those points.
7. Take distance $C$ to point 1 in the compass, with centre $F$ draw curves on both sides cutting the perpendicular line
 through 1. We will get the points P1 and P1'.
8. Similarly with centre F and distance C 2 draw curves on both the sides on line passing through point 2. Mark the points P2 and P2'. Repeat the same for other points.
9. Draw a smooth curve passing through the points and vertex V . The curve is the required parabola.

## Method 2: Rectangular method

1. We have given the base and the length of axis of parabola.
2. Draw a line $A B$ equal to the length of given base of parabola.
3. Draw a perpendicular bisector to line $A B$. Mark the point $F$ at distance equal to given length of axis of parabola.
4. Complete the rectangle ABCD with height MF.

5. Divide the line $A D$ into equal parts. In figure it is divided into 4 parts. The points named as 1, 2, and 3.
6. Divide half of the base i.e. AM into same number of parts of AD. The points are 1', 2', and 3'.
7. Connect the point $1,2,3$ with the apex point $F$.
8. Draw perpendicular line from point 1'. This line will intersect the line F1. Mark the intersection point P1.
9. Draw perpendicular line from point 2'. This will intersect the line F2. Mark the point P2. Repeat the procedure for point 3' and get point P3.
10. Repeat the same procedure for other side of the axis.
11. Connect the points starting from point $A$ then $P 1, P 2, P 3, F$ and same on the other side of the axis. The curve will be Parabola.

### 10.3 Hyperbola:

Hyperbola is a plane curve consisting of all points such that the difference between the distances from any point on the curve to two fixed points (foci) is the same for all points.
Thus a hyperbola is a set of all points $P$ such that the difference between the distances from $P$ to the foci, $F_{1}$ and $F_{2}$, are a constant $K$.

The center of a hyperbola is the point halfway between its foci. The principal axis is the straight line through the foci. The vertices are the intersection of this axis with the curve.

Hyperbola revolving on its axis gives hyperboloid. Hyperboloids are used for design of water channels, cooling towers etc.

## Method of construction:

Method 1: Drawing hyperbola curve when distance of focus point from directrix is given and eccentricity is given.

1. Draw a vertical line $A B$ and a horizontal perpendicular line $C D$. The $A B$ is directrix of the hyperbola curve and CD is the axis of the curve.
2. Suppose the given distance of focus from the directrix is 70 mm and eccentricity is $3 / 2$.
3. Divide the line $C D$ into 5 equal parts and the mark point $V$ vertex on the second division from point C . The point V is 3 parts away from focus point F.

$$
\text { Eccentricity }=\frac{\text { distance from focus point }}{\text { distance from directrix }}
$$


4. Draw a line from point $V$, perpendicular to line $C D$. Mark the point $M$ at distance equal to VF from point V i.e. put compass at point V, take distance VF in the compass and draw a arc cutting the vertical line. Mark the intersection point as M .
5. Join CM with a line and extend the line.
6. Mark some point 1, 2, 3 etc. between point $V$ to $F$ on the axis.
7. Draw a perpendicular line to CD from each point. Mark the points of intersection to line CM as 1', 2', 3' etc.
8. Take radius equal to $1-1$ ' in the compass, put the compass at point $F$ and draw arcs on both the sides of axis CD, cutting the line 1-1'. Mark the points as P1 and P1'.
9. Similarly draw perpendicular line from point 2 up to line CM , mark the intersection point 2'.
10. Take radius equal to 2-2' in compass, with the centre $F$ draw arcs cutting the line 2-2'. Mark the points P2 and P2'.
11. Repeat the same procedure for point 3 and obtain the point P3, P3'.
12. Draw a smooth curve passing through the points P3, P2, P1, V, P1', P2', P3' etc. The curve is hyperbola.

## Method 2: Rectangular hyperbola

We have to draw a hyperbola from a given point $P$.

1. Draw the lines $O A$ and $O B$ perpendicular to each other as axis. Mark the position of point $P$.
2. Draw a vertical line from point $P$ i.e. EF perpendicular to OA.
3. Draw another horizontal line from point $P$ i.e. CD parallel to OA.
4. Mark some random points 1, 2, 3 etc. on line CD as shown in figure.
5. Mark some points on line PE also like point 4.

6. Connect the points $1,2,3,4$ to the origin i.e. point O .
7. Mark the intersection points of lines O1, O2, O3, O4 etc. with line EF. Name the corresponding points as $1^{\prime}, 2^{\prime}, 3^{\prime}, 4^{\prime}$ etc.
8. Draw a line from point 1 parallel to line EF.
9. Draw another line from point 1', parallel to line CD.
10. Mark the intersection point as P1.
11. Repeat the procedure for all the points 2, 3, 4 etc. and get the points $P 2$, P3, P4 etc.
12. Draw a smooth curve from points P4, P, P1, P2, P3. The curve is hyperbola.
10.4 Cycloid: A cycloid is a curve traced by a point on the circumference of circle which rolls without slipping along a fixed straight line. Example is a rail wheel on rail. The fixed point may be wheel flat etc.

$$
\mathrm{D}=\text { Diameter of circle }
$$



## Method of construction:

1. Draw a circle with centre $C$ and given radius. Let $P$ be the generating point.
2. Draw a horizontal line PA tangential to the circle and with the length equal to circumference of the circle.
3. Divide the circle and the line PA into 12 equal parts. Mark the points $1,2,3 \ldots 12$.
4. Draw the horizontal lines through centre $C$ and through all other points on the circumference of circle.
5. Draw vertical lines from each point $1,2,3 \ldots$ of line PA up to centre line and mark the points as C1, C2, C3 etc.
6. Assume that circle starts rolling. Centre of the circle will move to position C 1 . Take the compass with radius of circle, put the needle point at point C 1 and mark the arc cutting the horizontal line passing through point 1 of the circle. Mark the intersection point as P1.
7. Similarly put the needle point at point C 2 and mark the arc cutting the horizontal line passing through point 2 of the circle. Mark the intersection point as P2. With this method mark all the 12 points.
8. Draw a smooth curve passing through points $\mathrm{P} 1, \mathrm{P} 2, \mathrm{P} 3 \ldots . \mathrm{P} 12$. This curve is the required cycloid.
10.5 Epicycloids: It is a curve generated by a path of a point placed on the circumference of a circle when that circle rolls on the curve path or on the another circle, is called an epicycloids.

## Method of construction:

1. With centre $O$ and radius $R$, draw the directing circle (Arc). Draw a line OP and extend it up to $C$, so that $C P=r$. The $r$ is radius of moving circle.


Epicycloids
2. Point $C$ is centre of generating circle and point $P$ be the generating point. In one full revolution the point $P$ will move up to point $A$. So that length of arc $P A$ will be equal to circumference of the generating circle.
3. Position of point $A$ can be located by formula,

$$
\begin{gathered}
\frac{\angle P O A}{360}=\frac{\operatorname{arcPC}}{\text { circumference }}=\frac{2 \pi r}{2 \pi r}=\frac{r}{R} \\
\angle \mathrm{POA}=360 \times \frac{r}{R}
\end{gathered}
$$

4. With this angle obtain the position of $A$.
5. With centre O and radius equal to OC , draw an arc. This is arc CB, on which the centre of moving circle will move on this path.
6. Divide generating circle and arc CB into twelve equal parts. Mark the point 1, 2, 3, 4 $\ldots .12$ on the circle. Mark points on $\operatorname{arc}$ CB as C1, C2, C3, C4......C12.
7. Take radius equal to $r$ and centers $\mathrm{C} 1, \mathrm{C} 2, \mathrm{C} 3, \mathrm{C} 4, \ldots . \mathrm{C} 12$ draw arcs cutting the respective arcs passing through point 1, 2, 3, 4.....on the moving circle.
8. Mark the intersecting points as P1, P2, P3 etc.
9. Draw a smooth curve passing through points P1, P2, P3.... This will be the Epicycloids.
11.0 Projections of objects: The representation of a solid in the drawing is made by projections of solid on the different planes. Two principal planes are considered at perpendicular to each other, called vertical plane and horizontal plane. Some times some other planes called auxiliary planes are also used as required to represent the object in more detail.

The system of drawing a solid object by projecting its surfaces horizontally and vertically, on the plane with perpendicular lines is called the projection of solid. A straight perpendicular line is drawn on the planes from the each junction point of the object and those points are connected sequentially then the figure represents the face of object from that angle is the projection of the object. The reference lines are called projectors.

Following are the methods used in the drawing

1. Isometric projection
2. Perspective projections
3. Orthographic projections
11.1 Isometric projections: In Isometric projection the object is visually represented as a three dimensional object on paper in two dimensions, in which three faces of object are shown in one view.

The angle of a edge is $30^{\circ}$ with reference line and the angle between two edges of the object is $120^{\circ}$. It is useful to look at Pictorial type of drawing. Pictorial drawings show several sides at the same time. The pictorial drawings are easier to understand. But they do not provide much information. The most commonly used pictorial drawing for technical information is called isometric drawings. Isometric drawings were developed to approximate perspective, but are much easier to draw.
11.2 Perspective projections: This is a method of projection in which a observer views the object form a definite distance and the drawing is how the object appears to the observer.

The picture plan on which the projections to be taken was kept between the observer and the object. Visual rays from the eye to the object converge to a point in the eye and therefore inclined to the picture plane. The rays pierce the picture plane and form an image on it. This image is the perspective of the object.
12.0 Orthographic Projections: Ortho - a Greek word means 'Perpendicular' or at 'Right angle' Orthographic projection is a means of representing a three-dimensional object in two dimensions. It is a way of drawing the solid from different directions usually a front side and plan views are drawn, so that are the important sides can be seen. It corresponds to a hypothetical view point i.e. like a view observed by camera lens at infinite distance away from the object, from different directions.

### 12.1 Principles of orthographic projections :

1. Projections on a plane, using lines are perpendicular to the plane.
2. The projections are parallel to each other.
3. No object line cut each other.
4. At-least one face of the object should keep parallel to the plane.
12.2 Planes and quadrants: Two imaginary planes are considered to take projections of object. These two planes are vertical plane and horizontal plane; both are perpendicular to each other. These planes are called as reference planes. It makes four quadrants, out of four first and third quadrants are used for orthographic projections as per the international practice. These are called as First angle method and Third angle method.
12.3 First angle Projections: In this method object is assumed in the first
 quadrant i.e. in front of Vertical Plane and above Horizontal Plane. The object lies in between observer and vertical plane. This is the standard adopted by ISO and primarily used in Europe.

The projections are taken from the observer to the object and extended to the vertical plane, horizontal plane and side planes like the image viewing as X-ray picture. The image made on the vertical plane is called Elevation or Front view. Then the projections are taken from top and the image made on the horizontal plane is known as Plan or top view. The horizontal plane is folded thus the plan comes below the elevation.


First Angle method

- the view from the front i.e. elevation is in the middle (Vertical plane)
- the view from the left is on the right (Side plane - right)
- the view from the right is on the left (Side plane - left)
- the view from the top is on the bottom ( Horizontal plane from top)
- the view from the bottom is on the top (Horizontal plane from bottom)
12.4 Third angle Projections: In this method object is assumed in the third quadrant i.e. behind Vertical Plane and below Horizontal Plane. The object lies behind the vertical and horizontal plane. The planes are assumed to be transparent in third angle method. The projections are taken on the transparent planes towards the observer. The image from front is taken on vertical plane and image from top is taken on horizontal plane. Again the horizontal plane is rotated clock wise or infolded to form a sheet of paper thus the plan comes above the elevation.

In this method:

- the view from the front i.e. elevation is in the middle (Vertical plane)
- the view from the left is on the left ( side plane - left)
- the view from the right is on the right (side plane - right)
- the view from the top is on the top (Horizontal plane)
- the view from the bottom is on the bottom (Horizontal plane from bottom)


Third angle projections are used in USA and England as per BS-8888-2006. In India also normally third angle projection is used.

The view of particular object obtained by these two methods are completely identical in shape, size and all other details, the difference lies in the relative positions of the view only. Some edges of the object are not visible in particular view, some may have internal features like slot, hole etc. to represent these hidden edges a thin hidden line (dashed line) is used in orthographic projections.
If hidden line is in continuation of the object line, it should start with space. When two hidden lines end at corners the dashed should meet at corners and there should not be gap at ends.
12.5 Symbols: The symbol for the first angle projection method and third angle projection method are shown in figure. For every drawing it is necessary to indicate the method of projection adopted. The symbol of the projection method is drawn in the title block of drawing.


First Angle method


Third angle method

## CHAPTER-III

## ENGINEERING DRAWINGS

1.0 General: Drawings for a structure is a medium to convert ideas and concepts on paper which can be understood by all concerned namely the Engineer, the contractor, the supervisor, the artisans and the user of the building alike. The details given on the drawing must be adequate not to leave any detail to be assumed or imagined by any of the parties mentioned above. This is commonly achieved by making a set of drawings for one structure and the overall purpose being to,

- Assist in planning and estimating the cost and time for the project
- Provide all parties involved (owners, contractors, inspectors, plan reviewers, artisans etc.) with clear Instructions regarding layout, materials, and the expected finished product
The drawing for a work or structure can be just one sheet or a set of sheets depending upon the size and intricacy of the structure. The drawings should be drafted on 'From the Whole to the Parts' concept i.e. one should visualize the overall structure in reference to the site and draw various elements that are likely to affect the construction of the structure, besides locate the work in an unambiguous manner. The level of various drawings can be divided as under,
Further, one should be able to visualize the agencies and the sequence in which the work

is to be executed. The work to be done in the casting yard or a centralized depot should be shown on separate drawing; similarly the work of plumbing or electric installations will be done by different agencies and should be drawn on separate sheets. If the drawings are being prepared in AUTOCAD there is a facility to prepare the drawings in layers and also
merge them to view an integrated drawing. The different drawings differ in detail and have to be considered as specific but there are a few common things such as site plan or location plan which are required for all works and are discussed below,


### 2.0 Site/Location plan (LEVEL-1)

The site plan is a 'birds- eye' view of the entire work. Site/Location Plan should clearly bring out the works required to start the work proper such as demolition of some structure, providing access road or leveling of earth work required (Cutting/Filling), shifting of services like pipeline, cable, drain etc. Normally for such works or if it contains more than one variety of structures, it is required to prepare that number of General Arrangement drawings (A1, A2 etc). It should have following details.
i) The magnetic north point and true north with magnetic variation, if known and where buildings are designed to suit a particular orientation is to be shown on the drawing.
ii) The names of the nearest junctions or terminals stations, that on the left hand being the one from which the kilometrage starts.
iii) The kilometrage from headquarters of the railway to the centre of the station, the kilometrage of all junction points, the zero of all branch lines, the centre of a station, junction point and zero of any line, when once adopted for any 'yard' or portion of the line, shall be a permanent origin for all future references and shall not vary with additions, alterations, or remodeling of yards.
iv) The original centre line of the railway route together with its chainages
v) The boundaries of land according to the land plans. Where it does not unduly interfere with important details of the plan, side widths from the centre line and boundary posts (and desirably their numbers) should be shown.
vi) Any known bench mark with the datum from which its value has been reckoned.
vii) All borrow pits, rivers and pipelines, streams, sullage, and sewer drains together with their direction of flow. For rivers their names and the highest known flood levels must be given.
viii) Temples, mosques and graves, roads and footpaths with the names of towns or villages they lead to.
ix) The position and block numbers of buildings. Where a building consists of two or more storey, the number of floors shall be mentioned and structure(s) to be dismantled.
x) Road crossings with their class and location; road over bridges and under bridges.
xi) Nearest part of the work closest to center line of track and Infringements to standard dimensions, if any.
xii) Dimensions between structures
xiii) Location of all utilities (gas, water, sewer/septic, electric) and respective meters or panels.
2.1 Many times the site/location plan is drawn as a part of the general arrangement drawing and not as a separate drawing especially when the work is not being planned in a much built up area and only single structure is to be constructed. The site plan must be drawn after collecting all site details and should be in adequate detail, but should not be cluttered up with minor details, not relevant to the work. It should not contain specifications and lot of writing should be avoided. The details to be put in the General Arrangement drawing should not be repeated in the site plan.

### 3.0 General arrangement drawing [LEVEL-2):

The General arrangement drawing (GAD) shows the overall shape and size of the structure with detailing the specific dimensions and specifications of materials and work. This will normally include the following,
i) Key plan of the work site in a box.
ii) Chainages of the center line of structure and its elements and elevations as R.L.s.
iii) Overall dimensions of structure, distances of structure from outer reference points or outer boundaries. The Plan and elevation along with sections at specific locations should be drawn wherever required to leave no ambiguity in the arrangement of the structure.
iv) Ground level, HFL, bed level in case of bridges, formation level of the plinth or embankment with reference to bench mark
v) Plinth area of building, total height of building, type of structure.
vi) Scale to which drawing is drawn.
vii) Presence of all required signatures of officers of all departments, alteration box, for future amendments to be issued.
viii) Authority of approval/sanction of work.
ix) The codes and specifications on which the work has to be executed.
x) Soil bore log details and the Bearing capacity of soil at founding levels.
xi) FLOOR PLAN: In case of a building a floor plan of the building with the roof removed at various floors.
xii) If there are more than 1 distinct structures in the work separate sets of GAD's and detail drawings should be prepared for each. e.g. there might be a residential complex, a power substation and a gymnasium constituting the work. Then 3 sets of GADs and corresponding detail drawings should be made.

### 4.0 Detail Drawings (LEVEL-3):

The detail drawings can not be generalized and are discussed under specific requirements of each type of work.

### 5.0 Project Drawings:

Drawings for New Line, Doubling and Gauge Conversion Projects: Following drawings are required to be prepared for all New lines, Doublings and GC projects as per Para 443 of Engineering Code,
a) Detailed Plan and Sections
b) Index Plan and Index Section
c) Plans and cross sections of rivers
d) Plans of station yards and Junction arrangements
e) Detailed drawings of structures.

### 6.0 Detailed Plan and cross-section:

These are drawn on $A 0$ sheet and 5 Km of line is shown on each sheet. The scale to be adopted is $1 \mathrm{~cm}=50 \mathrm{~m}$ for horizontal distances and $1 \mathrm{~cm}=5 \mathrm{~m}$ for vertical distances. The scale can however be changed to $1 \mathrm{~cm}=25 \mathrm{~m}$ or even $1 \mathrm{~cm}=10 \mathrm{~m}$ for hilly areas for better representation of topography.
6.1 Plan: The following features within 300 m on either side of the railway alignment should be shown on the plan,

- Boundary of states, towns, cities and village lands and in case of important town/cities names of important streets,
- Rivers requiring bridging length of 12 m or more
- Canals and other Railway affecting works
- Important road and bridges, culverts, and fractional KM posts of road.
- Hill peaks and other features of country
- Survey of India stations
- Temples, Mosques, graveyards etc
- Reserved forests
- Industrial units existing and under construction
- Contours as far as possible to define the nature of topography.

This is best drawn by enlarging the Topographic sheets using the graph paper method. The grid is drawn to the required scale of $1 \mathrm{~cm}=50 \mathrm{~m}$ (i.e.1:5000). Topographic sheets may be available to a scale 1:50000 i.e. $1 / 10^{\text {th }}$ of the required size. The contours and important features of the country are available from the topo-sheets and the railway alignment is marked on this sheet. However, with the advent of software like MX-Rail and AUTOCAD, the plan can also be prepared from the survey data without the topo-sheets.

The start and end of the curves should be marked by a circle. The alignment should be marked in red colour ( 0.8 mm thick). The position of all center line pillars, the apex points of curves, position of bench marks should be shown prominently. A typical detailed plan is given as annexure at end of Engineering code, may be referred for guidance.
6.2 Sections: The following details should be shown on the section,

- Ground level at the central line of alignment, above Mean Sea Level, at every 20m.
- Height of cutting or embankment and R.L. of formation at every 20 m .
- Bed level and HFL of all rivers
- Position and location of all bench marks and masonry pillars.
- Gradient posts i.e. chainage of change of gradient
- TPs (Tangent points) of all curves and their chainages.
- Center line chainages of all stations, bridges, level crossings, starting and ending chainages of all diversion of roads or water ways.
The convention for the colour scheme is
Ground levels and line- In Black
Formation level- In Red
Vertical ordinates showing the height of formation In blue
Vertical ordinates at change of gradients In red
Station by a vertical line ..... In Red

A typical detail section is enclosed as annexure to the Engineering Code, which may be followed for guidance.

### 7.0 Index Plan and Index section:

Index Plan and section is a summary form of Detailed Plan and Detailed Section, described above. Index plan and section is prepared on A4 size sheets and kept in a book form. The Index Plan and index section should be drawn to the scale of $1 \mathrm{~cm}=500 \mathrm{~m}$ horizontal distance and $1 \mathrm{~cm}=10 \mathrm{~m}$ for vertical distance. Preferably both plan and section should be shown on the same sheet but many times it is not feasible and in that case the plan should be on left side and section on right side of the book. Normally one A4 sheet will contain plan and section of about 12-13 Km Railway line. For double line section separate sheets are drawn for UP and DN lines.

## Further, the following should be ensured,

a) Each sheet should have reference number, name of railway, Division and scale.
b) The first and last sheet should be signed with date by the Engineer-in-charge of the survey, and all the sheets must be signed by the officer preparing the plans.
7.1 Index Plan: The index plan should be traced from the topo-sheets of the Survey of India map published to a scale of 1:50000. The width covered in the Index plan is 10 Km on each side of the rail track. Each sheet should be plotted in the direction of the through kilometerage so the kilometrage has to be read from left to right. Following should be included in the Index Plan,
a) The magnetic north should be indicated on each plan.
b) All towns, roads, canals, rivers, hills, boundaries of states and districts within a distance of 10 Kilometers on each side of the railway.
c) The centre line of proposed railway should be indicated by a full red line of 0.8 mm in thickness.
d) The degree and radius of all curves should be marked.
e) The height of bank/cutting above ground level should be marked at all change of gradients
f) The position of each station should be shown by a red block and the name of station should be mentioned.
g) The datum used for all plans and sections should be Mean Sea Level, and all heights should be referred to this datum in meters and decimals.

### 7.2 Index Section:

a) Index section should show the formation level in Red line.
b) The gradient should be figured.
c) The height of formation above Mean sea Level entered at each change of gradient.
d) The position of each important bridge should be indicated with the name of river and number and size of bridge span.
e) The position of each ROB, RUB, and level crossing with their classification should be indicated.
f) Position of each station with its name distance from fixed end should be mentioned.
g) The kilometrage from the fixed point should be marked and figured at every kilometer.

### 8.0 Plans and Cross - Section of Rivers:

The rivers of major bridge locations (cross-section exceeding 110 sqm under high flood) are required to be surveyed for at least 2 Km upstream and 1 Km down stream. The requirement of plan and section of river is given in Para 467 of Engineering Code. The item concerns more of field survey than the work for drawing office and as such is not dealt here.

## CHAPTER-IV

## DETAILED ENGINEERING DRAWINGS

1.0 Buildings: For All Building structures besides Site location plan and General Arrangement drawing as dealt in Chapter III, following drawings are to be prepared.
i. Foundation Drawings
ii. Floor Plans
iii. Elevation and Sections
iv. Roof Plan and Section
v. Plumbing Plan
vi. Electrical Plan

### 1.1 Foundation Drawings

## a) Location Plan

- Footing Plan showing center line of all footings and size and depth of all footings with reference to a reference line and datum.
- Soil bearing capacity values.
- Excavation lines and shoring, if required then the details of the same.
- All the footings should be given a distinct number even if the design is identical.

B.F. - Bottom level of foundation

F11, F12....F36-Foundation Nos. Location w.r.t. known land mark
b) Concrete Dimensions: The concrete dimensions of the footing are shown through a cross-section at center line both in front elevation and side elevation and plan. A leveling course of lean concrete $1: 3: 6$ or even $1: 4: 8,75-100 \mathrm{~mm}$ thick is placed below the footing. The bottom level of footing is to be ensured at the top of the leveling course. The width of the leveling course is normally 75 mm beyond the edge of the footing.

c) Reinforcement Drawing: In case of RCC footing the reinforcement details can be drawn along with the concrete dimensions, if the details are simple or can be drawn separately. It is preferable to have a separate drawing for reinforcements. Here also the reinforcement should be shown in all three planes namely, plan, front elevation and side elevation. The guidelines for reinforcement detailing are given in chapter VI.
1.2 Floor Plans: A floor plan is a top view or drawing of the interior of a building. This is essential to work out the plinth area and the carpet area of the building. This plan is primarily meant for the non-engineers and should be understood by the user and if required by the municipal authorities for any clearances etc. The internal dimensions of the rooms should be shown and not center lines dimensions. A typical floor plan would show:

- Interior and exterior walls, columns with thickness and specifications of material used e.g. grade of concrete, A or B class bricks or modular blocks etc.
- Detailed layout of Kitchen, toilets and WCs including location of wash basin, shower, cooking platform, appliances such as gas choolahs, refrigerators, water heater etc.
- Location and size of Windows and doors
- The use of all rooms should be indicated, preferably the proposed layout of furniture also be shown.

A Typical floor plan is at Annexure-A.
1.3 Elevations and sections: The exterior elevations both from front view as well as side view should be shown clearly bringing out the architectural features, windows, doors, openings, louvers etc. The total height, width and length of the building duly marked the R.L.s of each plinth level, G.L. and R.L. of the overhead water tank if any. Sections should be drawn at each column row showing the dimensions of the columns, beams and roof, their interspacing and clear head room above the bottom of beams. Normally the head room is specified above the finished plinth level then the height above the slab to the beam should be obtained by adding the thickness of flooring surface. All columns and beams should be identified by a number similar to the footings like C11, C12..... etc and B11, B12... etc.

The concrete dimensions of all beams, columns, roof slabs should be indicated, as also the grade of concrete and the finish quality. The reinforcement details can be shown on the cross-sections itself, subject to big enough scale being adopted for drawing. If the dimensions and reinforcement details in more than one beam or column are identical, the details need not be repeated, but it should be clearly indicated, that beam-x is identical to beam-y and similarly for columns. The slab reinforcement is tied along with that of beam as such the details of slab reinforcement in cross-section also be shown in the cross section. The cranking or curtailing of reinforcement bars should be shown with reference to a fixed datum apart from in the bar bending schedule. Cross-sections of beams and columns should be shown with details of reinforcement at center line, and near the support or at other sections where the bars are added or curtailed along the length. Further the reinforcement details at junction of beam and column has to be shown separately for clarity.

## A Typical Elevation and section is shown at Annexure B.

### 1.4 Roof Plan and section:

i) Beam plan showing location of all the beams supported on columns duly numbered as mentioned under 'Foundations'. This should be in a separate drawing and without cluttering the arrangement of walls and columns.
ii) Roofs can be spanning in one direction or in two directions. Further they can be restrained at the edges or free. The draftsman should ascertain the nature of fixity -
whether one way or two way from the designer. The detailing of reinforcement will be somewhat different in the different cases as given in chapter VI. The top view and bottom view of the slab has to be shown to clearly indicate the reinforcement details of a slab in top and bottom layer. The total thickness of slab along with the clear cover to reinforcement should be clearly shown. A typical beam plan and roof plan is shown at Annexure C.
1.5 Plumbing Plan: Since the agency for carrying out plumbing and water supply work is normally different from the civil contractor, even though department has awarded a composite tender, it is essential that plumbing plan is drawn separately. When drawings are prepared on AUTOCAD where there is a facility for making drawings in layers and also merge them for total view, plumbing plan is made in a different layer (and in different colour) from other civil works. In case of concealed plumbing, the location and specification for interning the duct or pipe is drawn on the floor plan and the height of the pipe from floor level is given in the notes.

Following items must be incorporated in the Plumbing plan,

- Service riser diagram
- Location of all new and existing fixtures
- Size and type of materials
- Size and location of all drains, vents, and clean-outs
- Location of pressure relief line
- Location and size of water meters
- Location of shut-off valves
- Resident water pressure
- Total developed length of water lines
1.6 Electrical Plan: Similar to the plumbing plan the electrical plan has to be drawn separately. This is to be drawn by draftsman adept in electrical works and as such not discussed at length. Normally, these days concealed wiring is being adopted in buildings and therefore the civil Drawing supervisor must understand some minimum requirements for providing ducts, openings and niches for accommodating electrical fixtures. To this extent, following item should be covered in the electrical plan,
- Location of panels and cut outs
- Location of all receptacles, lights, switches, and smoke detectors with appropriate circuit numbers
- Electrical panel schedule


### 2.0 Bridges:

2.1 Site Plan: The selection of site of a bridge is very important on which the length of waterway, the hydraulic characteristics, the protection work, river training works depend. This exercise is carried out by Survey team and the plan is drawn in the drawing office. Primarily there are two types of bridge crossings namely, i) Skew crossing ii) Skew

lignment square crossing. The square crossing is always preferred in Railways but is accompanied with two numbers of reverse curves in the approaches, which can have speed constraints if not designed properly.

The direction of flow of the stream should be shown and the nearby village names on up stream and down stream indicated.

Information about any dams, weirs or any flood affecting structures upstream should be shown, with necessary details like maximum discharge etc. Any other opening in the river/stream banks like inlet or outlet, presence of navigation requirement should be marked.
2.2 GAD of Bridges: In addition to the general requirements as given in the Para 2.1 above, the Bridge GAD should necessarily contain L-section showing pier and abutment location, various levels, dimensions of pier/abutment, plan and a typical cross section. The details of foundations such as dimensions and type, the founding levels (BFL), the bed levels in general and at each foundation location in particular, the lowest water level (LWL), the ground levels in approach of a bridge at least for 50m on either approach and proposed rail level on the bridge.

Similarly the cross-section and elevation of superstructure giving all salient dimensions like height above bearings, deck width, width of footpath if to be provided, any service ducts under the footpath, kerbs, railing, trolley refuge, expansion joint, wearing course, type of bearings should be indicated. The gradient in formation at the approaches, location of any signals or OHE masts on or near the bridge should also be shown. Further the notes about various assumptions of design should be written on the drawing, which include maximum discharge, afflux, source of HFL and LWL, the soil parameters along the depth of foundation at all foundation locations if available. The G.A.D. so prepared should show sufficient details to enable preparation of detailed estimate. All dimensions and provisions should be clearly shown on the drawing. The following items should always be incorporated in a Bridge GAD.
i) Highest flood level (HFL) of last 100years or as available
ii) Afflux under maximum discharge
iii) Vertical clearance and Free board available.
iv) Flow direction
v) Velocity of stream under maximum discharge
vi) Name of river/Stream
vii) Sanction no and competent authority.

## A typical GAD is shown at Annexure- D.

2.3 It is a good practice to provide a table of grade of concrete used and approximate reinforcement steel provided in each element of the bridge. This helps the estimator to calculate the quantities and prepare tender schedule. The table as under should be incorporated in the GAD.

| Sr. <br> No. | Bridge Element | Grade of concrete(*) | Appx. Steel qty |
| :---: | :---: | :---: | :---: |
| 1 | Well Foundations: |  |  |
|  | Cutting edge | Structural steel | 70Kg/RM |
|  | Curb | M30 | $80 \mathrm{Kg} / \mathrm{Cum}$ |
|  | Steining | M20 | 15Kg/Cum |
|  | Bottom plug | M15 | - |
|  | Bop plug | M15 | - |
|  | Well cap | M30 | $150 \mathrm{Kg} / \mathrm{Cum}$ |
| 2 | Pile Foundation: |  |  |
|  | Pile | M30 | 120Kg/CUM |
|  | Liner | - | Variable 4-6 mm MS plate |
|  | Pile cap | M30 | $130 \mathrm{Kg} / \mathrm{Cum}$ |
| 3 | Open Foundation |  |  |
|  | Leveling course(PCC) |  | - |
|  | PCC in footing | M20 | $5 \mathrm{Kg} /$ Sqm (surface Reinf) |
|  | RCC in footing | M30 | $100 \mathrm{Kg} / \mathrm{Cum}$ |
| 5 | Substructure: |  |  |
|  | Pier-PCC | M20 | 5Kg/Sqm (Surface reinf) |
|  | Pier-RCC | M30 | 100Kg/Cum |
|  | Hollow pier-RCC | M30 | 120Kg/Cum |
|  | Pier cap cantilever-RCC | M30 | $230 \mathrm{Kg} / \mathrm{Cum}$ |
|  | Pier cap fully supported | M30 | 80Kg/Cum |
|  | Bed Block/Pedestal | M40 | $80 \mathrm{Kg} / \mathrm{Cum}$ |

DETAILED ENGINEERING DRAWINGS

| 6 | Superstructure: |  |  |
| :---: | :---: | :---: | :---: |
|  | Slab-RCC | M25 | 100Kg/Cum |
|  | Slab-PSC | M30 | $40 \mathrm{Kg} / \mathrm{Cum} 50 \mathrm{Kg} / \mathrm{Cum}$ (HTS strands) |
|  | I-Girder RCC with slab | M30 | Girder-400Kg/CumSlab- $150 \mathrm{Kg} / \mathrm{Cum}$ |
|  | I-Girder PSC with slab | M40 Girder M30 Slab | Girder-170Kg/Cum $50 \mathrm{Kg} / \mathrm{Cum}$ (HTS strand)Slab-150Kg/Cum |
|  | Box Girder(PSC) | M40 | $200 \mathrm{Kg} / \mathrm{Cum} 50 \mathrm{Kg} / \mathrm{Cum}$ (HTS strand) |
| 7 | Return/Wing walls: |  |  |
|  | PCC | M20 | $5 \mathrm{Kg} / \mathrm{sqm}$ |
|  | RCC | M30 | 60Kg/Cum |
|  | Counter fort RCC | M30 | $120 \mathrm{Kg} / \mathrm{Cum}$ |
| 8 | Miscellaneous items: |  |  |
|  | Parapet | M25 | $10 \mathrm{Kg} / \mathrm{Sqm}$ |
|  | Railing | M40 | $10 \mathrm{Kg} / \mathrm{sqM}$ |
|  | Kerb | M25 | $5 \mathrm{Kg} / \mathrm{Sqm}$ |
|  | Expansion joint | Type to be mentioned |  |
|  | Bearings | Load coming on the bearings be mentioned |  |

(*) The grade of concrete should be used minimum as per Indian Railway Concrete bridge code depending on the extent of corrosive environment at the bridge site.
2.4 The standard notes for bridges drawings are listed under,
i) All dimensions are in millimeters except otherwise mentioned.
ii) Dimensions should not be scaled from the Drawing. Figured dimensions should be taken instead of scaled dimensions.
iii) The bridge is designed for Single track of MBG/ 25t axle load/DFC loading as per Bridge Rules.
iv) Before starting execution, a working cross-section at the site shall be taken by precision survey and the location of abutment and pier positions shown on G.A. drawing shall be verified on site. In case of any discrepancy or doubt, clarification shall be obtained from the concerned competent authority, beforehand.
v) The temporary Bench Mark is located at $\qquad$ and its values are.
vi) Angle of skew is $\qquad$ However, the piers \& abutments should be oriented parallel to flow direction at site and discrepancy, if any, reported to HQ beforehand.
vii) Rubble pitching should be done up to 0.60 m . above affluxed H.F.L. on both sides of approaches, for 30 m .
viii) Filling behind abutments and returns shall be as per Railways standard drg no.
ix) Adequate weep holes shall be provided in abutments, RCC returns, solid returns and outer walls of box returns at not more than 2000 mm centre to centre horizontally and 1000 mm centre to centre vertically, regularly staggered. The weep holes shall be provided up to the bed level.
x) Foundation levels shown on the drawing are tentative. Open foundation for abutments and piers shall be keyed into soft rock or exposed rock by a minimum of 1500 mm or into hard rock by a minimum 500 mm whichever gives a higher foundation level. Foundations for returns wings shall be keyed by a minimum of 500 mm into exposed rock.
xi) The specification of anti-corrosive treatment to the reinforcement or finished concrete surface, if required should be furnished.
xii) Arrangement for inspection of bearings shall be provided by means of a suitable ladder from girder to bed block.
xiii) Adequate arrangement for drainage of deck by means of properly designed water spouts shall be made. Suitable arrangement shall be provided in the bridge deck for inspection of the underside of girder/slab.
2.5 Detail Drawings of Foundations/ substructure: The following detailed drawings need to be prepared for execution of bridge works,
a) Foundation: The concrete dimensions and reinforcement details, the bottom of foundation and top of foundation levels to be clearly indicated. Embedment in rock as per 'I.R. Foundation and Substructure code' should be invariably shown in the drawing. In case of well foundations separate drawing to be prepared for cutting edge, well curb and separate for well steining.If the wells are to be launched by floating or any other method like Caissons, complete structural drawings for fabrication of steel caissons and launching scheme should be designed and drawn.

In case pile foundations are adopted, the method of construction like cast in situ, or pre-cast and driven etc should be indicated. Apart from the concrete dimensions and reinforcement details, steel liner if required its thickness and the depth up to which it is to be provided should be clearly indicated. Bottom plug and top plug, in case of well foundations be shown along with the cross section


In Seismic zones III and IV, the sand filling in the well is to be done only up to scoured bed level and correspondingly, the top plug is also at that level only. This is to keep the center of gravity as low as possible to minimize the earthquake forces.
b) Piers and Well/pile cap: The concrete dimension and reinforcement details for pile/well cap should be shown in elevation plan and cross-section. The location of the pier with reference to center lines of the well/pile cap must be shown. It is to be noted that any tilt and shift in constructing the piles/wells has be taken care of at pile/well cap level. The designer normally stipulates a range of eccentricity in which the design will hold good. This aspect should be clearly brought out in the drawing as well as mentioned in the notes of the drawing.
If the piles or well has been constructed using earthen island, the island is leveled at the top level of the foundation and leveling course of lean concrete is laid about 75 mm thick. If the well or piles have been cast using floating equipment i.e. without earthen island, suitably designed formwork is to be tied over the piles or well for casting the cap and in that case there would not be any leveling course. The reinforcement extending from piles/ well steining is to be suitably anchored in the cap concrete.
c) Piers could be solid mass concrete/ solid RCC or hollow RCC. In case of mass concrete piers, surface reinforcement has to be provided @ 10mm fat 200 mm c/c and for RCC piers suitably designed reinforcement is provided. These bars or any other bars to be continued into the pier have to be anchored in the cap and these must also be shown in the reinforcement detail of the cap. List of standard drawings for piers and abutments issued by RDSO is at Appendix-IX. A typical section of hollow RCC pier is shown below,

d) Pier Cap and Pedestal: These are generally heavily reinforced elements and detailing has to be done very carefully. If the pier cap is fully supported on the pier the details are comparatively simpler than if it is over hanging beyond the pier. The center line of bridge axis and the pier should be drawn indicating the true chainage of the location. No deviation can be allowed in this location and it must be true, without which the girders will not seat centrally on the bearings. Normally the details of pier cap and pedestal are shown in single drawing only. The area in front of the pedestal or on the sides, depending on the arrangement of the jacking of girder needs to be strengthened by providing a reinforcement mesh of $8 \mathrm{~mm} @ 50 \mathrm{~mm}$ c/c to accommodate the jack, over all the reinforcement for pier cap. This is generally a matter of detailing and many times designer may not indicate in the design.
It should be kept in view that, in Seismic zones III and IV it is mandatory to provide girder movement arresters on both the sides of girder or between the two pedestals
as shown in the sketch above, on the pier cap. These are also made in RCC and the reinforcement has to be anchored in the pier cap.
e) Abutments and ballast wall: Abutments are drawn separately in the same style as piers. The abutments could be solid with provision of return walls or wing walls to keep the water way clear of any earth flowing from the embankment or could be spill through type or buried type where the earth embankment continues in the bridge opening and has a slope of $1.5 \mathrm{H}: 1 \mathrm{~V}$. The pier cap for abutments known as abutment cap is cast integral with ballast wall in addition to pedestal and movement arrestors. Thus the details of all these are to be drawn on a single sheet duly showing the anchor reinforcements of each element. List of standard drawings for abutments issued by RDSO is at Appendix-IX. A Typical section and plan of Solid Abutment and Spill Through Abutments is given below,

f) Return Wall and Wing Wall: The return walls are structure not joined or cast along with the abutment and ballast wall and are designed as retaining wall extending up to the top of formation. The return walls can constructed in PCC or in RCC. These walls can also be splayed in plan and are known as wing walls. Typical plan of Solid Return, splayed Return or Wing wall and a box return wall is given below,


PCC SOLID RETURN WALL

The dimensions are only for guidance, the size and dimensions are to be supplied by Design Engineer.


PLAN OF TYPICAL BOX RETURN
2.6 Detailed drawings of superstructure: The superstructure can be in Steel, RCC or composite or PSC. RDSO has issued standard drawings for Steel spans and list of such drawings is at Appendix - X. Most of the times the standard drawings are only used for steel superstructure. Similarly, RDSO has issued standard drawings for RCC slabs and PSC slabs. The list of drawings for slabs is at Appendix - XI. List of PSC girders for BG Loading is at Appendix - XII. In spite of the standard drawings being available, number of times RCC and PSC superstructure has to be designed and drawings prepared for specific site requirements.
Following detailed drawings are normally required for simply supported PSC girders,

- Concrete dimensions of girder in plan, elevation and cross section at all locations of change of cross section along with at center and at support.
- Reinforcement detail along the length of the girder and on different cross-sections.
- End diaphragms and intermediate diaphragms, if any.
- HTS cable profile both in elevation and in plan. The ( $x, y, z$ ) coordinates should be given in a table at about every $2 m$ interval. The location of grout escape vents should be shown, which is normally to be kept at lowest points in the profile of cable or a sudden change of curvature. The supporting system for the sheathing in the reinforcement cage should be indicated. Table for 12.1 m (Clear span) having overall length of girder being 14100 mm , is given below,

| Cable <br> No. | Cut <br> Cable <br> Length | At CHAINAGE From end block |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $X=0, C / L$. of girder |  | $X=2350$ |  | $X=4700$ |  | $\mathrm{X}=7050$ End of girder |  |
|  |  | Elev., Z | Plan, Y | Z | Y | Z | Y | Z | Y |
| 1 |  |  |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  |

Note: X , is the distance from center line of the girder in length. Y , is the distance from the center line of the girder in the width direction and $Z$, is the elevation of the point from bottom of the girder. ( $\pm$ ) sign of coordinate means right or left from center.

- End Anchor blocks details showing all the reinforcement and the anchorage assembly. The detail of reinforcement along with the anchor tube is provided by the manufacturer of the system. This has to be replicated along with other requirements of reinforcement as given by the designer. The end diaphragm reinforcement also is to be tied along with the anchor block and the detailing has to cater to both the requirements. The anchorage system of commonly used 'Freyssinet System' is shown below.

(a) SECTION THROUGH CONES
(b) CROSS SECTION


## ANCHORAGE FOR FREYSSINET SYSTEM

- Cable stressing schedule both in terms of elongations and force at the stressing jack. The losses of elongation due to slippage of cables in the jack and at the wedges have to be separately shown as given by the designer.
- Many times the cables are terminated short of the end anchor block and they are to be anchored in blister blocks. The details of the blister block reinforcement are similar to the end block, but as there is continuity of concrete behind the blister, additional longitudinal steel reinforcement with closed stirrups are to be provided behind the blister block. Normally, this is a matter of detailing in the drawing as no specific calculation is done for this.
- The reinforcement detailing of any element have be calculated by the design engineer and the detailing in drawing follows common principles described in Chapter VI.
2.7 Miscellaneous details: There are several items required for the bridge superstructure where detail drawings are required to be prepared,
i. Bearings: The bearings are normally manufactured by the company's on their own design. The designers are required to give the various loads coming on the bearings and the expected movements. In case of Elastomeric bearings however the design and drawing is furnished by the owner department i.e. Railways, since the Code adopted for Railway loading is as per UIC and many manufacturers may not be well conversant with it. A typical drawing for Elastomeric/Neoprene bearing is given below,

ii. Expansion joint: Due to temperature variation the bridge deck expands and contracts. An expansion joint to cater to this movement is to be provided at the end of two girders/ decks. This expansion joint while providing for the relative movement also provides continuity on the deck surface
 so that no ballast drops in to the gap between two girders. There are several patented designs available but Expansion joint using a MS cover plate, as shown here is most common. The MS angles and the cover plate are normally galvanized to avoid corrosion.


## iii. WATER SPOUT (Cast Iron or HDPE)

Water Drainage Spouts: A cross slope or camber of 1:40 should be provided on the deck/ wearing coat towards one of the kerbs in case of double line bridge or towards both the kerbs in case of single line bridge. This is required for easy drainage of the deck. One water spout of $150 \mathrm{~mm} \phi$ is considered adequate per 20 Sqm of deck area. If the camber is on both sides of deck, the spouts should be distributed evenly on both sides and in case of camber only on one side all the spouts be provided on the same side only. The Spout Should be of Cast Iron but


WATER SPOUT (Cast Iron or HDPE) HDPE (High Density Poly Ethylene) is also used these days. The seating of the spout has to be proper and no leakage should take place from the seat.
iv. Wearing Coat/Course: Normally RCC of high grade(M30 and above, with low W/C ratio< 0.35) 75 mm thick with a 6 mm steel reinforcement bars at $200 \mathrm{~mm} \mathrm{c} /$ c in both directions is used as wearing course. The reinforcement is kept at the deck slab with a clear cover of 20 mm .
v. Railing: The railing should be detachable from the bridge deck for the convenience of replacing it, during service life of bridge. Therefore, the railing should be made with MS angle/channel posts and Heavy duty Gl pipes as runners. The posts should be fixed on the bridge deck by means of holding down bolts through a base plate.
3.0 RCC Box Culverts: RCC box is a very popular form of bridge for small discharge and for flood balancing requirements. Normally for span less than $2 m$, Hume Pipe culverts are preferred and above 2 m box culverts are adopted. RDSO has also issued standard plans for RCC box culverts. Drawing No. M-00004 is a general drawing for spans 2 m to 4.5 m with varying surcharge and height of culvert. There are 3 drawings for Box culvert to be used for limited height sub ways. The list is given in Appendix-XIII. A type drawing of RCC box culvert is shown in Fig at pg. 65.
However, due to increase in axle loads over Indian Railways and different site conditions, box culverts have to be designed and drawn very frequently. The dimensions and reinforcement are to be worked out by design engineer and the drawing should be made on the principles given in the typical drawing given here under. The base for a box culvert is made by a boulder soling $300-450 \mathrm{~mm}$ thick depending on span and lean concrete(1:3:6), 150 thick below the box. The wing walls or return walls are made as explained earlier in Para-2.5(f) above.

PLAN

The drawing for Box Culvert should have following Notes in the GAD. Notes:

1. All dimensions are in millimeter and levels in meters unless otherwise specified.
2. Suitability of foundation pressure should be checked as per site conditions.
3. Reinforcement details and thickness details are given in separate drawing.
4. Loading: Suitable for MBG and HM loadings.
5. HYSD deformed bars of Fe-415 shall be used for reinforcement.
6. Design Criteria: i) IRS Bridge rules incorporating A.C. slip No.37. ii) IRS Concrete Bridge Code, A\&C Slip No.7. iii) IRS Bridge substructure and Foundation Code incorporating A\&C Slip No. 22.
7. Lapping of bars should be minimized and staggered. Laps have to be decided at site, length and location to be as per IRS code.
8. Back fill material shall be as per Clause 7.5 of IRS Bridge Substructure and Foundation Code.
9. All RCC surfaces coming in contact with soil must be painted with bitumen or coaltar of approved quality @ $1.454 \mathrm{~kg} / \mathrm{sq} \mathrm{m}$.
10. Clear cover for reinforcing bars should be 50 mm .
11. Depth and size of foundation, length of return wall and levels of $U / S$ and $D / S$ shall be decided based on the soil type and site conditions.
12. All levels and dimensions should be reconciled before starting work.
13. Barrel length of Box culvert shall be decided based on site conditions and surcharge height of earth.
14. Gap if any between existing bridge and extended length should be connected suitably.
15. Tolerances shall be as per Concrete Bridge Code.
16. M35 grade of concrete shall be used for the span or height of box $>4 \mathrm{~m}$. or for severe conditions at bridge site. M30 should be used for lesser dimensions. For very severe conditions M40 grade concrete should be used irrespective of height and span.
17. Bed slope should be kept minimum 1 in 100 and may be suitably adjusted at site.
18. Weep holes of $75 / 100 \mathrm{~mm}$ dia. PVC/AC pipes staggered at 1000 mm C/C above LWL in both return wall and earth retainer of box should be provided.
4.0 Foot-Over Bridges: On the Indian Railways FOBs are to be constructed in large nos. in a routine manner. Since the FOB is required to span over running tracks, it has been found very expedient to use Steel structures. These are light in weight and easy to launch in short duration traffic block. In new line projects however RCC/PSC is also being used.
4.1 General Arrangement Drawing: The GAD of FOBs has to be carefully drawn, in as much as, not only the permanent structure should not infringe the Schedule of Dimensions but during the construction phase also no infringement should be there to the moving dimensions. FOBs are an amenity to the passengers their location, location of landings, vertical and horizontal clearances etc have to be carefully planned. SOD gives minimum distances but one should try and provide maximum possible clearances so that it does not cause obstruction to the passenger's movements. The location and clearances (S.O.D.) are dealt in Appendix-II.

The span arrangement has to be worked out taking the actual center to center distance of tracks in the yard and with consideration to other structures and facilities obtainable at platforms. If any column is to be constructed in between tracks or close to tracks, the plan dimension of footing, the excavation required for open foundations or the dimension of equipment required to make piles or shallow well should be kept in view and shown on the drawing. In open cut a self retaining side slope of $1 \mathrm{H}: 1 \mathrm{~V}$ is preferable which can be reduced to $1 / 2 \mathrm{H}: 1 \mathrm{~V}$ by
 use of proper shoring and strutting. It should be ensured that any part of sleeper is not unsupported.
As far as possible the FOB should be square to the track alignment. The landings on the platform should be minimum 5330 mm from center of nearest track. Similarly vertical clearance as per SOD should be kept. A typical elevation is shown below,


The various clear spans normally required are,
Crossing 2-lines-5.330+4.265+5.330= 14.925 m (for existing lines)
$-5.330+5.300+5.330=$
15.960 m (for new lines)

Crossing 3-lines $-5.330+4.265+4.265+5.330=19.190 \mathrm{~m}$ (for existing lines)
$-5.330+5.300+5.300+5.330=21.2660 \mathrm{~m}$ (for new lines)
4.2 Detail drawing: The FOB is constructed mostly with Steel Truss elements. The Truss structure is comparatively lighter and hence economical, besides requires lesser height of approach stairs and hence preferred by passengers using it. These days the fabrication is done mostly by welding though riveted fabrication is also done. The normal


## TYPICALDETAILS OF A ROB TRUSS

Joints A.B.C.D.E and F as seen in Elevation and Joints K.L.M.N.o and $P$ as seen in plan are typical joints required in fabrication of Truss FOB. These are to be detailed in the FOB drawing

spans used in Railways are 16m-24m. A typical plan and elevation of a FOB truss is shown here.

The junctions where different members are to be joined have to be carefully drawn giving the various dimensions of not only members but of Gusset plates and the location of holes in case of riveted girder and weld lines in case of welded girders. Typical details of the joints have been shown in the sketch below. The principle of riveting is equally applicable for welded truss also. After drawing the each joint, with members at different angles, the size and shape of the gusset plate has to be scaled off from the drawing. The detail of
dimensions and the convention for showing the same is described in Para $7 \& 8$ below. It should not be considered that the joint details are the job of the fabricator and need not be shown in the drawings. The fabricator has to make templates and full scale drawings before starting fabrication based on the drawings supplied by the department.
Dimensions like size of members, pitch and size of rivets, line of rivets, edge distance, size of Gusset plate etc. should be shown.

5.0 Road Over Bridge: Like FOB, ROBs are also to be constructed over the railway tracks and site plan and GAD has to be prepared with the same care and with same principles as for FOBs and signed by the road authorities and the Railway authorities. The typical notes to be written in the GAD are given below.

1. All dimensions are in mm and levels are in meters unless specified otherwise.
2. Dimensions are not to be scaled. Only written dimensions are to be followed
3. Existing railway tracks and existing railway land boundary are shown in green and proposed ROB and future tracks are shown in red.
4. Clear span, clearance above and horizontal clearances from center line of the track, road surface width including footpaths \& crash barrier are fixed. Other dimensions shown are tentative and shall depend upon final design.
5. Drainage spout, expansion joint \& wearing coat should be as per 'MOST' standard specification. RCC crash barrier shall be provided as per figure 4(a) of clause 115.4.5-IRC: 5-1998.
6. Minimum Grades of concrete for various components of bridge shall be as below.

| PCC | $\mathrm{M}-15$ |  |
| :--- | :--- | :--- |
| RCC |  | $\mathrm{M}-30$ for wearing coat \& footpath slab. Rest all RCC work in |
|  |  | $\mathrm{M}-35$ |

7. Pre-stress steel shall be HTS standard of class - 2 conforming to IS-6006/ 14628. As per detailed design. Reinforcing steel shall be of HYSD bars conforming to IS-1786 of Fe-500..
8. Strip seal expansion joint of approved quality as per most specification to be provided in deck over each pier. Elastomeric bearing/POT PTFE bearing shall be provided conforming to IRC-83-part-II.
9. Temporary engineering indicators shall be provided as per G.R. 15.09(i) (d). Temporary signaling arrangement will be done as per G.R. 15.09(i) (d) and G.R. 15.09(2) b.
10. The Railway Engineer should ensure that the necessary permission has been obtained from road authority for diverting the traffic temporarily prior to commencing the work.
11. Underground cable etc. if any, shall be removed \& re-aligned before the execution of work starts. S\&T cables (OFC, RE-cables, signaling cable) may be passing along the track; they shall be protected at site by executing agency by manual digging up to 1.5 m . All precautionary steps must be taken according to JPO/1/signal 2004 (W. Railway).
12. Necessary suitable shoring \& strutting shall be provided for casting of structural members and other place where ever required and shoring to be approved by the railways.
13. Provision of clamps in the superstructure for supporting the AC traction wire if any shall be made in consultation with the concerned authorities.
14. Representative of telecom and signaling department should be made available before commencement of prop. Work in the vicinity of signal and telecom cable.
15. During the construction of bridge the existing track shall be protected suitably imposing necessary speed restrictions.
16. Protective screens to be provided on both side of bridge as per RDSO drawing No. ED/C/0068 modified by engineering department.
17. Level crossing will be closed permanently for road traffic after commissioning of proposed Road Over Bridge. The approval of collector,................district is received vide letter No. .....
18. Sanction of CRS-Mumbai shall be obtained for this work.
19. For details of sub-structure and superstructure within railway refer separate drawing duly approved by railway.
20. The approaches are in RCC/PSC T-beam deck slab type superstructure and RCC retaining walls at ends
21. Details of bridge shall be as per latest relevant code of IRC/IRS for the works within railway boundary.
22. Only manual digging is allowed between and close to the running tracks.
23. For launching of PSC girder over the existing railway track refer separate drawing submitted by tenderer/party and duly approved by railway.
24. For the safety of PSC girders over the track, till the deck slab diaphragms cast, refer drawing no. CE (W) 9318-HQ/R.
25. For the detail drawing of erection of staging for casting PSC girder over existing running railway tracks or launching scheme of PSC girder over existing running railway tracks and phase work drawing refer separate drawing submitted by tenderer/party and approved by Railway.
26. For temporary diversion of existing Road/or shifting of level crossing, refer separate drawing duly approved by concerned officers
27. Work should be carried out by the party under the supervision of railway engineer within the railway land limit.
28. Approach gradient shown in this drawing are tentative and will be as per site requirement
29. OHE masts coming under the ROB shall be relocated.
30. In order to set proper OHE profile under ROB, OHE mast having distance less than 10 m from the edge of ROB shall also be relocated to maintain minimum distance of 10.0 m from the edge of ROB.

In case of ROBs, the work is carried out in cost sharing with State Government authority and hence additional knowledge of rules for cost sharing should be known by the draftsman to foresee any complications in future. Provision of para E1816 of Engineering code read along with the letters and amendments issued from time to time provide us with following cases and the details of the cost sharing as below.

### 5.1 ROB on roads other than National Highway

(a) Two Lane Road: Where TVU is more than 1.0 lakh. Bridge width for cost sharing shall be 7.5 m for carriageway and 1.5 to 1.8 m footpath on either side in urban areas as per the requirement of road authority and the crash barriers. The overall width is not to exceed 12 m .

## (b) Four Lane road:

i. New ROB to be sanctioned as four lane: Where TVU is more than 3.0 lakh and road traffic comprises of not less than 6,000 road vehicle units.
ii. Existing two-lane ROB to be converted to four lane: Where TVU is more than 5.0 lakh and road traffic comprises of not less than 10,000 road vehicle units and increase of TVU since the construction of the original two lane bridge is more than 2.0 lakh comprising not less than 4,000 road vehicle units. In addition four-laning of existing two lane ROB can be taken up only when concerned road authority has committed for four-laning of the approach portion
Bridge width for the cost sharing in both the above cases shall be 7.5 m for 2 lane carriageway for each way i.e. up and down and 1.5 to 1.8 m footpath on either side in urban areas as per the requirement of road authority.

### 5.2 ROB on National Highway

No LC can be provided on National Highway for new railway line construction. Entire cost of ROB in such cases over existing National Highway shall be borne by the Railway.
In case of cost sharing works the stipulations are as below
(a) Two Lane National Highway: Road width for the purpose of cost sharing would be equal to the roadway width in approaches subject to limit of 10 m for hill roads and 12 m for other locations inclusive of crash barrier and/or footpath.
i. $\quad 9.5 \mathrm{~m}$ wide carriageway with two raised kerbs of 0.75 m
ii. $\quad 7.8 \mathrm{~m}$ wide carriageway with footpath of 1.5 m on either side

Total width in no case shall not be more than 12.0 m
(b) Four Lane National Highway: Bridge width for the cost sharing shall be 9.75 m for 2 lane carriageway for each way i.e. up and down and 1.5 to 1.8 m footpath on either side in urban areas as per the requirement of road authority. If median is provided on the approaches same width shall be continued. Total width shall be limited to $24 \mathrm{~m}(9.75+4.5+9.75)$ between the outer faces of the railing kerbs.
6.0 Steel Structures: The steel structures are mainly platform shelters, industrial sheds, godowns etc. The PF shelter design is normally adopted on RDSO drawings. The standard drawings for different width of Platform shelters have been issued by RDSO, the list is at APPENDIX- XIV. However, several steel structures sheds for godowns, workshops etc are to be designed and drawings prepared. The design Engineer gives the size and
arrangement of members. It is the job of the draftsman to provide proper joints, gusset plates etc. for field engineer to fabricate the job properly. Primarily, the drawings for steel Structures involve drawings of various joints and dimensioning various members.
6.1 Steel Members: It should be understood that Equal angle have same strength on both X and Y directions, but I-Sections and Channel sections have much less strength about Y -axis compared to X -axis. Designer always uses a member with its direction in higher strength. It is therefore important that members' especially Unequal angles, Ibeams (Joists) and channels are used in a direction to use maximum strength.
6.2 Joints: A no of members when meet af a joint, they should be so placed that their axis passes almost through the point of application of stress lin the member i.e. shquid have least eccentricity. For this purpose gusset plates have to be used for joint in preference to directly fixing the members in lap joint. - -- -

6.3 The steel fabrication can be either in "Rivets" or in welding. It is important that proper representation of the joints of either type is shown on the drawings. Certain standard conventions have been formulated accepted all over the world to represent the details. The design engineers normally work out the requirement of rivets and welds, however their proper placement and drawing is to be done by the draftsman for which minimum knowledge of various conventions and even some of the design aspects should be known to them. Brief description is given in following paras.
7.0 Welding: The structural details of welded joints are mainly three types,
i) Type of weld (Denoted by symbols)
ii) Type of finish of weld (denoted by supplementary symbols)
iii) Dimensioning of weld
iv) Location of weld (denoted by arrows and reference line)
7.1 Symbols: Various types of welds are denoted by symbols as under,

| Sr.No. | Designation | Symbol |  |
| :---: | :---: | :---: | :---: |
| 1 | Edge flanges weld <br> (The raised edges being melted down completely) |  | $\lrcorner$ |
| 2. | Square butt weld | 7/774 81.7 | $\cdots$ |
| 3. | Single V butt weld | 77771818 | $\nabla$ |
|  | Double V butt weld | VIITーV | $x$ |
| 4. | Single bevel b utt weld | 27777015 | $\nabla$ |
| 5. | Bevel Butt | Qlllat | 厄 |
| 6 | Single U butt weld | 7/77x ${ }^{\text {a }}$ | $T^{\top}$ |
| 7. | Double U butt weld |  | $\bigcirc$ |
| 8. | Single J butt weld | 27774 | P' |
| 9. | Double J butt weled | Zllan | 5 |
| 10. | Backing run, back or backing | 777720 | $\sigma$ |
| 11. | Fillet weld |  |  |

7.2 Supplementary Symbols: These symbols are used with main symbols of welding. These symbols indicate the top finishing of the welding like concave, convex, flat etc.

| Sr.No. | Description | Symbol |
| :--- | :--- | :--- |
| 1 | Flat (finished flush) |  |
| 2 | Convex |  |
| 3 | Concave |  |
| 4 | Grinding finish | G (is added to the 1,2,or 3 above) |
| 5 | Machine finish | Chipping finish |
| 6 | Weld all-around | Cield or site weld |

Some examples of application of supplementary symbols :

| 677710110 | $\stackrel{\text { G }}{ }$ |
| :---: | :---: |
| $7777 \quad 178$ | X |
|  | $\Delta^{M}$ |
| [7/7, 718 | $\begin{aligned} & \hline{ }^{c} \sqrt{V} \\ & \frac{V}{G} \end{aligned}$ |


| 8777418 | $V$ |
| :---: | :---: |
| 2777 | X |
|  | $\triangleq$ |
| 77771178 | $\underline{\square}$ |

7.3 Dimensioning of welds: The important dimension of the weld are the height and side of the weld, the angle of the groove and the length and pitch of the weld.
Some examples of dimensioning of welding in the drawing:

In the first case ' $z$ ' is the fillet's side of triangle and the ' $a$ ' is height of the triangle. In the second case ' 1 ' is the length of continuous weld; ' e ' is the gap between two weld and ' $n$ ' is the number of welds.
7.4 Location of the weld: The complete description of the weld is given by means of an arrow and a reference line. The horizontal line-called the reference line-is the anchor
 to which all the other welding symbols are tied. The instructions for making the weld are attached along the reference line. An arrow connects the reference line to the joint that is to be welded.
Quite often, there are two sides to the joint to which the arrow points, and therefore two potential places for a weld. For example, when two steel plates are joined together into
 a $T$ shape, welding may be done on either side of the stem of the $T$.
Arrow side is the one which is visible to the welder and non-visible side is the other side. Arrow is basic portion of symbol and it must point towards the point which requires welding. Following is used to represent a weld as

1. A arrow and a reference line to indicate the location of a weld in a joint
2. A basic symbol to specify the type of weld ( Table on pre-page)
3. Cross sectional dimensions and length of weld if required.
4. Supplementary symbols to indicate special instructions, such as finish, weld around, weld on site etc.
The following figure gives the normal representation of a weld and the different details to be drawn to represent the weld.


An example of a fillet weld on both sides of the plate having a size of weld height as 6 mm and 5 Nos. of length 25 mm placed at a gap of 10 mm after each weld is represented below. The details in words as shown in the example are not to be written but only the reference line, the arrow, the symbol, the supplementary symbol and dimension only is to be marked.


### 7.5 Rules / Conventions:

i) Symbols for fillet and similar welds should be shown such that vertical portions of the symbol are indicated on the left hand side of symbol, irrespective of orientation of the weld metal.
ii) If the welds are to be made on the arrow side of joint, the corresponding symbol should be inverted and placed below the reference line.
iii) If the welds are to be made on the other side of a joint, the corresponding symbol should be placed above the reference line.
iv) If welds are to be made on both sides of a joint, the corresponding symbol should be placed on both sides of the reference line.
v) Dimension of the weld is indicated without inserting unit 'mm'.
vi) For fillet welds of unequal legs, the sizes should be indicated on L.H.S. of the symbol.
vii) If a weld is required to be made all all-around a joint, a circle should be placed at the 'elbow' connecting the arrow leader and reference line. If the weld is to be made at site the circle is filled with pencil/ink.

Following Examples illustrate the above:

| Triangle shows it is fillet weld. 6 shows size of weld is |
| :--- | :--- |
| 6mm. The symbol is above the reference line means |
| weld on other side of the arrow. |

### 8.0 Rivets and Riveted joints:

Rivet is a mechanical part made of steel. It is used for fastening two or more plates / parts permanently. It has a head and a cylindrical shank. This head is called factory head which is originally available. The shank is slightly tapered at the end. The other end made at site is called buckled head. The joint made with the rivet is called riveted joint. This is permanent joint and cannot be disconnected without cutting off rivet heads from one side of joint. The
 rivet supports tension loads i.e. loads parallel to the axis of shaft however it is more capable of supporting shear loads i.e. loads perpendicular to the axis of the shaft. Bolt and nut joint is better suitable for tension applications.
8.1 Rivet heads: Different rivet heads are used for different purpose. The snap or cup head is commonly used. The countersunk head is used when surface of plate is required flushed after riveting. The conical and ellipsoid heads are generally used for boilers.

(i) SNAP OR CUP

(ii) PAN

(iii) CONICAL (iv) COUNTERSUNK

(v) ROUNDED COUNTERSUNK

(vi) ELLIPSOID

### 8.2 Symbols:

| S. No. | Description | Symbol |
| :--- | :--- | :---: |
| 1 | Shop Snap Rivet | $\bigoplus$ |
| 2 | Shop CSK ( near side) rivet |  |
| 3 | Shop CSK ( For side) rivet |  |
| 4 | Shop CSK ( both side ) rivet | $\not$ |
| 5 | Site snap headed rivet | $\not$ |
| 6 | Site CSK ( near side ) rivet | $\neq$ |
| 7 | Site CSK ( for side ) rivet | $\neq$ |
| 8 | Site CSK ( both side ) rivet | $\neq$ |
| 9 | Open hole | $\psi$ |

(CSK - Counter Sunk Rivet)
Parameters of rivet joints: The main parameters of the rivet joints are diameter of rivet, position of holes from the edge of plate, distance between the two rivets with reference to the thickness of plates.
Terminology:
Gauge line - A line through the centre of a row of rivet parallel to the edge of plate Pitch ( $p$ ) - distance between the centre of adjoining rivets parallel to the line of seam. Diagonal pitch (Pd) - It is the centre to centre distance of the rivet to the centre of another rivet in joining row.
Overlap- The amount by which one plate covers the other plate (minimum =3 d)

### 8.3 Types of riveting:

(a) Zigzag Riveting: Rivets in one row are placed midway between two rivets of the other row.
i) $\quad \mathrm{d}=6 \sqrt{t}$ diameter of the rivet should not be less than 6 times of square root of plate thickness.
ii) $p=3 d$ the distance between the adjoining rivet should not be less than three times of diameter of the rivet.
iii) $\mathrm{m}=\mathrm{d}$ the distance between the edge of rivet hole and the edge Thickness of the plate should not be less than the diameter of the rivet.
(b) Chain Riveting: In this method rivets are placed in rows directly opposite to each other:
Back or transverse pitch (Pt)- Distance between two adjacent gauge lines in the same plate.
d-Diameter of the rivet
$t$ - Thickness of plate
m - Margin (distance between the nearest edge of plate and the rivet)
8.4 Types of Joints: There are different rivet joints classified on the basis of position of the plates put together for joint. Two different types are a) Lap joint b) Butt joint
a) Lap joint: In this joint the plates to be joined are put overlapping each other. The surfaces of the plates are in contact with each other. The rivets are directly put on the plate and no other joining plate is used in this type of joint. When joint is made with only one row of rivet it is called as single rivet lap joint. The minimum overlap of plate should be 3 times of diameter of rivet. The centre of rivet should be at distance of minimum 1.5 times of diameter from the edge of the plate.


When the joint is made with two rows of rivets the joint is called as double overlap joint. The rivets are placed in the parallel row i.e. in chain or in the zigzag manner.
$P$ - Distance between the rivets
$P_{r}$ - distance between the rows

In chain riveting $P_{r}$ should not be less than 0.8 P , where as in zigzag riveting $P_{r,}$, should not be less than 0.6P.
b) Butt joint: The plates are butting together it means they are joined at the edge on same level and joint is covered by separate plate on one side or on both the side of joint. Then the plates and cover plates are riveted. The covered some times called as buttplate or butt straps.

Thickness of the butt-plates: For one strap thickness of butt-plate should be minimum equal to the thickness of plates to be connected i.e. $t_{1}=t$ minimum
For two straps thickness of butt-plate should be 0.7 times of thickness of plates to be connected. The width of the butt-plate should be a minimum 6 times of diameter of rivet.


Butt joint

ANNEXURE-A


ANNEXURE - B (Sheet 1)



ANNEXURE-C


BEAM PLAN AND RCC DETAILS OF FOOTING, COLUMN, BEAM \& SLAB


GENERAL ARRANGEMENT DRAWING OF BRIDGE

## CHAPTER - V

## STATION YARDS DRAWING

1.0 Basic Principles: The station yard occupies substantial land and length of track besides cost. An efficient yard design would not only reduce the cost of construction but also improve the operating efficiency. The planning of station yards is primarily the role assigned to Traffic Department but after being given the requirements by traffic department the actual layout in the space available has to be given by Engineering Department. The basic principles of yard design are quite simple and once grasped can be applied to solve complicated problems also. It should be understood clearly that for a good design of yard, some basic concepts of train running and safety of train operations should be gathered prior hand. Here, a few terms and concepts are discussed below,
1.1 Station and Station Limit: Any place on Railway line where traffic is dealt with, or at which an authority to proceed is given under the system of working is called a Station. The portion of Railway which is under the control of a station manager and is situated between outer most signals of the station is called Station Limit. On double line the station limit may be different in the different directions. Shunting limit board is also considered as a signal. In case there is no advance starter signal and also no shunting limit board, the station limit is between the outer most facing points.
1.2 Interlocking of Points and Signals: Normally all train movement is guided by position of signals that the driver observes. Whenever, the train is being received or dispatched into or from a station, route is required to be set by operating points for the desired route. The driver can see the signal but not the position of the point, this anomaly is removed by interlocking the points with signals. The signal can be taken 'OFF' or 'ON' only after the point has been set for the route. This is a very simple definition of rudimentary interlocking but there are several other aspects also linked to interlocking of more advanced types. In advanced interlocking classes, several features like simultaneously setting of more than one point and signals is involved, to set the route from one end the next station, there are features of warning the driver in advance of possibility of stopping at next station or next signal etc.
1.3 Fouling Mark: The location at which the infringement of fixed standard dimensions occurs or is fouled when two lines meet or cross each other is provided with a tablet at ground level indicating the 'Fouling Mark'.
1.4 Clear Standing Room (CSR): The distance between the two fouling marks in the two directions is the Clear standing Room/Length of a line i.e. the train with a length of CSR can stand on a line without infringing/fouling any other movements in the yard. Operationally, the distance between the stop signal(Starter) and the rear fouling mark, is called the Clear Standing Room/Length (CSR) or (CSL) and there can be anomaly in the two distances, if
signals are not placed just at fouling marks. For the engineering yard plan the CSR is taken as the distance between fouling marks less13m to accommodate block joint etc. As a thumb rule, the clear standing room (CSR) on running lines should be $7 \%$ more than the maximum permissible length of train( Theoretical buffer to buffer distance added up for all vehicles) plus the length of one engine or two engines where trains frequently run with two engines. The 7\% margin is allowed for slackness of couplings. In siding this margin is not required.
As per latest guidelines the clear standing room (CSR) on running lines should be minimum 686 meters. Where train operation requires 3 or 4 multiple loco on account of steep gradient, and/or on account of Heavy Mineral loading, the CSR shall be 732 meters to account for 4-locomotives. While planning new yards or lines 13 m may be added to above CSR to get the distance between FM to FM as explained in Para 1.6 below.
1.5 Running Line: Any line in the station or out of station which is governed by one or more signals and includes connections if any, used by a train while leaving or entering the station or when passing through a station. In practical terms a line on which reception or dispatch is controlled by signals is a running line.
1.6 Insulated Joint: Each block is protected by a signal at its entrance, a driver approaching the signal responds to its 'stop' or 'go' indication and either stops the train at the signal or proceeds into the block accordingly.
A "track circuit", is a low current circuit passing through the running rails. This is used to detect the presence of the train. The track circuits in different running lines of the yard are isolated from each other and from the block section by means of insulated joints. These are sometimes also known as "insulated block joints". In color light signaling, the signal aspect is controlled by the location of Insulated Joint and as soon as train is detected by the insulated joint the signal will change its aspect. Thus the distance between stop signal post and Insulated joint controlling the signal reduces the CSR by equal amount. Normally it is about 13 m i.e. 1 rail length. The position of Fouling mark, signal post and Insulated joint is as shown below,

1.7 Isolation: If in a station yard on any line any train or wagon is stabled, it can roll down toward a point and foul the running line/lines where another train is being received or dispatched. To avoid any such possibility, the running lines are isolated from all such lines where any train or wagon/coach may be stabled. The isolation is provided by a derailing switch or dead ends spur or sanded dead humps. Similarly the running lines are also isolated from other running lines as per GR-4.11(1) stipulates a speed restriction of 50 Km
even on run through line if isolation is not provided. For simultaneous reception of trains on single line section i.e. receiving a UP train and a DOWN train without stopping one of the trains at outer signal, the provision of isolations is necessary. As per latest instructions of Railway Board, Snag dead ends or Sanded dead humps should only be provided
 and derailing switch should only be provided if both of them are not feasible.

A derailing switch is provided at the start of turn in curve so that any vehicle rolling down will be derailed outwards before infringing the adjacent track. The Snag dead ends are to have minimum length of 180 m so that the train can be stopped using emergency brakes.
The same in case of Automatic signaling territory is reduced to 120 m . If due to constraint of space, snag dead end can not be provided; sanded dead hump is provided of lesser length, which would provide equal resistance.
The design of sanded dead hump as adopted in S. Rly is given below,


TYPICAL CROSS SECTION OF SANDED DEAD HUMP
Beyond sand humps sufficient clear space should be left. Cabins, quarters, or other buildings or running lines should not be located in front of sand humps where their safety would be seriously endangered in case a train over-shoots and runs in to the sand-humps.
1.8 Signal overlap: Enough braking distance is provided to allow a train to comfortably stop at the stop signal, but should it fail to do so for any reason (wet rails, brake failure, inattention by driver, etc.) there is still some distance to allow the train to stop short of any obstruction, such as another train. A signal overlap is the length of track beyond a
stop signal that is proved to be clear of vehicles in the controls of the previous signal, as a safety margin. It is to be noted that where ever the stop signal is located short of fouling mark by adequate distance i.e. 180 m in absolute block system and 120 m in automatic signal territory or the isolation is provided on the line, the requirement of signal overlap is not required additionally.
1.9 Shunting: At junction stations, and at terminals, Shunting movements are an important part of railway operation for formation of a train, for attaching / detaching the load / engine. While preparing a yard plan of a new yard this should be kept in mind that-
i. The length of shunting movements should be as small as possible.
ii. Shunting movement should not interfere with arrival departure of trains.

Shunting neck : To make a movement from one line to another the vehicle have first to drawn on to a line which is common to both; the portion of line which is common to two or more lines functions as the shunting neck.


Thus the main line functions as the shunting neck for the lines $B S$ and $B C D$; the portion $P Q$ functions as the shunting neck for the line $Q R$ and $Q C D$.

To facilitate shunting the length of a shunting neck must be sufficient to hold all the wagons which it is required to deal with at a time plus an engine. The length of shunting neck should not only be sufficient but should have a direct connection with all the lines it is intended to serve.

### 2.0 Points and Crossings:

(a) Turn outs: On the Indian Railways normally standard turn outs of crossing angle 1in 12 and 1 in8.5 with curved switches and fixed heels, are being used. In special circumstances T/Os of 1 in 16 and 1 in 20 are also used. Track Manual gives salient dimensions of various turn outs; however for laying out these T/Os, the dimensions when measured on center line representation are more useful. The center line representation of a T/O is shown in diagram below. The dimensions required for laying out a T/o are, F (angle of crossing) A, is the distance from stock joint (SJ) to point of intersection of center lines of straight and T/O side. C is the distance between Actual Toe of switch to the Stock joint. M is the distance of intersection point to theoretical nose of crossing (TNC), and K is the distance from TNC to heel of crossing.


## CENTER LINE REPRESENTATION OF A TURN OUT

In terms of Para-410 of IRPWM, minimum 1 in 12 turnouts should be laid on the running lines carrying passenger trains. However, 1 in $8.5 \mathrm{~T} / \mathrm{O}$ with curved switch may be laid in circumstances where the space is not adequate to lay, 1 in $12 \mathrm{~T} / \mathrm{O}$. Further T/Os when taken off from outside of curved track, 1in $8.5 \mathrm{~T} / \mathrm{O}$ may be used subject to the main line curve being not less than 30. 1in 12, T/O taking off from inside of curved track with curvature sharper than 40 is not to be laid and 1 in $8.5 \mathrm{~T} / \mathrm{O}$ can not be laid on inside of curve in running lines.
For the laying out of the T/O in the field, Location of Stock joint, the intersection point of straight and $\mathrm{T} / \mathrm{o}$ side i.e. point P and the distances M and K are required. However, in the drawing the point no., Crossing No., Type of switch (Curved or straight), SJ location, Heel of crossing of T/O is only required, since for standard layout the values are constant or are to be calculated in case of curved track etc. The system of numbering the points and crossings is simple and normally the two ends of the yard are designated as $\mathrm{N}, \mathrm{S}$ or E,W as the direction in which the yard lies and any cross-over points are given same no. with a subscript A or B. for example a typical no. of point could be 23A(E). This would indicate point no. 23 A of a cross-over on east side of yard.
The values required for laying them on ground for standard T/Os are given in ANNEXTURE - A of this chapter.
b) Turn in curve: The curve joining the T/O from the heel of crossing with the main line/ running line is termed as turn in curve. The radius of the turn in curve should be kept same as that of lead curve i.e. turn out curve in normal cases. In terms of Para-410 of IRPWM the radius of turn in curve should not be less than 220m on B.G. No transition or super elevation is provided.
Example: Considering the above case of turn in curve, where C/C track is 4.725 m , the crossing No. is 8.5 , for keeping the radius of curvature of Turn in curve same as for 1 in
8.5 T/O i.e. 221.52 m , the distance of tangent point beyond SJ and straight length between heel of crossing and beginning of turn in curve, can be found by simple trigonometry. (Ref.:-IRICEN publication "Layout Calculations")


The importance of point $T$ is that the $C / C$ of track is 4.727 m only after this point and any derailing switch etc. is to be placed at this location and even, the FM is to be placed opposite this point. In case of 1 in $12 \mathrm{~T} / \mathrm{O}$, these values can be calculated on similar lines as above and the distance of T from SJ is 92.03 m and length of straight between $\mathrm{T} / \mathrm{O}$ curve and $\mathrm{T} / \mathrm{l}$ curve is 15.64 m .
c) Symmetric split Turnout: When a T/O is so laid outside of a curved track, that the radius of the curve from where it takes of is same as radius of the turnout lead radius, it is known as symmetrical split turnout. If a 1 in 8.5 crossing is laid on the outside of a 40 curve, the effective radius of the lead curve of Symmetric split 1 in $8.5 \mathrm{~T} / \mathrm{O}$ will be appx. $40\left(1 / R_{\text {effective }}=\{[1 / R 1]-[1 / R 2]\}\right.$. This is very often used for providing snag dead end sidings to save space and have the same speed potential of the loop as for 1 in 12 T/O. The overall length of S.S. 1in 8.5 turnout (with curved switch on PSC sleepers with CMS crossing) is same as for normal Left hand or right hand 1 in $8.5 \mathrm{~T} / \mathrm{O}(\mathrm{A}+\mathrm{B}=12.025+16.486=$ 28.511 m for PSC sleeper Layout with CMS crossing).


The figure above illustrates that the overall length of cross-over with one in 12 and other with 1 in 8.5 (symmetrical split) T/Os is 92.421 m with speed potential of 30 Kmph . The standard length of a cross- over with 1 in $12 \mathrm{~T} / \mathrm{Os}$ (Track centers 4.725 m ) with same speed potential would be 97.578 m i.e. a space saving of about 5157 m , apart from 1 in 8.5 T/O is cheaper in cost.

### 3.0 Cross over and Scissors Cross

over: When it is required to go from one track to another, a cross over is required which is a set of 2-T/Os one on each track in opposite directions linked with plain track. In center line representation it would look as shown along side. The overall length, $L$ will depend on the tracks spacing (D). More the track centers more will be the overall length and more space requirement for laying the cross over.


CROSS-OVER WITH STRAIGHT

If sometimes, the space to accommodate a cross over with a straight between two T/Os (i.e. OL) is not available then the straight track between two T/Os is replaced by a reverse curve,but this is not a desirable feature as it involves problems in maintenance and should be avoided.
The Overall length (OL) of cross-overs with straight between the T/Os can be given as, $\mathrm{OL}=2 . \mathrm{A}+\mathrm{D} . \operatorname{Cot} \mathrm{F} \quad$ ( $\operatorname{Cot} \mathrm{F}=8.5,12,16$ or 20 depending on crossing no.)
(Note: For different layout designs with reverse curve, with non parallel lines, curved lines etc. instead of straight, refer the IRICEN publication- "Layout Calculations")

Example: Find the Overall length required to lay a cross-over with 1 in $12 \mathrm{~T} / \mathrm{Os}$ on PSC sleepers, between tracks which are at $5.300 \mathrm{~m} \mathrm{c} / \mathrm{c}$. The rail section is 60 Kg . There is no restriction of space.
Solution: Since there is no space constraint one must provide cross-over with straight track between the two T/Os.
From the table in Annexure-A, for 60 Kg PSC T/O, $A=16989$, $B=22914$ \& $D=5.300$, Cot $\mathrm{F}=12$
$\mathrm{OL}=2 \times(16989)+5300 \times 12=97578 \mathrm{~mm}$ or 97.578 m
Whenever two cross-overs are required to enable crossing over both in up and down direction, the space required to accommodate the cross overs will be double the space for one cross over as shown in figure below. If however the space to accommodate 2cross overs is not available, Scissor cross-over is provided to serve the same purpose. The Scissor cross over involves a diamond crossing of double the angle of the T/Os used for cross over.


The standard designs from RDSO are available only for 4.725 m and 5.180 m track centers for Scissors cross- over with $60 / 52 \mathrm{Kg}$ rail on wooden sleepers and for 4.725 m only on PSC sleepers. Normally 1in 8.5 Scissors are being used. The overall length of these is,
For $\mathrm{c} / \mathrm{c}$ track $=4.725 \mathrm{~m}, \mathrm{OL}=2(12000)+4725 \times 8.5=641625 \mathrm{~mm}$ or 64.163 m
For $\mathrm{c} / \mathrm{c}$ track $=5.180 \mathrm{~m}$, OL=2(12000) $+5180 \times 8.5=68030 \mathrm{~mm}$ or 68.03 m
3.1 Diamond Crossings: For crossing two tracks at an angle a diamond crossing is used. It consists of 2 acute and 2 obtuse crossings. On Indian Railways diamond crossings should not normally be flatter or less acute than 1in 8.5. A basic diamond crossing does not have any moving parts and is called fixed diamond crossing. However, when it is

required that the train will cross the other track normally but if required it may be also diverted on other track then diamond crossings with slips are used. When such diversion is required in one direction, single slip diamond is used and when diversion is required in both directions double slip diamonds are used. The overall length of the diamond crossing is governed by the, track gauge, angle of crossing and to some extent on rail section used. The overall length of diamond crossing 1 in 8.5 for BG tracks is,
For 60 Kg Rail, $\mathrm{OL}=\mathrm{P}+2 \mathrm{H}=28922+2 \times 2975=34872 \mathrm{~mm}$ or 34.872 m
For 90R Rail, OL=P+2H=28876+2×1805=32486 mm or 32.486 m
The diamond crossing using CMS crossings 1 in 8.5 , both acute and obtuse is also available, where the H i.e. distance of ANC to heel would be different and the overall length would be some what less.

For CMS crossing 60 kg (1in 8.5) H, Distance of heel to Nose of crossing= 2075mm, the overall length shall be (28922+2x 2075=) 33072 mm .

The representation of diamonds with slips is shown in fig. below,


The OL of diamonds with single or double slips also is same as for normal diamond crossing as given above. In terms of Para- 416 of IRPWM, normally diamond crossings on curved track should not be laid, as the straight diamond crossing gives kinks in the track. However, if unavoidable at least 20 m track on approaches should be without super elevation and speed will be restricted. If diamond crossing is on straight it should be seen that at least 50 m track in approach is straight i.e. the curve should not begin within 50 m of heel of acute crossing to permit full speed on the crossing.
4.0 Curved Track: A curve on a track is defined by a) the angle of divergence between the track, D b) the chainage of tangent points of circular curve i.e. the points where the circular curve starts and ends, T1 and T2, c) the start and end of the transition curve i.e.TP1 and TP2 and length of transition curve d) shift of curve due to transition curve and the d) radius of curve. These are to be indicated on the drawing for all curves on main line.
Knowing the divergence angle, radius of curve and sectional speed, cant to be provided is decided. Based on Ca , actual cant provided, the transition length is decided. Normally for new lines L, length of transition in meters is taken as Ca in mm i.e. a cant gradient of 1 in 1000.If space is not available cant gradient up to 1 in 360 i.e. $L=0.36$ Ca can be adopted.


In case of reverse curve which is formed by two circular curves which curve in opposite directions, common transition may be provide between two curves in terms of Para407(9) of IRPWM. However on mainline for A \& B routes a straight of at least 50 m be provided between two transition curves, failing which speed in excess of 100 Kmph should not be permitted.
5.0 Ladders/gathering lines: For gathering lines in goods yard ladders are used to minimize the space requirement. Ladder is a set of lines taking of from 1-line. There can be different layouts of ladder at angle F, 2F, 3F etc. as can be seen in the diagram. It will be evident that the CSR with $3 F$ - layout is more than CSR obtained in $2 F$-layout and which is more than CSR obtained in F- layout, especially after 1st or 2nd lines. When several lines are required, it is preferable to adopt 3F-Layout, however for fewer lines $2 F$ and F layouts can be adopted.

6.0 Gradient in yards: As per Schedule of Dimensions (SOD- 2004), the recommended gradient for new yard is 1 in 1200; however in unavoidable circumstances we can lay the yard up to 1 in 260 with provision of slip or catch siding. The power of condonation of gradient steeper than 1 in 400 and up to 1 in 260 shall vest with CRS and is to be adopted only in inescapable circumstances.
6.1 For the purpose of the above rule, a station yard will be taken to extend:

1. On single line to a distance of 50 meters beyond outermost points at either end of the station
2. On double line where 2 aspect signaling is provided, from Home signal to a distance of 50 meters beyond outermost points at the trailing end, or where there are no loops, to last stop signal of each line.
3. On double line where multiple aspect signaling is provided to a distance 50 meters beyond outermost points at either end of station or where there are no loops, from Block section limit board to last stop signal at each line.
6.2 There should be no change in gradient within 30 m of any point and crossing i.e. 30 m from heel of crossing as well 30 m from stock joint.
6.3 The gradients in the yard should be so provided that it is self draining through side drains into a back bone drain or to low lying area in the vicinity. A falling gradient of not flatter than 1 in 400 , on both sides of center line of yard discharging into low land, is ideal. This may not be available many times, then under ground longitudinal drains connected to cross drainage has to be planned.
7.0 Safety sidings: Ordinarily steep gradients are not desirable in station yards because a steep falling gradient coming out of station would mean risk of vehicles slipping away from the station, while approaching trains will have the risk of parting if they are to re-start after stopping outside signals. On the other hand, a steep falling gradient coming in to station will make it difficult to stop trains at the station, thereby increasing the risk of accident.


On hilly sections, however, gradients are unavoidable. If the gradient in the yard is steeper than 1 in 260, two kinds of safety sidings are provided, called Catch and Slip sidings. Similarly if thee gradient in the approach of the yard are steep, Catch and slip sidings are provided.
Catch sidings are provided to protect the station from run-away vehicles or trains from the block section and Slip sidings are provided to prevent vehicles escaping from station yard and fouling/blocking the block section. These are laid on a rising gradient, which helps to bring run-away vehicles to a stop quickly. There are no standard designs or length available for these sidings, depending upon the gradients available and space available the length and gradients are decided. The normal position of points will be leading to siding. The points for such sidings must be interlocked with the block instruments.
7.1 Slip siding: Slip siding has to be provided, where the gradient steeper than 1:100 falling away from the station in its close vicinity (within 45 m of outer facing point as per SR-3.50(1) of C.Rly). This is to prevent vehicles escaping from the station and trying to enter in to the next block section. The siding collects the escaping vehicle and avoids it to foul the block section.
7.2 Catch siding: Catch sidings are provided to trap vehicles coming uncontrolled from block section and trying to enter in to station. As per SR-3.50(1) of C.Rly. the approaching
gradient of 1 in 80 or steeper within the 45 m of outer facing point of the station makes it necessary to provide Catch siding.These are laid on a rising gradient, which helps to bring run-away vehicles to a stop quickly. The normal position of points will be leading to siding.

## It is therefore necessary to show details of gradients, curves etc. for minimum 50 m beyond the outer facing points of any yard.

8.0 Centre to centre distance of track: As per the SOD-2004, for existing yard the minimum center to center spacing of two lines is 4265 mm and for new yard or addition to new yard it will be 5300 mm . This is uniformly applicable for goods as well as passenger yards.
9.0 Station Yard: The station yard is one of the most technical exercises required to be done, involving expertise of several departments. For drawing a yard plan first and foremost requirement is to assess realistically the requirements to be served at the station yard. This has to be furnished by the Traffic department however understanding of some of the basics are also required to be known by the Engineering department so as to optimally utilize the available space. Many of the requirements are station specific but several others are not station specific and can be also provided at neighboring station or any other station in the section. The station yards could be divided into 4 categories, namely,
i) Way side stations
ii) Junction Stations
iii) Terminal Stations
iv) Goods/Freight Station
9.1 Block Stations or Way Side Stations: These stations are primarily run through stations, mainly dividing the section into block sections for convenience of operations of trains running at substantial speed differential in case of double line section and also for crossing trains in opposing direction in case of single line sections. These could be 2 or 3 line stations on single line sections and 4 or5 line stations for double line sections. On busy sections whether on single line or double line following facilities should be provided.,
a) Arrangement for simultaneous reception of trains and.
b) Sufficient no. of platforms for passenger trains

While the number of platforms at stations should be sufficient to permit passenger trains from both directions being berthed at the same time, it is not necessary and in fact wasteful, to signal all the platforms for reception and dispatch in all directions. Normally platforms should be earmarked for each direction, allowing for simultaneous reception of trains. On SL section, where several crossings of trains is organized, it is preferable to have 2 platforms, other wise only 1 platform can suffice. Where two platforms are provided, usually they are sited opposite each other but if there is a space limitation they can be even in staggered manner.


Apart from the requirement of tracks as above, at every about 50 Km , a sick wagon siding is provided to hold detached sick wagons, en-route. This is to hold about 4-5, 8-wheeelers. Additionally, track-machine maintained sections require another siding for stabling track machines. This is a small about 100 m length siding. If the sick wagon siding is having entry from both ends, the Track machine siding could be combined with sick siding by increasing the length of the same.

Similarly, in double line sections every 4th station or so should have a facility of changing tracks from UP to DOWN and vice versa in case of emergency requirements. This is provided by providing emergency cross-overs of 1 in 8.5 , at extreme location of the yard in the trailing direction as shown in Fig (v) above. In Fig. (vi) a common loop is provided between UP and DOWN lines. It is called common loop as it serves as a loop to both the lines. The method of providing common loop in the middle of UP and DOWN lines is most efficient as trains using it need not infringe the main lines, either for receipt or dispatch. The common loop can be provided on one side, i.e. either near the UP-loop or DOWNloop but in that case the main line of the other direction would be blocked for receiving or dispatching a train from common loop. In Fig.(v) each UP and DOWN lines is provided with loops but UP loop is not used for DOWN lines and vice versa except in emergency, by using emergency cross over(Shown by dotted line). If it is the intension to use the loops for both direction trains, then isolation (Dead end) should be provided on both ends of the loop.

On most sections where maximum trains whether goods or passenger will have to run through majority of stations, it will be an advantage to site the platform on the loop, so
that while a stopping train occupies the platform line, the non stopping train can run through on the main line without reducing speed to negotiate turn out. On the contrary, on those sections which are expected to carry very little traffic, for example branch lines which will have only a few trains and all of them stopping at all stations, it would be useful to have the platforms on the main line, so that the normal setting of points would not require to be altered for passage of train and every train will not have to pass over turn-outs at every station.
9.2 Junction Stations: A station which receives and dispatches trains in more than 2directions i.e. when traffic from more than 2-directions is handled at a station, it is a Junction Station. Here minimum 3 faces of platform should be available and facility of simultaneous reception of trains is considered essential. Normally at junction stations, there may be requirement of holding Accident Relief Train and accident medical relief trains apart from sick wagon siding and many times small sidings for slip coaches, inspection carriages and shut down locomotives. The ART and ARME sidings have to be with facility of entry and exit from both ends and also to any other direction as in case of junction station. The others can be dead end sidings located in such a way that too much criss-cross movement is not involved. A skeletal arrangement of junction station layout is given below,


Many times the junction stations also have trains originating and terminating from it. Then, additional facilities of stabling a rake and maintaining it is also required. For this purpose stabling line dead end siding or otherwise with rake cleaning facility may be required. The normal passenger platform can only be used for receipt and dispatch of trains.
9.3 Terminus Station: A "terminal" or "terminus" is a station at the end of a railway line. Trains arriving there have to end their journeys (terminate) or reverse out of the station. In a few cases, however, the railway line continues for a short distance beyond the station, and terminating trains continue forwards after depositing their passengers, before either proceeding to sidings or reversing back to the station to pick up departing passengers.

There may also be a bypass line, used by freight trains that do not need to stop at the main station. In such cases all trains passing through that main station must leave in the reverse direction from that of their arrival. There are several ways in which this can be accomplished:
a) Arranging for the service to be provided by a multiple unit, or push-pull train, both of which are capable of operating in either direction. The driver simply walks to the other end of the train and takes control from the other cab.
b) By detaching the locomotive which brought the train into the station and then either
i) using another track to "run it around" to the other end of the train, to which it then re-attaches;
ii) attaching a second locomotive to the outbound end of the train; or
c) By the use of a "Triangle", track and points and crossing where a train can reverse direction and back into the terminal.
9.3.1 A terminus station in addition to receiving and dispatching trains has to have facilities for stabling rakes and maintenance of rakes. These facilities are to be created as an independent unit not influencing the station area.

9.3.2 When a junction or way-side station also serves as a terminal or originating station for few of trains, a 'dog leg' platform usually serves the purpose. This has entry from one end only and connected to one of the running lines for receipt and dispatch.

9.4 Goods/Freight Station: Goods or freight stations deal exclusively or predominantly with the loading and unloading of goods and may well have marshalling yards (classification yards) for the sorting of wagons. Presently, Indian Railways is not moving wagon load
consignments but is moving bulk consignments in rake loads and as such the requirement of marshalling yards is least.
A goods station is usually equipped with a large number of stabling and loading sidings with or without goods platforms, in order to fulfill its task. Stations where the primary purpose of the station is the handling of containers are also known as Container terminals. A container terminal is a facility where containers are transshipped between different transport vehicles, for onward transportation. The transshipment may be between ships and land vehicles, in which case the terminal is described as a maritime container terminal. Alternatively the transshipment may be between land vehicles, typically between train and truck, in which case the terminal is described as an inland container terminal. In container terminals arrangements are provided for cranes, gantries etc and storage of containers. Sufficient space is required for all these activities near the loading unloading area and accordingly separate depot or yard is normally created.
If only a small section of a station is used for the loading and unloading of goods, it may be referred to as the "loading area" and has its own access. Medium-sized and larger goods stations usually have marshalling or shunting sidings to enable trains to be divided amongst the various local loading and sorting sidings and Private sidings. On Indian Railways, since so far the stations are common for both goods and passengers, exclusive goods stations are not existing nor planned but in most of the big goods handling stations, a separate goods area is demarcated, which is controlled from the station but physically away from passenger area.
10.0 Important Points: As stated earlier, the facilities required are best worked out by traffic department and depending upon the space availability, it is generally better to keep passenger activity totally away from the goods facility or maintenance facilities. Study of details of various efficient existing yards is one method of understanding the features which should be incorporated in new works. The treatment here is by no means exhaustive or after taking into account all the conditions of the field but is to serve as basic concept required in yard drawings. Some of the points that should be kept in mind while framing a new yard are,
i) Directional traffic should be preferably dealt at different platforms, except when the traffic is very meager.
ii) Parcel traffic needs special attention as it mostly infringes with passenger areas.
iii) Simultaneous reception facilities for passenger and even goods trains should be planned.
iv) Feasibility of extension of loop lengths at least on one side should be there.
v) Easy accessibility of passenger area as well as goods areas should be available, preferably without any level crossing. This may be generally possible if the passenger station and the Goods Shed and other facilities are on the same side.
vi) Minimum shunting should be involved for placements and removals of goods rakes.

### 11.0 Check List for Scrutiny of a yard Plan:

The yard plan should contain following details-

1. Clear length of all the lines.
2. Centre to centre distance of track.
3. Isolation
4. Length of platforms.
5. Chainage of all the points, curves, signals, telegraph post/O.H.E. mast, Kilometer post etc with reference to centre of station building
6. All other features like bridges, level crossings, curves with chainages
7. Gradient in yard.
8. North direction.
11.1 The work proposed should be shown in full red lines. And the provisions made for future development of traffic should be shown in dotted red lines.
11.2 Following is a checklist of items which should be seen in any yard plan.

| Sr.No. | Item |
| :---: | :---: |
| 1 | TITLES AND NUMBERING OF DRAWINGS <br> (Title block size $-170 \mathrm{~mm} \times 65 \mathrm{~mm}$ with basic information) <br> i) Name of Railway <br> ii) Name of Division / Constn. Organisation <br> iii) Name of work <br> iv) Reference to sanction particulars ( Pink book item No./year) <br> v) Scale of drawing and reference to standard drawing if any <br> vi) Drawing number <br> vii) Completion drawing number <br> viii) Dated initials of concerned officials <br> ix) Alterations, if any, with full particulars in red on existing plan |
| 2 | Scale of plan in meters ( 10 meters to $1 \mathrm{~cm}=1: 1000$ ) |
| 3 | The magnetic north point and true north with magnetic variation |
| 4 | Spelling of station names, with kilometers and chainage |
| 5 | Designations and serial nos of all lines and sidings with Direction of traffic ( Up \& Dn lines) |
| 6 | The names of the nearest junction or terminal stations, on either side |
| 7 | Type of turnout, crossover for passenger lines, Goods lines siding etc. i.e. 1 in $8 \frac{1}{2}, 1$ in $81 / 2$ (Sym.), 1 in 12,1 in 16 etc. |
| 8 | Chainage of points (Existing \& proposed) |
| 9 | Track Centre between the lines and sidings. |


| Sr.No. | Item |
| :---: | :---: |
| 10 | Trap points with isolation as required, opening away from the important running lines other than main line. |
| 11 | Dead end for isolation and simultaneous reception |
| 12 | CSR from FM of all lines \& sidings, leaving one rail length |
| 13 | Holding capacity of all running lines and siding etc. |
| 14 | Type of passenger platform with its length and width |
| 15 | Type of goods platform with its length and width |
| 16 | Gradient posts with chainages with permissible grade within the station yard |
| 17 | Railway boundary with the distance from main line |
| 18 | Complete description of bridges with chainages |
| 19 | L.C. Gate No., \& class and its kilometers/ chainages and its distance from nearest point, whether manned / or not |
| 20 | Length of overlap siding (dead ends) to be with 120 m or 180 m for overlap and restriction on dead end siding if any (e.g. No stabling) |
| 21 | Chainage of FM |
| 22 | There must be no change of grades within 30 meters for BG \& 15 meters for MG from SRJ or heel of crossing of any point |
| 23 | All concerned officers signature should be on plan. |

## ANNEXURE-A

| Rail Section | X-ing BUILTUp |  | Dimensions(mm) |  |  |  |  | Rad(m ) $R$ of lead Curve | RDSO Drawing No. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | A | B | C | M | K | $L=\quad A+B=$ <br> T.Length of T/o |  |  |
| 90R | 1in8.5 | 12000 | 16260 | 840 | 14295 | 1965 | 28260 | 232.32 | T-307 |
|  | 1in 12 | 16953 | 22687 | 1500 | 20147 | 2540 | 39640 | 442.12 | T-31 |
|  | 1in 16 | 20922 | 30750 | 844 | 26842 | 3882 | 51672 | 824.22 | T-67 |
|  | 1 in 20 | 24664 | 38118 | 844 | 33540 | 4578 | 62782 | 1303.8 | T-98 |
| 52kg | 1in8.5 | 12000 | 16274 | 1500 | 14295 | 1979 | 28274 | 232.20 | T-286 |
|  | 1in12 | 16953 | 22706 | 1500 | 20147 | 2559 | 39659 | 442.36 | T-184 |
|  | 1in16 | 20992 | 30750 | 844 | 26842 | 3908 | 51742 | 824.22 | T-135 |

CMS CROSSING ON WOODEN OR ST SLEEPERS

|  |  | A | B | C | M | K | L | R |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 90R | 1 in 8.5 | 12000 | 17404 | 1500 | 14294 | 3109 | 29404 | 232.32 | $\begin{aligned} & \text { TA-20148 } \\ & \& 20822 \end{aligned}$ |  |
|  | 1in12 | 16953 | 23968 | 1500 | 20147 | 3815 | 40921 | 442.12 | $\begin{aligned} & \text { TA-20125 } \\ & \text { \&20839 } \end{aligned}$ |  |
|  | 1in16 | 20922 | 31421 | 844 | 26842 | 4579 | 52343 | 824.225 | $\begin{aligned} & \text { TA-20138\& } \\ & 20813 \end{aligned}$ |  |
|  | 1 in 20 | 24664 | 39470 | 844 | 26842 | 5930 | 64134 | 1303.81 | $\begin{aligned} & \text { TA-20122\& } \\ & 20804 \end{aligned}$ |  |
| 52 kg | 1in8.5 | 12000 | 17418 | 1500 | 14295 | 3123 | 29418 | 232.20 | TA20196\&20835 |  |
|  | 1in12 | 16953 | 23981 | 1500 | 20147 | 3834 | 40934 | 442.36 | TA20171\&20831 |  |
|  | 1in16 | 20922 | 31447 | 844 | 20147 | 4605 | 52369 | 824.225 | TA20141\&20828 |  |
|  | 1in16(H <br> S) | 22693 | 31447 | 850 | 26842 | 4605 | 54140 | 816.48 | T-403 |  |
| CMS CROSSING ON PSC SLEEPERS |  |  |  |  |  |  |  |  |  |  |
|  |  | A | B | C | M | K | L |  | R |  |
| $\begin{array}{ll} \hline 52 \mathrm{Kg} & \& \\ 60 \mathrm{Kg} & \end{array}$ | 1in 8.5 | 12025 | 16486 | 1500 | 14270 | 2216 | 28511 |  | 232.26 | $\begin{aligned} & \hline \text { RT- } \\ & 4865 \end{aligned}$ |
|  | 1in12 | 16989 | 22914 | 1141 | 20111 | 2803 | 39903 |  | 441.36 | $\begin{aligned} & \hline \text { RT- } \\ & 4218 \end{aligned}$ |
| 60 Kg | 1in16 | 20970 | 30558 | 844 | 26794 | 3764 | 51528 |  | 784.993 | T-5691 |
| 60 Kg | 1in20 | 25850 | 38031 | 844 | 33480 | 4550 | 63881 |  | 1283.10 | T-5858 |

(NOTE: The center line representation and the distances are useful for calculating and laying out the T/O in field as well as on drawing as well as for understanding but on Engineering drawings T/Os are drawn as they actually are either in single line or double line representation).

## CHAPTER-VI

## REINFORCEMENT DETAILING FOR R.C.C. STRUCTURES

1.0 General: It is customary to prepare detailed reinforcement of various elements of the structure on separate sheets, e.g. the foundations, beams, columns, each storey floors, roof slabs etc of a building are put on separate sheets. However for small works, the different details can also be put on one single sheet. To ensure clarity, in addition to plan and elevation of the element x-section and longitudinal sections should also be shown, detailing the reinforcements. Further following should be ensured,
i) For clear demarcation the reinforcement on the front face should be shown in dark black lines and the ones in the rear face in dark black dotted lines.
ii) All bars requiring hooks and bends should be demarcated clearly or a note should be given in the drawing to this effect. The bar bending schedule should invariably show the true shape and dimension of the bar.
iii) Lap lengths, point of bend, cut off points should be clearly shown in the drawing and general remarks like at L/3, L/4 etc should not be relied upon.
iv) Clear and adequate details of special and unusual circumstances should be marked so as to leave no ambiguity while placing reinforcements.
v) The reinforcement details of beams, columns, slabs and other elements should be shown in a tabular form indicating detailed dimensions, point of bend, hooks etc along with their nos. required for an element. This is known as 'Bar Bending Schedule'.
1.1 Symbols and notations: All reinforcement bars shall be numbered and designated both on drawing and bar bending schedule. The following symbols and designations are standardised as per I.S.Code (SP-34),
a) Cross sectional shape and size of bar:

| Bar type | Designation/Symbol | Example |
| :--- | :--- | :--- |
| M.S. Rounds | $\phi$ <br> diameter | $\phi 20$ means M.S. bar of 20 mm |
| HYSD or CTD bars | $\#$ OR $\boldsymbol{\Phi}$ <br> of 20mm dia. | $\# 20$ (OR $\boldsymbol{\Phi}$ 20), means twisted bar |
| Square plain bar | $\square$ | $\square 20$ means $20 \times 20 \mathrm{~mm}$ square plain <br> bar |

Note: The symbol is used on the left of the diameter/size.

## b) Relating to position and direction:

| Type | Symbol | Example |
| :--- | :--- | :--- |
| Reinf. Each way | EW | $\frac{\phi 20,10 \mathrm{no} . \mathrm{EW}}{}$ |
| Centre to centre of reinf. | $@$ | \#20? @ 100 means 20 mm <br> dia bar at $100 \mathrm{~mm} \mathrm{c} / \mathrm{c}$. |
| Limit of area covered by bar | $\longleftarrow$ | \#20@100 bars within the <br> area marked |
| Direction in which bars extend | $\longleftrightarrow$ |  |

C) Relating to type of bar along its length:

| Type | Symbol | Example |
| :--- | :--- | :--- |
| Alternate bar | ALT | \# 20 @ 200 ALT and ? <br> \#25@ 200 ALT. means alternate <br> bars of \# 20 and \# <br> 25 @ 200 mm c/c. |
| Bent bar | BT | If few bars are to be cranked/ <br> bent at some point and some to <br> go straight then, \# 20 @200 BT <br> and \# 20 @ 200 ST |
| Bottom bar | B | In plan bottom bars are shown <br> dotted and top bars solid. If <br> some bars are intermediate <br> they will also be dotted. BT <br> designates the bottom bars and <br> T the top bar. |
| Straight bar | ST | Same as per bent bar |
| Stirrup | STP | To distinguish long bars from <br> stirrups, STP is used for <br> stirrups |
| Spiral | SP | Spirals are normally used in <br> circular column and anchorage <br> block of PSC girder etc. |
| Column Tie | CT | Ties are provided to support the <br> column stirrups at between <br> points. |
| Top Bar | T | Same as for B bar |

Representation on Drawing：

| S．No． | Type | Representation on drawing |
| :---: | :---: | :---: |
| 1 | Concrete line | $\longrightarrow$（Thin） |
| 2 | Hidden conc．Or masonry line | －－－－－－－－（Thin） |
| 3 | Reinforcement bar line | $\longrightarrow$（Thick） |
| 4 | Reinf．Bars in different layers | ーーーーーーーー（Thick） |
| 5 | Section of reinf．Bar | $\bigcirc$ |
| 6 | Centre line | （Thin chain line） |
| 7 | Dimension lines |  |
| 8 | Bar bent at rt． Angle to paper | $0$ |
| 9 | Bar with hooks | The hooks should be drawn to scale． |
| 10 | Bar with $90^{\circ}$ bend |  |
| 11 | Bars shown separated on Drg． |  |

Additional representations as per ISO-3766-1977:

| S. No. | Type | Detail sketch |
| :---: | :---: | :---: |
| 1 | Bundle of bars | Bundle of identical 3 bars |
| 2 | Each set of identical bars, stirrups, ties indicated by 1 bar, within extreme bars |  |
| 3 | For simple details on plan of drawing. The top and bottom layer reinforcement shown by designation $B$ and T. |  |
| 4 | All the types of stirrups, ties should be indicated, if required by additional sketch. | OR $\square$ |
| 5 | All details must be shown if required on a sketch along with the drawing. |  |

### 2.0 General Detailing requirements:

a) Cover: The designer normally will provide the information of cover required however the draftsman should have adequate knowledge of requirement of covers in different elements for different environmental conditions,

| S. No. | Element of structure | Minimum covers in mm. |
| :--- | :--- | :--- |
| 1 | At each end of <br> reinforcement | 25 mm or 2 x dia of bar whichever is greater |
| 2 | Long bars in column | 40 mm or the dia of bar, whichever is <br> greater.In case of slender columns of one |
|  |  | dimension being $\leq 200 \mathrm{~mm}$, having long bars <br> of dia 12 mm or less, the cover can be 25 mm |
| 3 | Long bars in beams | 25 mm or dia of bar whichever is greater. |
| 4 | All reinforcement in slab | 15 mm or dia of bar whichever is greater. |
| Marine or aggressive climate: |  |  |
| 5 | Structure immersed in <br> sea water | 40 mm extra over the covers provided as per <br> above (1-4), but not more than 75mm. |
| 6 | Alternate wetting and drying <br> in sea water | 50 mm extra over the covers provided as per <br> above (1-4), but not more than 75 mm. |
| 7 | For higher grade <br> concrete $\geq$ M25, <br> in marine area. | The extra cover can be reduced by <br> half i.e. 20mm extra in 5 and 25 mm <br> extra in 6 above. |

b) Anchoring bars in compression and tension zones: The development length of bar i.e. the embedded length of bar to develop the required strength of the reinforcement at the critical section. The values are different in compression and different in tension.
i) Anchoring in Tension zone: The deformed bars (HYSD, CTD, TOR) may be anchored without hooks or bends, provided the


DEVELOPMENT LENGTH IN TENSION development lengths are satisfied. The plain M.S. bars however should invariably be provided with hooks and bend to satisfy the required development length. The standard value of anchorage for hooks and bends, beyond the straight length of bar, is as given in Para 2.1 below, but not more than 16x Diameter of bar.
ii) Anchoring in Compression Zone: In compression however, the hooks and bends are not effective and the length in hooks and bends is not accounted towards the total development length required. Further, in case of bent bars as shown in sketch below, only the projected length is counted towards the development length.


COMPRESSION ZONE (ABOVEN.A.ONLY)

c) Dimension of Hook and Bends:


Standard Hook ( $>16 \phi / 8 \Phi$ ) Standard $90_{0}$ bend $(>8 \phi / 6 \Phi)$
Standard Value of K for bends and hooks
For M.S. steel - 4
For Tor steel- 2
2.1 Development length: The development lengths for different bars in tension and compression can be worked out from first principle and are also given for normally used concrete mixes in tables below for ready adoption,
a) MILD STEEL BARS:

| Dia <br> bar <br> Mm <br> M.S. <br> Steel | Development length in Tension <br> The length of hook and/ or $90^{\circ}$ bend <br> (IN MM) |  |  | Development length in <br> compression <br> Hook and bend not to accounted in the <br> development length(IN MM) |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | M15 | M20 | M25 | M30 | M15 | M20 | M25 | M30 |
| 6 | 32.6 | 27.2 | 23.3 | 21.8 | 26.1 | 28.1 | 18.6 | 17.4 |
| 8 | 43.5 | 36.3 | 31.1 | 29.0 | 34.8 | 29.0 | 24.9 | 23.2 |
| 10 | 54.4 | 45.3 | 38.8 | 36.3 | 43.5 | 36.3 | 31.1 | 29 |
| 12 | 65.3 | 54.4 | 46.6 | 43.5 | 52.2 | 43.5 | 37.3 | 34.8 |
| 16 | 87.0 | 72.5 | 62.1 | 58.0 | 69.6 | 58 | 49.7 | 46.4 |
| 18 | 97.9 | 81.6 | 69.9 | 65.3 | 78.3 | 65.3 | 55.9 | 52.2 |
| 20 | 109 | 90.6 | 77.7 | 72.5 | 87 | 72.5 | 62.1 | 58.0 |

REINFORCEMENT DETAILING FOR R.C.C. STRUCTURES

| 22 | 115 | 95.7 | 82.0 | 76.6 | 91.9 | 76.6 | 65.6 | 61.2 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 25 | 131 | 109 | 93.2 | 87.0 | 104 | 87.0 | 74.6 | 69.6 |
| 28 | 146 | 122 | 104 | 97.4 | 117 | 97.4 | 83.5 | 78.0 |
| 32 | 167 | 139 | 119 | 111 | 134 | 111 | 95.5 | 89.6 |
| 36 | 188 | 157 | 134 | 125 | 150 | 123 | 107 | 100 |

b) Fe- $\mathbf{4 1 5}$ BARS:

| Dia <br> bar <br> Mm | Development length in Tension <br> The length of hook and bend <br> is inclusive in the development length. <br> (IN MM) |  |  | Development length in <br> compression <br> The lenght of Hook and bend not to <br> accounted in the dev. Length. |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | M15 | M20 | M25 | M30 | M15 | M20 | M25 | M30 |
| 6 | 33.8 | 28.2 | 24.2 | 22.6 | 27.1 | 22.6 | 19.3 | 18.1 |
| 8 | 45.1 | 37.6 | 32.2 | 30.1 | 36.1 | 30.1 | 25.8 | 24.1 |
| 10 | 56.4 | 47.0 | 40.3 | 37.6 | 45.1 | 37.6 | 32.2 | 30.1 |
| 12 | 67.7 | 56.4 | 48.4 | 45.1 | 54.2 | 45.1 | 38.7 | 36.1 |
| 16 | 90.3 | 75.2 | 64.5 | 60.2 | 72.2 | 60.2 | 51.6 | 48.1 |
| 18 | 102 | 84.6 | 72.5 | 67.7 | 81.2 | 67.7 | 58.0 | 54.2 |
| 20 | 113 | 94.0 | 80.6 | 75.2 | 90.3 | 75.2 | 64.5 | 60.2 |
| 22 | 124 | 103 | 88.7 | 82.7 | 99.3 | 82.7 | 70.9 | 66.2 |
| 25 | 141 | 118 | 101 | 94.0 | 113 | 94.0 | 80.6 | 75.2 |
| 28 | 158 | 132 | 113 | 105 | 126 | 105 | 90.3 | 84.2 |
| 32 | 181 | 150 | 129 | 120 | 144 | 120 | 103 | 96.3 |
| 36 | 203 | 169 | 145 | 135 | 162 | 135 | 116 | 108 |

c) Fe- 500 BARS:

| Dia <br> bar <br> Mm | Development length in Tension <br> The length of hook and bend <br> is inclusive in the development length. <br> (IN MM) |  |  | Development length in <br> compression <br> The lenght of Hook and bend not to <br> accounted in the dev. Length. |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | M15 | M20 | M25 | M30 | M15 | M20 | M25 | M30 |
|  | 40.8 | 34 | 29.1 | 27.2 | 32.6 | 27.2 | 23.3 | 21.8 |
|  | 54.4 | 45.3 | 38.8 | 36.3 | 43.5 | 36.3 | 31.1 | 29.0 |
|  | 68.0 | 56.6 | 48.5 | 45.3 | 54.4 | 45.3 | 38.8 | 36.3 |
|  | 81.6 | 68 | 58.3 | 54.4 | 65.3 | 54.4 | 46.6 | 43.5 |
|  | 109 | 90.6 | 77.7 | 72.5 | 87.0 | 72.5 | 62.1 | 58.0 |
|  | 122 | 102 | 87.4 | 81.6 | 97.9 | 81.6 | 69.9 | 65.3 |


|  | 136 | 113 | 97.1 | 90.6 | 109 | 90.6 | 77.7 | 72.5 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | 150 | 125 | 107 | 99.7 | 120 | 99.7 | 85.4 | 79.8 |
|  | 170 | 142 | 121 | 113 | 136 | 113 | 97.1 | 90.6 |
|  | 190 | 159 | 136 | 127 | 152 | 127 | 109 | 102 |
|  | 218 | 181 | 155 | 145 | 174 | 145 | 124 | 116 |
|  | 245 | 204 | 175 | 163 | 196 | 163 | 140 | 131 |

d) Stirrups and ties: The development length in stirrups and transverse ties is satisfied, if the ends of the bar are bent,
a) at least $90^{\circ}$ round a bar of diameter not less than its own diameter and is continued beyond the curve for at least $8 x$ diameter
b) at least $135^{\circ}$ round a bar and is continued beyond the curve for at least $6 x$ diameter
c) at least $180^{\circ}$ round a bar and continued beyond the curve for at least $4 x$ diameter of bar.
2.2 Splice length of bars: The bars are normally spliced using a lap. In tension members like beams etc. the splice should be provided at a point where the moment is less than half of maximum moment, which in simply supported beams is at $1 / 3^{\text {rd }}$ span and towards the support. Further, they should be staggered and not more than $50 \%$ bars be spliced at one point. Following needs to be complied,
a) Lap splice shall not be used for diameters more than 36 mm .
b) For staggering the splice a centre to centre distance of not less than 1.3x lap length should be kept.
c) Lap length in flexural tension should be same as development length as described above or $30 x$ diameter of bar whichever is greater. Lap length in case of direct tension members should be $2 x$ development length or $30 x$ diameters whichever is greater. In case of hooks or $90^{\circ}$ bends provided in the end of bars, the straight portion should be not less than $15 \times$ diameters or 200 mm whichever is greater.
d) Lap length in compression should not be
 less than the development length or $24 x$ diameter of bar whichever is greater.
e) Lap length in a column is provided by an offset in one of the bars at a slope not less than 1:6 and both ends should be parallel to the axis of column. The point A where the crank offset starts needs to be provided with stirrups to support the outward thrust exerted by the rod.
f) When bars of different diameters are to be spliced the development length is to be calculated based on diameter of smaller diameter bar.
3.0 Shape and dimensions: Some of the normally used shapes and the straight lengths of bars are given below,

| Method of dimensioning | Straight Length of <br> and |
| :--- | :--- |
| Sending <br> Bending Schedule |  |

REINFORCEMENT DETAILING FOR R.C.C. STRUCTURES

|  | $A+E-R / 2-D+2 B$ | $A \underbrace{}_{E}$ |
| :---: | :---: | :---: |
|  | A+E-R/2-d+2H | ${ }^{A} \underbrace{C_{R}}_{E}$ |
|  | $\mathrm{A}+\mathrm{E}+1.33 \mathrm{D}+2 \mathrm{H}$ |  |
|  | If angle with horizontal is $<45^{\circ}$ and $\mathrm{R}<12$, $\mathrm{A}+\mathrm{E}+2 \mathrm{H}$ |  |
|  | If angle with horizontal is $<45^{\circ}$ and $\mathrm{R}<12$, $\mathrm{A}+\mathrm{B}+\mathrm{B}+\mathrm{H}-2(\mathrm{R}+)$ | ${ }_{8}^{4} \int_{0}^{0}$ |
|  | L+2H | $E^{\mathrm{E}-7 \frac{1}{0}}$ |
|  | $\mathrm{A}+\mathrm{E}+2 \mathrm{~S}+2 \mathrm{H}+$ |  |
|  | $\begin{aligned} & \mathrm{A}+\mathrm{E}+\mathrm{C}+2 \mathrm{H}-\mathrm{D}- \\ & \mathrm{Root}\left(\mathrm{C}^{2}-\mathrm{D}^{2}\right) \end{aligned}$ |  |

REINFORCEMENT DETAILING FOR R.C.C. STRUCTURES

|  | $\mathrm{E}+2(\mathrm{~A}-\mathrm{D}+\mathrm{C}+\mathrm{H})$ |  |
| :---: | :---: | :---: |
|  | $2(A+C)+4$ | $\left[\begin{array}{l}3 \\ E\end{array}\right.$ |
|  | $2(A+C)+20$ | $\left[{ }_{B}\right.$ |
| $\left[\begin{array}{c} \mathrm{F}_{\mathrm{E}} \mathrm{E} \\ R \end{array}\right] \frac{1}{1}$ | $2(A+C)+28$ | $\left[\begin{array}{l}0 \\ E\end{array}\right.$ |
|  | $2 \mathrm{~A}+\mathrm{E}+\mathrm{C}+12+\mathrm{B}$ |  |
|  | $2 \mathrm{~A}+\mathrm{E}+\mathrm{C}+9+\mathrm{B}$ |  |
|  | $2 A+3 D+22$ | $-\iint_{-D}^{A}$ |
|  | When pitch. $\mathrm{P} \leq \mathrm{D} / 5$, (D+)+8d |  |

4.0 Bar bending schedule: The bar bending schedule is a very important part of any R.C.C. drawing and it is given in a tabular form. Following should be included in the bar bending schedule.
a) Description of the structure element
b) Position of the bar in the element
c) Bar identification number
d) Diameter of bar
e) Shape and bending dimensions of the bar
f) Length of straight bar
g) No. of bars in the structural element and total no of bars in the structure

### 4.1 TYPICAL BAR BENDING SCHEDULE:


4.2 Some points to be kept in mind: Following are some general points to be kept in mind while preparing reinforcement drawings
a) All reinforcement shall be placed and shown at centre to centre of the bars.
b) Indicate proper clear cover to reinforcement.
c) Reinforcement across a construction joint should not be continued. There should a complete discontinuity at a construction joint.
d) The main reinforcement in flexural members should preferably be not terminated in tension zone.
e) Bars of diameter more than 36 mm should not be bundled.
f) Different types of steel viz M.S., Fe 415, and Fe 500 should not be used side by side to avoid confusion in the field. However, the secondary reinforcement like ties, stirrups, links etc. can all be of M.S. whereas the main reinforcement is TOR steel of Fe415 or Fe500.
g) Under no circumstances the bar should be bent at the welds, if provided in the bar.
h) A column should have minimum 6 No. main bars to tie the helical or transverse reinforcement.
i) For M.S. bars hooks and for TOR steel bars $90^{\circ}$ bends should be provided. It is however not mandatory to provide bends in TOR steel if the development lengths are achieved.
j) In a two way slab at mid span, the main reinforcement shall be put in the bottom layer for the short span and above for the longer span, and reverse at supports i.e. short span bars at top and long span bars at bottom.
k) Grade of reinforcement steel should be clearly shown in the drawing and also in the schedule.
I) At beam column intersection it should be ensured that the main bars of beam avoid the main reinforcement of column.
m) In beam-beam intersection, it should be so ensured that the bars in mutually perpendicular directions are at different levels.

### 5.0 Typical reinforcement details of common elements:

The requirement of steel reinforcement is to be worked out by the design engineer who is expected to be fully conversant with the behaviour of the structure, ways of calculating the requirements and the relevant codal provisions in this regard. However, the proper placement
and distribution of the calculated reinforcement is many times the job of the drawing office personnel. It is very essential that they are also conversant with the typical arrangements and requirements of various structures and provide the necessary and proper details in the drawings, so that field engineers understand the drawings with clarity and do not make any error in executing the works. The sketches given hereunder are only for reference to this extent and do not replace the role of design engineer or the codes and sound engineering practices.

### 6.0 Foundation:

The reinforcement is normally shown in plan and elevation. In the plan the reinforcement of the foundation is shown as in case of a slab along with the starter bars and stirrups and dimensions of footing. In elevation the reinforcements are shown as in beam. In case of pile foundations, the pile is similar to a column and the pile cap similar to footing.


## a) Isolated/Individual footing:

The starter bar or continuous bar is provided up to the pedestal keeping the development length of the bar above the pedestal. The main tensile reinforcement is provided at the bottom face in both directions in case of a square/rectangular footing. The main bars should be provided with $90^{\circ}$ bend if the development length is not achieved without them.

b) Combined strip footing: In this case the detailing of longitudinal and transverse reinforcement is similar to that of beams. In case of column is on the edge of the footing due to constraints of space to accommodate a longer footing, U-shaped bars are placed horizontally around the starter bars.



SECTION-AA


SECTION-BB
6.4A COMBINED COLUMN FOOTING

c) Pile foundation: As sated earlier the pile cap is similar to a footing. Typical details of reinforcement are shown for a group of 2-piles and a column resting on it. Similar principle is adopted for 3-pile, 4- pile and multiple pile groups

d) Raft Foundation: It is a continuous beam and slab arrangement and the rules for beams slabs are followed. Normally, the rafts will be cast in a few number of segments and therefore it is essential that due attention is given to the construction joints and detailing thereof is followed. The detailing of splices are to be done carefully as the direction of bending is reversed in case of rafts when compared to roof slabs and beams.
7.0 Beams: The following points need to be taken into consideration while detailing the reinforcement in beams,
a) The longitudinal bars shall be placed symmetrically to the width of the beam. In case only two bars are to be placed they shall be placed at the corners of the beam leaving the required cover.
b) Where longitudinal bars of different diameter are to be place in single row, the bigger diameter bars shall be placed outside and smaller bars in between. Where
different diameter bars are to be kept in different rows, the larger diameter bars are kept closer to the cover and other bars in above layers.
c) The spacing of longitudinal bars shall not be less than the diameter of bar or nominal size of aggregate +5 mm . whichever is greater.
d) In case of bundled bars are used in more than one layer, they should be one above another, i.e. in vertical line, with a spacer bar of 15 mm or $2 / 3$ rd the size of aggregate whichever is greater.
e) The shear reinforcement or the stirrups shall go round or otherwise be adequately secured to the outermost tension and compression reinforcement bars. In Tee, I or L-beams the stirrups shall go round the outermost bars of the slab/ flange.
f) The stirrups should not be spaced greater then 0.75 xd when vertical stirrups and d, when at an angle of $45^{\circ}$ or $60^{\circ}$. In no case the spacing shall be more than 450 mm .



### 7.1 Opening/ Closing Corners and Cranked beams:

These beams require special attention in detailing reinforcement and normally details would be required to be given by the design engineer. However, the typical reinforcement detailing for different cases is shown in sketches below,


### 7.2 Haunches in beam:


7.3 Deeper beams: The beams with depth more than 750 mm are considered deeper beams and additional reinforcement on the two faces is to be provided at a spacing not more than 300 mm . The quantity of such steel is to be equal to $0.1 \%$ of the web area of concrete and distributed equally on two faces.

7.4 Grade beam or plinth beam: The grade beam to support the brick wall between pile foundations or footings should not be less than 150 mm deep. Minimum 3 nos. longitudinal bar of $10 \mathrm{~mm}(\mathrm{MS})$ should be provided on top and bottom with stirrups of $6 \mathrm{~mm}(\mathrm{MS})$ at spacing not more than 300 mm . When the grade beam is provided on Black cotton type soil, gap of minimum 80 mm should be kept above the ground.


TYPICAL LONG SECTION OF GRADE BEAM ON B.C. SOIL



TYPE-3

### 8.0 COLUMNS :


i) Minimum 4 longitudinal bars should be provided in a rectangular and 6 No. in circular column, along with transverse stirrups or in helical form.
ii) The bars shall not be less than 12 mm diameter nor the spacing along the periphery more than 300 mm .
iii) The footing dowels are a part of foundation and not column and accordingly, should be included in the schedule for footing and not column.
iv) The diameter of polygonal/rectangular links shall not be less than $1 / 4^{\text {th }}$ of largest longitudinal bar but not less than 6 mm in any case.
v) The pitch of the helical reinforcement should not be more than 75 mm , or $1 / 6^{\text {th }}$ of core diameter of column. It should also not be less than 25 mm or 3 times the diameter of the bar forming the helix.
vi) 2 no. temporary fixing stirrups are provided at the location of splice to hold the reinforcement in position. This should be shown in the drawing.
vii) Splice in long bars should be as described in Para 2.2(e) above.



WHEN LONG BARS ARE <75MM C/C, TRANSVERSE REINF. NEED GO ROUND CORNER AND ALTERNATE BARS

TRANSVERSE REINF. IN COLUMN


WHEN LONG REINF, PROVIDED IN MORE THAN 1 ROW, THE INNER LAYER SHOULD NOT BE AT LESS THAN 3 DIA OF BAR IN INNER ROW. ALSO THE TRANSVERSE REINF PROVIDED ON OUTERMOST LONG BARS
LONG. BARS IN MORE THAN 1 ROW
8.1 CORBEL/ BRACKET ON A COLUMN: A corbel is a short cantilever beam taking of from the face of the column. The main bars taking the load of the beam have to be anchored very securely at the face of corbel either by welding(Full Strength) to the transverse bars of beam or by bending them backwards to form loops as shown below. The cantilever load pulls the corbel/bracket away from column in horizontal direction and the stirrups in horizontal direction are to be placed in the $2 / 3^{\text {rd }}$ effective depth of the corbel.

8.2 Mushroom Head column: In case of flat slabs, mushroom heads are provided at the top of the column and are cast normally with the rest of the column. It is therefore necessary that the reinforcement of the mushroom head is formed in a separate cage and the slab reinforcement can be placed after casting the mushroom head. Typical reinforcement is as given below.

9.0 SLABS: The floor slabs can span in one direction, in 2 directions and may be free simply supported or restrained. The design engineer will give due consideration to the above conditions and work out the requirement of reinforcement.
i) The minimum cover to the longitudinal, transverse or shear stirrups shall not be less than 15 mm or the dia. of the bar whichever is greater.

ii) The main bars shall not be less than 8 mm (TOR steel) or $10 \mathrm{~mm}(\mathrm{MS}$ steel). The distribution steel (In cross direction to main steel) could however be 6 mm .
a) One Way Slab or simply supported slab:
i) The slab supported on all 4-sides but where the L/B is more than 2, or a slab supported on two sides is considered as one way slab.
ii) The bars in shorter direction are placed at lower level i.e. closer to cover and transverse steel in upper layer.
iii) Minimum 50\% of main reinforcement (in short direction) should extend fully to the support and other $50 \%$ can be cranked upwards within a distance of 0.1 L from support.
b) Two way slab: The reinforcement in both directions is main reinforcement and serves as transverse steel also. The rules for detailing in 2-way slabs are same as for 1-way slab, but in both directions.

Here also the bars in the shorter direction are placed at lower level and the cranking the $50 \%$ bars are allowed only in 0.1 L from the support.

c) Restrained slab: When the corners of the slab are not free to lift up under bending, such slab is called a restrained slab. Normally this condition arises when upper floors of brickwork hold the slab restrained from lifting up. In such a case torsion reinforcement in the form of U-bars at the corners are be provided additionally. When the 2 -ends are discontinuous the U-bars have to be provided in span/5 in each direction and when the corner is discontinuous in one end only then the $U$ bars have to be provided on span/5 on both continuous sides of slab.


CORNER WITH 2 - DISCONTINUOUS ENDS


CORNER WITH ONE DISCONTINUOUS END
d) Cantilever slab: The slab may be cantilever overhanging beyond a wall or may have beam either above the wall or independently. The typical detailing is as shown below,


### 10.0 STAIRS:

The stairs may be supported on edge beams, walls or on a central beam. The reinforcement details of stairs supported on edge beams is similar to the stairs supported on walls on both sides. While the reinforcement in stairs supported on central beam is like a cantilever beam equally overhanging on two sides.
The beams either the edge beams or central beams have to be designed as cranked beams, and the reinforcement details are as described in Para 5.3 above. The typical reinforcement details are shown below in the two cases.


10.1 STAIRS SUPPORTED AT FLIGHTS/LANDING AT TWO ENDS IN BRICK WALL:

Many times the stairs are supported by walls at two ends of the landing or flights, without any beam either at edge or centre. Here the stairs are designed as slab or a beam, duly taking care the aspects of crank at the level of landing. Typical reinforcement details are shown in sketches below,


STAIR SUPPORTEDAT ENDS OF LANDING TYPICAL LONG. REINF


### 11.0 WATER TANKS OVER GROUND:

a) Rectangular tank: The corners of the tanks support the vertical walls and thus produce tension in the middle of outer face and at inner face of the end of walls, these tension parts are to be provided with horizontal reinforcement along with the vertical reinforcement for cantilever walls. The bottom slab has to be provided reinforcement in double layer i.e. both at bottom and top layer of slab.

b) Circular tank: Hoop reinforcement is placed either in single layer or double layer depending on size of the tank. The spacing of hoop reinforcement is varied from top to bottom, more at bottom and lesser at top. Normally the variation is done in band of 1 m . Distribution steel is provided in vertical direction.
The base slab is provided reinforcement in two layers, i.e. both at bottom and at top of slab. The bars in top and bottom layers are kept at right angles to each other. Corner bars are provided in the haunch to provide continuity of slab and vertical shell.


SECTION THROUGH A CIRCULAR TANK-HOOP REINF IN 1 - LAYER


OETAILS OF MAIN BARS
PLACED ALONG HERE

## CIRCULARSLAB

11.1 OVERHEAD TANKS: Primarily the main difference in the tank at ground or overhead is in the method of support, uniform support at ground in one case and normally edge beam support in other. Typical overhead circular tanks are Intz tanks and there are standard drawings available for the same from manufacturers etc. The design of Intz tanks have several features depending on the designer choice and not given here. RDSO has issued standard drawings for Intz tanks of capacity varying from 50,000 liters to 450,000 litres for Seismic zones I to IV. The list of drawings is given at Appendix XV. These may be referred to for detailing of reinforcement of any other capacity of Intz tank.
12.0 RETAINING WALLS: The retaining walls may be cantilever or counterfort. In cantilever walls normally they may be L-shaped or T-shaped. Typical reinforcement details in three cases is shown below,


## CHAPTER - VII

## PLANNING OF RAILWAY STATIONS

### 1.0 Station Types:

## i) Line Stations

Line stations or Block stations are the normal stations from which the railway line passes through and those which are not junction stations. Most of the C, D and E class stations of Indian Railways belong to this category. They serve to the passengers whose origination and/or destination is the catchment area of these stations.
Design considerations may include:
a) Facilities for the peak passenger movements
b) Facilities for staff involved in operations.
c) Rudimentary snacks and tea facilities
ii) Terminal Stations

Terminal stations are located at the end of the Railway line network and are mostly important and bigger places. These tend to have significant inter-modal transfers for places connected to different towns e.g. New Delhi station connects to many neighboring towns of UP, Himachal and Punjab and people go by bus to these places as these places are either not connected by train or the services are not that frequent. Terminal stations tend to serve passengers from beyond the immediate station catchment area. Then second category of traffic is commuter Passenger flows which tend to be unidirectional depending on the time of the day - morning or evening. In case of Long Distance trains at the Terminal Station, the Passenger flow is equally spread over the day. Some of the passengers coming from hinterland arrive and sometimes depart from the station either much earlier than departure of trains or wait at the station before convenient road transport available.

Design considerations shall include among others:
a) Facilities for large peak passenger movements associated with terminating and originating trains.
b) Waiting room/ area for odd hour trains.
c) Food and snack facilities.
d) Inter-modal transfer to transit and non-transit modes (e.g., bus, auto-rickshaw, taxi etc.)
e) Park-and-ride, kiss-and-ride facilities
f) Stabling tracks and maintenance facilities
g) Accommodation of staff facilities.

## iii) Junction or Transfer Stations

Junction stations/Transfer stations connect railway lines coming from different directions and are subject to large transfer passenger flows. Transfer connections are typically made via passageways and FOBs connecting other areas of the station and platforms. Passenger transfers should be made within the paid areas of stations i.e. they should not be required to go out in non-ticketed area. Itarasi, Jalgaon and Allahabad stations are examples of this. Design considerations may include the following:
a) Providing an accessible transfer between station platforms (Ramps/lifts for physically challenged persons)
b) Safety and security
c) Transfer concourses, waiting areas and passageways.
d) Food and snack facilities.

For the busier and bigger stations one has to plan for the mechanized means of transport like escalators, moving walkways for covering longer distances > 150 m

## iv) Inter-modal Stations

Inter-modal stations provide connections from the railway stations to other modes of public transportation including bus, light rail transit, people movers, and metro transit systems. In India most of the tourist destinations and religious places fall under this category but not in the true sense. Design considerations may include:
a) Accommodation of large numbers of passengers with baggage.
b) Accommodation of large peak passenger movements associated with other modes
In India however, not much concerted development has taken place in this respect and New Delhi station would be the first to have when the world class station comes up and also once the Airport line built by Delhi Metro comes up. These stations would eventually require following facilities
c) Moving walkways (travelators) to assist customers and reduce travel time over long (i.e. > 150 m ) distances
d) Development of large transfer halls (the hub of the inter-modal facility), ticketing facilities and waiting areas.

### 1.1 Station classification on Indian Railways:

On the Indian Railways the stations are classified into the following 8 categories based on the annual passenger earnings as well as based on stations of tourist importance and important junctions.

| Class | Annual Passenger <br> Earning | Remarks |
| :--- | :--- | :--- |
| A1 | $>$ Rs. 50.00 Crore | Non-suburban stations only (Newly classified) |
| A | $>$ Rs. 6.00 Crore but < <br> Rs. 50.00 Crore | Non-suburban stations only |
| B | $>$ Rs. 3.00 Crore but < <br> Rs 6.00 Crore | Non-suburban stations with annual passenger <br> earnings between Rs.3.00 crores to Rs.6.00 <br> crores |
| C | No Limit | Stations of tourist importance or important <br> junctions (to be decided by GMs) |
| D | $>$ Rs 1.00 crore but <br> $<$ Rs 3.00 Crore | Non-suburban stations only |
| E | $<$ Rs 1.00 crore | Non-suburban stations |
| F | No Limit | Halt stations, Contractor operated or others |

The categorization of stations based on originating earnings was first fixed during Dec'2003. This is to be revised at a frequency of once in five years. The first revision was done during 2007-08 based on the earnings of 2006-07 and next revision is due in 2012-03 based on earnings of 2011-12. The class of station, adopted on IR is determined only on the basis of originating traffic and it is assumed that practically no separate facilities may be required for a passenger getting down at the station, and the same passenger will also be a an originating passenger for the return journey from the same station. This assumption is likely to be mostly true.
The Annual passenger earning consists of earnings from both reserved and unreserved passengers. With introduction of PRS, the earnings collected at a PRS center may not reflect the actual earnings of that station. Therefore, earnings in respect of reserved passengers are taken on the basis of Passengers boarding the trains from the station and the same is obtained from various PRS centers from where the passengers for those stations are booked. In respect of earnings from unreserved passengers, the data is collected from the tickets sold, through SPTM/UTS, card tickets, etc. The method for calculating earnings from UTS (unreserved ticketing system) for passengers boarding the trains at a station would be same as that for PRS. As far as engineering department is concerned, commercial department in the division would be having the details of the passenger earnings. However there are some shortcomings mainly for junction stations,
as the transfer passengers do not give any earning to the transfer station due to through ticket purchase by passengers. This can distort the requirement of facilities.
This classification does take into account the requirements in large measure, Scale of Passenger Amenities is classified into three categories based upon the importance of the station and the relative need of the station.

Minimum essential amenities (MEA) - The list and the scale of these are prescribed and are to be provided at all the stations and for the new works these are to be charged to the plan head under which the station is being constructed. If the station is a part of new line project the cost of MEA will be charged to accounting head 1100. Any further additions at a later date over and above the MEA will be chargeable to the head "Passenger and other user amenities". A booklet called "Passenger Amenity booklet" is prepared and updated each year showing the MEA requirement and provisions. This is updated every year and sent to Railway Board.

Recommended level of amenities - Further augmentation after the MEA have been provided comes under the recommended level. These can be provided only after the MEA have been provided. The difference between MEA and recommended is that MEA gives minimum scale irrespective of passenger traffic at a station but recommended links the scale of the amenities to the number of peak hour passengers. The details are given in chapter 4 of IRWM and may be referred.

Desirable amenities - These are amenities to further improve the passenger satisfaction and this would depend upon the specific need of the station and unlike MEA provision of these can be done even if all the recommended amenities have not been provided. E.g. provision of retiring rooms becomes important at places of tourist interest.

### 2.0 Planning

2.1 Period: The planning of facilities at the station is to be done for the design year, design daily passenger and peak hour passenger volume for the Station. The station should be planned with reference to the passengers and other users expected to avail of the station facility, not only in immediate future but also the projected future requirement. All the facilities need not be provided in the first construction, however the planning should include the same and earmarked space be kept for future development of about 40 years.
2.2 Elements of Station planning: Station configuration addresses the geometry and functional needs of the station design. Station configuration issues involve the design of station entrances, the arrangement of the train platform(s), the location and relationship of the ticket issuing and ticket checking areas to the entrance(s) and platform(s), parking facilities, work and rest areas, and the integration of ancillary and support facilities with the public functions. Following shall be the key elements of the planning of the Station
a) Maximum Passenger Convenience
b) Safety and Security
c) Fast and Efficient Passenger Flow

Stations should be designed to minimize the possibility of accidents. Particular attention must be paid to the more accident-prone areas, such as the platform and vertical circulation elements. The designer must keep in mind the fact that the transit passenger is a customer and that a primary goal of the Station design is to create a comfortable, convenient, and attractive environment that attracts and retains the customer. Design issues that contribute to this include:
a) The minimization of customer travel distances;
b) The provision of pedestrian routes those are as logical and direct as possible;
c) The provision of assisted locomotion (elevators, escalators, and moving walkways) where appropriate and feasible to speed customer flow and assist the mobility impaired or burdened customers;
d) The provision of adequate customer amenities; and
e) Material finishes of elements, such as flooring, walls, structures, furniture, sanitary fittings, etc. within the public areas of the Station where surfaces either come in direct physical contact of passengers or are visible to them should be highly durable, need low maintenance, less frequent cleaning, and be less amenable to catch dust or cobwebs.
3.0 Free flow of passengers: Strategies to facilitate the free flow of passengers shall include, but shall not be limited to the following:
a) Separation of different categories of passengers.
b) Design of a clear, simple, and direct passenger circulation system, minimizing turns and decision points
c) Minimizing travel distances
d) Efficient and strategic use of FOB's and others accesses like subways etc.
e) Efficient and strategic use of electronic boards to display information about train schedules, etc.
f) Minimizing cross-flows and conflicting passenger movements.
3.1 As per International practice (J.J Fruin's Queue) the area required per person for free flow depending upon the level of service (LOS) divided in A,B,C,D,E or F categories, is as given below,

| Level of Service | Description | sq. m. per Person |
| :---: | :--- | :--- |
| A | Free circulation zone | 1.17 or more |
| B | Restricted circulation zone | $0.9-1.17$ |
| C | Personal comfort zone | $0.63-0.9$ |
| D | No-touch zone | $0.27-0.63$ |
| E | Touch zone | $0.18-0.27$ |
| F | Body ellipse | 0.09 or less |

The higher level of service is available when we use the higher category of LOS, i.e. A provides better service than B and so on. Thus depending on the class of passenger and the time a passenger has to spend in any element, a particular level of service (LOS) should be chosen for design.
3.2 Similarly the flow in the queuing area at different level of service is as under:

| LOS | Passenger <br> space $\mathbf{m}^{2 /}$ <br> person | Flow per <br> unit width <br> person/m/min | Description |
| :--- | :--- | :--- | :--- |
| A | $>1.9$ | $<16$ | Standing and free circulation possible in <br> queuing area without disturbing others |
| B | $1.4-1.9$ | $16-23$ | Standing and partially restricted circulation <br> possible in queuing area without disturbing <br> others |
| C | $0.9-1.4$ | $23-33$ | Standing and restricted circulation possible <br> in queuing area with disturbing others |
| D | $0.7-0.9$ | $33-43$ | Standing without touching is impossible. <br> Forward movement possible only in a group <br> and uncomfortable for long time in queue |
| E | $0.4-0.7$ | $43-56$ | Standing without physical contact is <br> impossible. Circulation within the queue <br> impossible. Slow Movement is sustained for <br> very short time. |
| F | $<0.4$ | Variable | Virtually all persons are standing in contact <br> of each other and no movement is possible. <br> State of panic and pushing exists in the <br> queue. |

3.3 Almost similar stipulations are given by International Air transportation Association (IATA) for air-terminals and can also be adopted for important stations.

|  | Allocated area ( $\mathbf{m}^{2} /$ person) |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| LOS | A | B | C | D | E | F |
| Check-in queue | 1.71 | 1.53 | 1.35 | 1.17 | 0.99 | System Break |
| Wait/Circulate | 2.61 | 2.25 | 1.80 | 1.44 | 0.99 |  |
| Hold room | 1.35 | 1.17 | 0.99 | 0.81 | 0.54 |  |

4.0 Entrances: Station entrances provide the link between the station and the surrounding streets, and their design must reflect the distinct requirements of both. Entrances should not be negatively influenced by adjacent pedestrian flows, activities, or events unrelated to the station. Special attention must be paid to the potential impact of adjacent land uses on station access and vice versa. The following table provides an example for the type of standard that should be developed for establishing emergency egress capacity from the stations depending on the level of fire safety risk assigned to a particular area.

|  | Entry/Exit Element | Min $^{m}$ Width (mm) | Capacity Rating <br> persons/minute |
| :--- | :--- | :--- | :--- |
| 1 | Horizontal | 915 | 183 |
| 2 | Stair in one direction | 1120 | 157 |
| 3 | Ramp in one direction | 1120 | 224 |
| 4 | Door | 810 | 162 |

Vehicle circulation strategy within the parking facility shall be based on following features. The station should provide ease of access for all travelers by minimizing physical and psychological impediments to their use of the Station. The positioning and character of the Station's access points will have a critical influence in satisfying this requirement. Calculation for entrance capacity for example would involve passenger movement analysis that should take the more restrictive requirements of access to the station during the peak hour of the peak day or the safety evacuation of the station. Normally, a minimum door width of 914.4 mm and maximum egress capacity of 5 mm per person per minute is considered for working out the capacity requirement of entrance/exit. e.g. if a passenger load of 3 terminating trains at the same time, has to exit a station (say 5,000 Nos.) that needs to be in a maximum of 4 minutes or less, would require ( $5000 \times 5 /(914 \times 4)=6.8$ opening) or 7 numbers minimum door widths of 914 mm . At every inter-modal connection and every street access, there should be at least one handicap access entrance.
Entrances and FOB's etc. shall be protected from the weather. Escalators shall be sheltered as per stipulated standards.. Entrance canopies provide weather protection and are another visual identifying element, providing system recognition. Entrance canopy designs may also incorporate signage and lighting (wherever feasible).
4.1 Station Entrance Protection - All station entrances pedestrian access ways that are adjacent to vehicular pathways and must be provided with high security. Bollards (a vertical rigid or flexible post to psychologically separate the areas) with chain or curbstones with provision for removal of bollards for access of emergency and service vehicles shall be provided.
4.2 Pedestrian access - All pedestrian access either from the street or the other exterior areas sections of the station complex shall be designed as to permit barrier separation from the station operating area. Normally, at each entrance to the station a walking plaza
should be provided which is a raised platform, higher by about 200 mm from the street level, so that no vehicle can foul this area.

### 5.0 Advertising Display:

Advertising Elements of advertising shall be standardized in size, type, mounting details and methods, and location throughout a station. (e.g. on specific wall where advertising is permitted there should be only one type and size of advertising permitted so as not to create visual pollution). The advertising module must be coordinated with other modular elements in the station, including signage, structure, control and construction joints and finishes. Advertising panels should complement the architecture of the station and not impair the visibility of any functional/architectural element of Station. This can be ensured only at the stages of approval of the plan when it comes to the engineering department for signature of concerned officer.

### 6.0 Parking and Vehicular Access

Parking should be located away from the station structure and separated by physical barriers or by bollards and chain. Vehicular access to station operation area should be limited to the drop off points and preferably should come directly from the street and not through the other parts of the station complex. The capacity of parking facility should be catered as per the table below,

| S. No. | Type of vehicle | Minimum provision required |
| :--- | :--- | :--- |
| 1 | Cars | $60 \%$ |
| 2 | Two wheelers | $75 \%$ |
| 3 | Taxies | $50 \%$ |
| 4 | Auto-rickshaw and others | $50 \%$ |
| 5 | Cycles | $80 \%$ |
| 6 | Buses etc | $80 \%$ |
| 7 | Other modes | $50 \%$ |

* Number of vehicles coming to the station


### 6.1 Vehicle circulation should be on the following concepts,

a) Internal Circulation with the parking facility to be based on clockwise movement.
b) Encourage inbound access movement, bringing inbound vehicles on-site quickly and conveniently to prevent on-street backups at key entrances.
c) Facilitate easier access in the peak periods and reduce on-street congestion. Entrances should allow the accessing driver to drive past as much of the lot as possible before entering, thus allowing visual inspection of the facility for available spaces.
d) Entry/Exit and circulation routes shall be free from vehicular and other obstructions maintaining free flow of traffic at all times.
e) All competing modes including private cars, private two wheelers, auto rickshaws, taxies, public transport buses/mini buses shall have provisions for proper circulation, drop off/pick up facilities and parking facilities within the station complex.
f) All circulations in station area shall be unidirectional and preferably in clockwise direction. Arrivals and departures shall be planned such that there is no conflict of traffic.
g) Drop off and pick up bays shall be provided at most convenient locations.
h) All circulation roads shall be free of on-street parking.

### 7.0 CONCOURSES

### 7.1 Capacity

Station patronage is a function of the station catchment's area as defined in the preliminary planning process. The basis of determining the patronage at any specific station entrance shall be based on the Travel Demand Forecasting Model, or equivalent, which establishes design passenger flows entering and exiting the station from each zone in the catchments area. The concourse area will be determined by this model, the LOS established in section above and incorporation of the requirements of the specific type and size of station amenities such as food shops, retail shops etc. that the Railway proposes to include in this space. Calculations for the actual size of a concourse will involve at a minimum the establishment of a peak passenger load for the concourse developed by the model (which may vary from the peak departure load depending on the station operation) times the LOS criteria minus the area to be occupied by amenities and the requisite space factors applied for circulation and access.

### 7.2 Design

The design of the concourse and station control areas shall channel and segregate incoming and outgoing passengers to minimize cross-flows and conflicts. Arrival and departure areas should be distinct and separate and where feasible on different levels with no direct passenger connection between them.
Arrival areas should be in the direct flow of passenger traffic entering the station and platforms. Departure areas should be remote from arrival areas and facilitate exiting through different station access point from the main arrival areas. Concourse area will be contiguous with all main entry gates and contain the following functions;
a) Access to all platforms
b) Unreserved waiting areas
c) Reserved waiting areas
d) Lounges
e) Toilets
f) Cloak room (luggage storage)
g) Concessions (food shops, convenience retail shops)
h) Tea stalls/ food shops (unreserved waiting areas)
j) ATM's
k) RPF help-booths and stations

Concourse will be the main congregation space for the station. Its design should reflect the highest quality public space aesthetic for public open space. The finishing materials used should be of the highest durability and be of appropriate acoustic qualities.

### 8.0 FOB/Escalator

It is recommended that a minimum of two side-by-side VCEs (Vertical carrying equipment - two escalators or stair and escalator) be provided as the minimum vertical circulation unit on platforms.

Foot over bridges or subways as convenient and techno-economically feasible should be provided keeping in view the following factors:-
(a) Interconnection with high level \& low level platforms
(b) Total number of passengers dealt with at the station
(c) Frequency of train services
(d) Blocking of the lines between platforms by freight trains
(e) Stations with high level platforms should be provided foot over bridges on programmed basis.
The design \& location of the foot over bridge should be guided by the criterion of rapid dispersal of passengers through the identified exit points and keeping in view the future expansion of station building.

The foot over bridges should land near the entry/exit points so that the platforms are not congested. Otherwise entry/exit points should be created near the FOBs. On single faced platforms on busy stations while one landing or two landings (one on either side) can be provided to the platform another landing should be taken directly into the circulating area so as to avoid unnecessary movement of passengers in the platform. Though this has a disadvantage that public who want to cross the tracks from one side to the other may use this bridge necessitating additional ticket checking staff to avoid it becoming a through fare, but this will help in reduction of congestion on the platform especially in those cases where exit to station is far away from the landing of FOB.

The width of the foot over bridge or subway should be adequate to permit a free unhampered movement of passengers. The number of passengers who can be discharged per minute per metre width of FOB/subway shall be taken as under:-

| Location | Suburban | Non-suburban |
| :--- | :---: | :---: |
| In level portion \& stairway downward | 60 | 40 |
| In 1 in 10 ramp (UP \& DN) \& stairway upwards | 55 | 35 |
| Stairway both upward \& downward | 50 | 30 |

At stations where there is more than one platform without foot over bridge or subway connecting them, a pathway for passengers should be provided connecting the ends of platforms. The pathway should have a minimum width of 2 meters and it should be ensured that it is clear of all obstructions such as signaling equipments etc. which should be suitably bridged. Notices in prescribed languages should be prominently displayed near such pathway crossings to warn the users to look out for trains before using the pathways. The train drivers are also expected to whistle through out before and while passing the station.
The design of foot over bridge should provide for covering which should preferably provided at initial stage itself. For foot over bridges, subways \& pathways, the lowest overhead clearance for movement is 2.75 m .

Subway is desirable wherever is can be conveniently provided as it does not restrict the vertical expansion and hardly any maintenance is required if the aspect of leakage of water is taken care of in the initial construction. The local soil conditions and water level are important criteria for deciding whether to go in for the subway or not.

### 8.1 Queuing and Runoff Space (FOB)

i) Provide a minimum of 9.0 m of queuing and runoff space, as measured from the upper and lower escalator/ FOB working points, clear to any obstruction at the top and bottom of each escalator so as to not to cause congestion.
The footprint of escalators/FOB on platforms should be minimized.
Ramps shall only be used for small changes in level or for use by wheelchairs and the following gradients shall apply:

| S. No. | Element | Maximum gradient |
| :--- | :--- | :--- |
| 1 | Stair | $1: 12$ |
| 2 | Ramp | $1: 20$ |

Ramps shall be a minimum width of 1200 mm for unidirectional movement and 1500 mm for bi-directional movement. Rest platforms should be considered for long ramps (exceeding 10 m in height) provided for wheelchair users. Rest platforms should provide a level area (Landing) 1800mm long at intervals of approximately 10 m . Capacity of ramp is considered as 0.0819 persons per millimeter per minute. Minimum size of ramp is 0.914 m .

### 8.2 Height and Run

The rise of the stairs shall preferably be limited to 3500 mm . However, specific site conditions may cause an increase in this dimension.
For greater rise heights, the entrances shall be divided into two portions, the upper portion consisting of stairs for both up and down movement and the lower portion consisting of an escalator for upward movement and a staircase for downward movement.

A staircase taking traffic from an escalator shall be of sufficient width to provide capacity at least equal to the escalator.

### 8.3 Design Parameters

Continuous flights of stairs for use by the public shall have the following design parameters:

| Risers per flight | 3 No(minimum) <br> 12 No (maximum) <br> Height of riser (subject to Pitch) 150 mm (maximum) |
| :--- | :--- |
| Length of tread (subject to pitch) | 300 mm (minimum) |
| Stair width | 1800 mm or 3 lanes(minimum) for normal <br> movement of passengers 1200mm or 2 lanes <br> (minimum) for emergency use of passengers. |
| Length of intermediate landings | Lesser of 2000 mm or width of stairs. |
| Length of floor Landing <br> (entrances with stairs only) | 2500 mm (minimum) |
| Vertical Clearance | 2700 mm (minm) measured from the finished <br> step level (on line of nosing) to underside of <br> suspended ceiling. 2350 mm (minm) <br> measured from finished step level to <br> underside of signs. |
| Handrail | 850 mm high, 50 mm diameter 45 mm <br> clearance between hand rail and inside <br> balustrade or wall finish. |

### 9.0 Platform Area

The platform area is where customers access trains. The platform area must facilitate multiple customer circulation functions: circulation along the platform, boarding and alighting trains, queuing at the platform edge while waiting for a train, queuing at FOBs/VCEs, runoff at FOBs/VCEs, and waiting at benches or rest areas. Because of these complexand often conflicting-circulation characteristics, overcrowding on the platform may create uncomfortable or dangerous situations where customers are crowded near the platform edge. Therefore, sizing station platforms is critical and designers should err on the side of safety when determining the size of the station platform.

### 9.1 Capacity

The capacity of platforms will assume in all instances the worst case scenario for the alighting and detraining of trains in a station. A center platform will assume two 100\% capacity trains detraining and evacuating from the platform at any given time. A side platform assumes one 100\% capacity train detraining and evacuating from the platform at any given time. Evacuation for the purposes of fire safety does not need to consider operational alighting and detraining flow. However, the station capacity analysis model should identify these distinct requirements that have passengers coming from and going to different concourses and apportion the FOBs/VCE's accordingly. Following is a sample calculation for the determining of platform size and number of VCE's required to safely evacuate a center platform and shall be taken as a minimum requirement and issues of passenger flow should be factored accordingly to ensure adequate capacity for normal peak operation irrespective of emergency evacuation capacity.

| P.F. Capacity | 24 Coaches $\times 75$ persons/Coach $\times 2=2304$ Nos. |  |  |
| :--- | :--- | :---: | :---: |
| Evacuation time | 4 Minutes or as decided |  |  |
| FOB's/ Vert. Escalators etc |  |  |  |
| FOB stairs (1.12m) - 5 Nos. | $(0.055)-$ person/min/mm | 1232 |  |
| Escalator(1.12m) - 3 Nos. | $(0.083)-$ person/min/mm | 1115 |  |
| Total capacity | 2347 |  |  |
| Minimum exits | $(2304 * 5 / 4) 2880 \mathrm{~mm}$ opening required -3 units be <br> installed @ 200m C/C to cover 600m length of P.F. <br> so that average walking distance doesn't exceed <br> 100 m. |  |  |

Platform length is typically determined by the length of the longest train anticipated for the station (e.g., a 24 -coach train at 22.5 m per coach with a 22 m engine at each end will require at least a 584 m platform) plus 4.5 m or as directed by INDIAN RAILWAYS. A demarcation line should be drawn 1.80 m from the edge of the platform along its length where trolleys shall not be allowed to move to enable free movement of passengers in the area.

### 9.2 Width

Platform width is typically determined by several factors: circulating along the platform length, and a 0.13 m buffer zone along the length of the obstruction. Where a platform edge rubbing strip is employed, the width of the rubbing strip shall not be included within the preferred minimum clear distance and the edge of the platform shall be measured from the inside edge of the rubbing. The rubber strip will not be included as part of the .609 m width of the platform safety edge,station patronage and emergency exiting requirements.


Minimum Width of Home Platform $=5.33+1.80+X-1.67=5.46+X$ m $X$ is the width of the largest obstruction on the platform and minimum 1.8 m for passage. Space requirements as determined by Level of Service requirements.
The total width of the platform is equal to the sum of these factors. In addition to FOB/ Subways, circulation space, safety edges, and buffer areas, platforms must provide room for the following program requirements, many of which may contribute to the width of the platform:
a) Train information panels (freestanding map/information "kiosks;" refer to Signage and Graphics section)
b) Public telephones, including accessible and text telephones
c) Advertising panels
d) Benches
e) Trash and recycling receptacles
f) Customer Information Signs
g) Platform end gates
h) Fire protection/firefighting facilities (e.g., standpipes, hose cabinets, and extinguisher cabinets)
i) Help-Point Intercoms
j) Support areas (service and ancillary spaces)
k) Emergency egress (e.g., stairs, vestibules, corridors as required)

As a thumb rule, in the absence of specific survey data, the capacity of station platforms in discharge of passengers per meter width of unobstructed passage for movement in both directions is 60 per minute for suburban and 40 per minute for non-suburban passengers

### 9.3 Height of platforms

The height of platform for high level passenger platforms for Broad gauge should be between $760 \mathrm{~mm} \& 840 \mathrm{~mm}$ above rail level and that of low level passenger platforms should not be above 455 mm from rail level. The ends of platforms must be ramped to slope of 1 in 6 for a width of not less than one meter from face of platform wall and the rest can be ramped to same slope or fenced. . It should be kept in mind that the at the end of platform at the ramp location, the height is less and the horizontal clearance at lower height is more than at high platform level and the coping stone projection beyond the platform wall should be made 'NIL'.

### 9.4 Design Principles

The following principles should be applied to the design of station platforms:
a) All elements of the platform area must support safe customer circulation and access to the trains.
b) The design of the platform must minimize the need for customers to make decisions that may cause unnecessary hesitation while circulating.
c) Because platforms are typically crowded and subject to customer surges and cross-flows, pausing customers can cause circulation problems for all patrons. The design of the platform must allow vehicles near the points where VCEs intersect the platform.
d) Facilitate the clearing of the platform as soon as possible.
e) Platform access points and VCEs should be situated to encourage balanced vehicle loading and unloading.
f) Visual obstructions should be minimized and alcoves or other hidden areas on the platform avoided for orientation, safety, and security reasons.
g) The platform areas should not contain any ancillary or non-transit functions (e.g., vending or concessions) that may obstruct, inhibit, or impede customer circulation.
h) The path of emergency egress along the platform must be clearly delineated and lead as directly as possible to an area of safety.
i) It is preferred that the track alignment in the station area be straight and parallel to the platform edge. If necessary, the alignment may be curved within the constraints of Indian Disability Act and ADA compliant platform edge gap requirements.

### 9.5 Minimum Clearances at Platform

a) The preferred minimum clearance from the platform edge to any fixed obstruction at any point along the platform shall be 3.660 m .
b) Provide a 0.792 m deep clear area at track level beneath the platform edge. In center platform stations, provide a 0.609 m wide clear area outside the dynamic envelope of the train along the station wall opposite the platform edge. In side platform stations, provide a 0.609 m wide clear area outside the dynamic envelope of the train between the two tracks.

### 9.6 Platform walling \& coping

The distances from center of track to face of platform coping and face of platform walling can be seen in figure below. For new platforms and extension of existing ones, the face of platform wall can be constructed at a distance of 1905 mm instead of 1675 mm and for this difference of 230 mm (1905-1675), the platform coping be corbelled out by 230 mm , so that when wider stock is introduced in the section, the coping can be shifted inside towards platform by 230 mm . This will obviate the need to slew the track and corbel out coping by 230 mm or shift the platform wall inwards by 230 mm to introduce the wider stock. All the single face platform are to be provided fencing 1800 mm high above the platform level and it the berm of the platform bank should extend to a width of 600 mm beyond the fencing.


Extra clearance to be given for platform on curve as per SOD, 2004 as given below:-
(a) If PF is on outside of curve, ( $27330 / \mathrm{R}$ )+( $5 / 4 \times$ Lean)- 51 mm Lean $=(h / g) \times s$ where ( $h$ is height above RL, $g=$ gauge \& $s=s u p e r ~ e l e v a t i o n) ~$
(b) If PF is on inside of curve, ( $29600 / \mathrm{R}$ )-25mm

### 9.7 Platform Slope

The platform shall be sloped to the platform edge to insure positive drainage, to insure safety, and to prevent wheeled devices from rolling off the platform edge. The typical slope employed for drainage will be $1 \%$. The maximum longitudinal slope (along the length)
of the platform is $0.5 \%$ ( $0.3 \%$ preferred) as dictated by the track alignment. The preferred maximum allowable cross-slope (perpendicular to its length) of the platform is $1.5 \%$ ( 1 in 60 ). The maximum allowable cross-slope is $2 \%$. If platform edge doors are provided, the platform shall slope away from the platform edge and platform floor drains shall be provided.

### 9.8 Structures on platforms

The basic consideration in location of various structures on platforms is that it should not obstruct the free flow of passengers on the platform. Except for benches \& water fountains on platforms \& stalls on other than home platforms, it is best if all other amenities are provided in the station building itself so that the platform is available for the movement of passengers. The various considerations for structures on platforms are given below:-

## (i) Stalls

All the stalls should be converted to modular stalls and reduced in size as per the Board's circular no. 99/TGIV/10/P/NID dated 15.3.99. The following points need attention in location of the stalls
(a) All stalls on single face platforms should be provided on the berm leaving no gap between the platform fencing and the stall. All stalls should be in one line or within a demarcated line along platform length.
(b) For the stall in front of the station building, these should be, as far as possible accommodated in the line of the building so as to not to encroach upon the space on the platform and if this is not possible they should be provided without any gap with the station building. Efforts should however be made to provide
(c) Stalls on island platform should be located at the center of the platform.
(d) Effort should be made to avoid cooking activities on the platform and instead beverage vending machines and sale of pre-cooked and packed food should be encouraged.
(e) Effort should also be taken to reduce the number of trolleys to minimum.
(f) The number of stalls inside platform covering should also be reduced to bare minimum requirement.
(g) Automatic vending machines should be encouraged to replace existing vending stalls.
(h) Bain-maries should be provided at A\&B class stations.
(i) Water drums of stalls should not be allowed on platforms and instead overhead tank should be provided by stall owners above the stalls and float valves provided and maintained so that water does not overflow on the platforms.
(j) A good underground drainage system should be available to discharge the water from stalls. The water from the stalls should not be discharged into the tracks.
(k) Solid and liquid wastes from the stalls should be properly disposed in municipal/ Railway bins and not dumped inside Railway boundary.

## (ii) Latrines \& urinals

Toilets should be provided either in the station building and if on platform should be provided at one end of home platform. However at `D' \& 'E' category stations it should be provided near the station masters office for easy maintenance. All sanitary pipes should be taken out behind the platform.
All latrines should be sanitized and provided with water borne sanitation. All toilets should be gradually converted to Pay \& Use toilets as per guidelines issued under Board's letter No. 05/TGIV/10/SAN/32/Pay\& Use Policy dated 7.6.06.
Out of latrines calculated as per scale of minimum amenities and recommended amenities as stipulated in chapter IV of IRWM (Indian Railway works Manual, one third should be reserved for ladies. If there are two latrines one should be reserved for ladies. The total number of latrines \& urinal to be provided as per the scales shall include those provided in waiting halls
For toilets provided on the platforms, the length of the toilet block shall be along the length of the platform and breadth along the width of the platform. Gents urinals shall be provided at the ends and shall have entrance from the side. Toilet blocks should be designed in such a way that it occupies minimum width of platform.
If number of urinals is less, they can be provided along the breadth and if they are more they can be provided along the length in two rows. The gent's urinals shall be separated from each other by cuddapah/granite slab of height of 1500 mm from pedestal level. The pedestal level of urinal shall be 150 mm above floor level and slope shall be provided towards the channel. The distance between two vertical slabs separating the urinal shall be 750 mm .

The minimum size of $W C$ shall be $0.90 \times 1.20 \mathrm{~m}$ with minimum door width of 0.75 m .
(iii) Water fountain

Where piped water supply is available taps shall be provided at the rate of one tap for two coaches. For island platform the number of taps should be doubled. The direction of the taps shall be such that the queue is formed along the length of the platform and does not obstruct the movement of passengers. On single face platform it shall be situated farthest from the platform coping and on island platform, it shall be at the center.
At small stations determined by the commercial department where piped water supply is technically and economically not feasible, tube wells with hand pumps should be provided. The size and numbers can be decided by the Engineering department. In addition portable water can be supplied through mobile or stationary water containers and the number, size, type and deployment of such containers should be determined by commercial department who shall procure and maintain them.

## (iv) Seats/benches on platforms

The criteria laid down in the scale of amenities to be provided as per minimum essential amenities (MEA) and recommended amenities is in terms of seat and one bench can have as many number of seats.

The seating can be provided in form of chabutras around the column of cover over platform or around trees. A mild slope should be given towards outside so that the water gets drained off.

### 10.0 Waiting Areas and Lounges

Lounges and Waiting Areas for an Railway station must be provided. In some stations the waiting time gap between connecting trains is significant so as part of the station project the Railway may think of including in the immediate proximity of the station a budget hotel.

There should be separation between non reserved and reserved and further separation within reserved for premium ticket holders. The passengers must be facilitated with lounging furniture and amenities, such as television, music, library of news papers, and food and drinks vending machines. AC waiting rooms are being provided for the AC passengers, which is common for the ladies and gentleman. This can be considered if justification is provided by the commercial department.

VIP waiting and meeting room is also provided at important stations like Railway divisional headquarters, district headquarters of important districts and important stations. This is normally provided adjacent to the station manager's office.

### 10.1 Capacity

Capacity of waiting areas shall be based on the station capacity analysis model that must include a passenger profile to establish the waiting area requirements for reserved and unreserved passengers as well as the premium lounges.

Following is a sample calculation for the different types of concourse waiting spaces. as per international practice.

Table: Sample Calculation for Concourse Waiting Space

| Waiting Area | Total Peak | LOS | $\mathrm{m}^{2} / \mathrm{person}$ | Total area m ${ }^{2}$ |
| :---: | :---: | :---: | :---: | :---: |
| Unreserved | 1750 | C | 1.8 | 3150 |
| Reserved | 560 | B | 2.25 | 1260 |
| 1st class lounge | 250 | A | 2.61 | 653 |
| Executive lounge | 50 | A+ | 3.00 | 150 |
| Total | 2610 |  |  | 5213 |

As per IRWM, Annexure 4.4, the waiting hall area $=1.394 \mathrm{~N}_{\mathrm{db}} \mathrm{m}^{2}$ (for A \& B stations)

$$
=1.394 \mathrm{~N}_{\mathrm{ds}} \mathrm{~m}^{2} \text { (for C \& D stations) }
$$

where,
$\mathrm{N}_{\mathrm{db}}=0.3 \mathrm{~N}_{\text {max }}$
$N_{\mathrm{ds}}=0.45 \mathrm{~N}_{\text {max }}$
Thus for $D$ class station having passengers $\mathrm{N}_{\max }=2610$ no.
Waiting hall area required is $\quad=1.394 \times 0.45 \times 2610$
$=1637.25 \mathrm{~m}^{2}$, which is much
less than the international practice.

### 10.2 Types

Size and location of the lounges and waiting areas may be decided taking into account the climatic conditions, the importance of the stations, availability of space, etc. Premium lounges with special amenities shall keep in view the demand from different type of clientele. Types of areas are:
(a) Unreserved waiting areas, amenities include:
i) Seating
ii) Toilets
iii) Outsourced/departmental food and retail shops
(b) Reserved waiting areas, amenities include.
i) Seating
ii) Toilets
iii) Food and retail shops (restaurants)
iv) Cyber cafes
v) Cell and computer charging points
vi) $\mathrm{Wi}-\mathrm{Fi}$
(c) Premium lounge amenities include
i) Upholstered seating
ii) Separate climate control.
iii) Toilets and showers
iv) Food and retail shops (restaurants)
v) Cyber cafes
vi) Cell and computer charging points
vii) Wi-Fi

### 10.3 Design Requirement

A survey and analysis of the data for the specific requirement for lounges in terms of numbers and levels of luxury should be carried out. Adequate toilet facilities will be provided based on number of passengers using the facilities. Adequate numbers of toilet to maintain clean and hygienic situation at all times.

## a) Waiting hall

Waiting halls should not be built detached from main building and should be nearer to the platforms so that the passengers can move to the platforms quickly at the time of arrival of the trains. Since waiting halls are meant for paid passengers, they should have entry from platform side only. At small stations, where some shelter is available for the passengers near the booking office, this area can be deducted from the gross area determined on the basis of recommended amenities as stipulated in chapter IV of IRWM and the balance area can be provided in form of covered area of the platforms. At suburban stations, extension of platform shelter in lieu of construction of waiting hall may be done.

## b) Waiting rooms

The difference between waiting hall and waiting rooms should be clearly understood. A waiting room is self contained with WC, bath, urinals \& wash basins with mirror and is intended for passengers who have to wait for long hours especially where they have to stay overnight for getting their connecting trains or when train arrives late night or very early mornings but a waiting hall is intended for passengers who have to wait for short duration and awaiting for arrival of train. The waiting hall figures in minimum essential amenities and recommended amenities in all categories of stations except $C$ class (Suburban), but waiting room figures in desirable amenities in 'A1', 'A', `B' \& `D' class stations only.
For A1 \& A class stations separate waiting hall for upper class and separate waiting hall for ladies are provided. For general waiting halls it is desirable to have separate toilets for ladies \& gents. The waiting halls should be provided in the station building itself. Waiting rooms should have proper seating arrangements \& public address system. Facilities for charging mobiles can also be provided in the waiting rooms. TV with cable is provided in upper class waiting rooms.

## c) Retiring rooms

Retiring room is a desirable amenity for `A1, `A., `B, \& `D' class stations. Retiring rooms should be provided only when a minimum of $60 \%$ occupancy is expected by the commercial department. Retiring rooms should have toilet facilities, good furniture and should be well lighted.

Size and location of retiring rooms should take into account the climatic conditions, importance of the station, availability of space etc. As dormitory type of retiring rooms
offer accommodation at cheap rates to the passengers, keeping in view the demand from different type of clientele, local conditions of the place, availability of comparable type of accommodation in the vicinity and other factors considered relevant, preference may be given to dormitory type of retiring rooms.

While construction of dormitory type of retiring rooms, cubicles should be made for each bed with half partitions up to the level of sill of windows which will give some privacy for the passengers. Each compact cubicle can contain a single bed, a bed side table, a small table and a chair, an inbuilt cupboard and a fan. One or more dormitories can even be air conditioned as per climatic conditions and demand. If there is a demand a separate dormitory with beds as per expected occupancy can be earmarked for ladies as well.

### 10.4 Maintenance

(a) All lounges and waiting rooms shall be maintained to the acceptance and approval of health authorities.
(b) All rest rooms and other amenities including any food service areas connected to lounges must be maintained in accordance with national health and safety requirements and local municipal corporations' regulations, whichever is more stringent.

### 11.0 Booking offices

The booking windows should be so located that the circulation at the entrance or exit from the station or the waiting hall is not affected by the queue in front of the booking window. The length of the queue can be estimated at the rate of half a meter per person waiting in the queue. The booking offices should be well illuminated.
A standardized lay out of the booking window may be formulated on the basis of the following design parameters.
(i) Size of cubicle :- $1.8 \mathrm{~m} \times 1.5 \mathrm{~m}$
(ii) Counters :- 0.60 m in width and height of one metre above floor level from passenger side. For convenient working of the booking clerk, either taller chairs should be used or height of flooring should be increased inside the booking office. A layout of computerized booking window is shown on next page.
(iii) Ticket tubes :- On both sides of counter
(iv) Furniture :- Chairs with canned seats, revolving type with short back and facility for seat adjustment.
(v) Partition between passenger \& clerk:12mm thick toughened glass or 4mm thick clear acrylic sheet with hole for communication and opening at counter level for collection of fare \& issue of tickets and partition protected on passenger side with steel or aluminum grill.
vi) As per IRPWM, one booking window is required to deal with 100 Pass./Station


Floor Level inside－ー ー ー ー ー ー ー ー ー ー ー ー ー
Floor Level outside $\qquad$


A layout of computerized ticket window

12．0 Important points to be kept in view while upgrading amenities at stations＊
（a）All toilets should be gradually converted to Pay \＆Use toilets as per guidelines issued under Board＇s letter No．05／TGIV／10／SAN／32／Pay\＆Use Policy Dt 7．6．06．
（b）All the signage at the station should be standardized in terms of Railway Board＇s circular No．97／TGII／39／11／signages dated 11．3．99．
（c）For location of signage，a plan should be made for each station．
（d）All stalls should be made modular and reduced in size as per the Board＇s circular no．99／TGIV／10／P／NID dated．15．3．99
（e）Effort should be made to avoid cooking activities on the platform and instead beverage vending machines and sale of pre cooked and packed food should be encouraged．Effort should also be taken to reduce the number of trolleys to minimum．
（f）Ban－maries should be insisted upon in the refreshment rooms at A\＆B class stations．
(g) The number of trolleys and catering stalls under the platform shelter should be reduced to a minimum.
(h) There should be effort to reduce the stalls to the bare minimum.
(i) In the circulating area, proper traffic movement flow plan should be made. Proper landscaping in the circulating area should also be developed. Wherever circulation areas are redesigned, altered, or whenever stations are congested, possibility of providing FOB landings directly into circulating area should be examined as it decongests main platforms. There should be proper segregation of incoming and outgoing passengers, wherever considered necessary (Detailed guidelines have been issued under Board's letter No. 2005/LMB/02/267 Dt.7.12.05).
(j) Automatic vending machines should be encouraged to replace existing vending stalls.
(k) The enquiry and Booking Offices should be specially brightened up at all the stations.
(I) The illumination at the stations should be improved.
(m) All unauthorized entry points into the stations irrespective of their class should be closed excepting the specified exit and entry.

### 13.0 Facilities for Physically Handicapped

Railways are to provide convenience to the physically handicapped persons to comply with the provision of "The Persons with disabilities (Equal Opportunities; protection of rights and full participation)" Act, 1995. As per provisions of this Act, equal opportunities are to be given to handicapped persons in
(a) Ramps in public buildings
(b) Adaption of toilets for wheel chair users
(c) Braille signals and auditory signals in elevators/lifts
(d) Ramps in hospitals, primary health centres and other medical care and rehabilitation institutions.

These are mainly for the two kinds of challenged people
(i) Physically challenged
(ii) Visually challenged

For the former the basic requirement are that the platform are accessible using a wheelchair and the facilities in the wash rooms are designed for their need e.g. wash basins at low levels, holding rails near the commode, hand rails at low level near WC etc. For the latter the requirement is to provide engraving in the pathways and more necessarily engraving to warn about the edge of the platform. This is done by provided chequered tiles. Manual
of stations to be shortly issued by RDSO contains the sketches and details of the provisions.

Design of the sewerage scheme and its estimation should be a part of the main estimate. Similarly the storm water pipes and system and water harvesting if any should also be not lost sight of. Chapter VI of IRWM may be referred for further details. Proper ducts should be provided to carry the storm water pipes, sewage pipes and the various cables of S\&T and electrical departments. Number of the ducts would depend upon the layout of the building, its area and the actual requirements for various facilities.
It is always a good idea to plan for plantation of the trees and landscaping during the construction stage as the plants can be properly cared then and grow to a survivable size by the time station is commissioned. The estimate should have provisions for not only the planting but also of maintenance for a reasonable period of 1-2 years. Fencing, tree guards, gabions and similar protection may also have to be included depending on the local requirements.

## CHAPTER VIII

## PIPE LINE CROSSING

1. General : Pipe line crossing under the Railway Track are provided for carrying cables, water, sewage, petroleum product etc. Instructions have been issued from time to time by RDSO. In this connection a master circular was issued by PCE / WR vide circular No. 54 of.97, which covers guide lines issued by RDSO/Railway Board up to September-97 and gives typical drawings to aid the preparation of the drawings for the pipe crossing.
Details of different types of pipe and guide lines as per above PCE/ WR circular are listed below along with type plans in annexures. These will be very useful for preparation of drawing and execution of work.
Pipes for track crossings have been broadly divided into following categories -
a) A. 1 :- Carrying non electrical cable such as Telephone Wires/TV cables / Optical Fibers cable etc.
b) A. 2 :- Conveying water, Sewage or other Non-inflammable Effluents without pressure.
c) A.3.1 :- Conveying Water, Sewage or other Non-inflammable Effluents under pressure through carrier pipe of dia up to 600 mm .
d) A.3.2 :- Conveying Water, Sewage or other Non-inflammable Effluents under pressure through carrier pipe of dia. More than 600 mm and up to 1200 mm .
e) A. 4 :- Conveying Inflammable Effluent like petroleum, oil or gas etc. Pipelines included under this category are those installed to carry oil, gas or other inflammable or highly volatile substance under pressure might cause damage if escaping on, in the vicinity of the Railway property.
2. Standard Plan: The type plans showing the standard arrangement with measurements and specifications for track crossing of above pipes are annexed which are as under:
3. Type plan No. 1: Pipeline crossing of category A. $1 \& A .2$ up to 300 mm dia carrying telephone wires. TV cables / Optical Fiber cable etc. (Appendix - 'A' - Sheet 1)
4. Type plan No.2: Pipe crossing of category A. 2 Conveying water, Sewage or other Noninflammable Effluents without pressure. (Appendix - 'A' - Sheet 2)
5. Type plan No.3: Pipe crossing of category A.3.1 where end of casing pipe is at or above ground level the crossing shall be provided. (Appendix - ' $A$ ' - Sheet 3)
6. Type plan No.4: In case the pipe line crossing of category A.3.1 \& A.3.2 are below ground level. (Appendix - 'A' - Sheet 4)
7. Type plan No.5: Pipeline crossing of category A. 4 conveying inflammable substance like petroleum, oil and gas etc. (Appendix - 'A' - Sheet 5)
8. Standard Notes: The standard notes to be mentioned in the type drawings are also very important as they give general guidelines to the executive for carrying out the work and also ensure that small but important issues are not lost sight of. The notes common
to all type plans are reproduced below and notes which are special to individual type drawings are shown in the respective type drawings.

### 3.1 Following notes are to be mentioned on all Type Plans

1 Existing work shown in black
2 Proposed work in red
3 All dimensions are in mm unless otherwise shown
4 Work of passing of casing pipe by pipe pushing, auger boring, direct drilling or cut \& cover would be done under speed restriction of 20 kmph and observation of all safety precaution, protection of track is to be provided in accordance with para 801 to 808 of IRPWM during the pipe pushing operation at the end of the days work, if pushing of casing pipe should be kept under careful observation even after pipe pushing is completed and suitable sr may be continued, if required more stringent sr may be imposed if track gets disturbed
5 Pipe line trench should be covered with sand / quarry dust or cohesionless soil with proper ramming and consolidation in the formation width of formation. warning bricks in railway land to be provided where open excavation is done
6 Measures are to be taken to prevent the railway. cable passing in the railway land from getting damaged the work should be executed in the presence of S \& T/ electrical representatives for which written intimation is to be given well in advance
$7 \quad$ Route marker are to be provided within rly. land boundary location and at toe of the embankment and at an interval of maximum 10 m .
8 Any work required to be carried out in connection with addition /alteration ...../modification in future will be carried out by the party at their own expenses irrespective of the fact whether such addition/alteration/ modification is required by the railway or the private party, prior permission will be necessary in case party desires to carry out such works.
9 Work should be done under the supervision of rly. engineer taking suitable precaution so that no settlement of track take place at the time of pipe insertion.
10 Temporary engineering indicator will be provided as per G.R. 15.09 (i)(d) and S.R. 15.09(2)b (inyard).

11 Suitable speed restriction will be imposed by the concered SSE (p.way) which will be relaxed to normal speed after completion of work.
12 Carrier pipe can be of R.C.C. as per IS : 458 of type NP - 4. or galvanised steel carrier pipe or fabricated steel pipe of thickness 5 mm minimum in accordance with IS : 2060 or IS: 226 with suitable anti corrosive treatment should be used.(only for type plan no. 1)
13. An agreement with pipe line owning party be finalised before execution of work at site.
14. Before taking work in hand it should be ensure that administartive approval shall be obtained from competent authority for the proposed deposit work to be carried out by Rly. or by the party
15. S \& T cable passing along the track, preventive measure will be taken to avoid damage to cable while execauting the work. written information will be given to chief signal and inspector well in advance.

### 3.2 In addition to common notes, following notes to be written on Type Plan No. 3 \& 4 only. <br> NOTES FOR WATER (UNDER PRESSURE) PIPELINE CROSSING.

1. Work of passing casing pipe by pipe pushing, auger boring, direct drilling would be done under speed restriction of 20kmph and observation of all safety precaution, protection of track is to be provided in accoradance with para 801 to 808 of IRPWM till casing pipe is fully inserted. when at the end of the days work pushing of casing pipe is not completed, the soil at pushing end of the pipe should be suitably protected. the track formation should be kept under carefull observation even after pipe pushing is completed and suitable SR may be continued, if required more stringent SR may be imposed if track gets disturbed.
2. Slope of $1: 100$ to be provided to drain out rain water.
3. Size and depth of the sump to be decided by the site engineer, key of sump to be kept with SSE (P.Way).
4. Both casing \& carrier pipe should be of mild steel fabricated as per IS:3587 from steel plate conforming to IS 2062 or IS 226 where screw or coupled joined are used these joints should be weldedto the pipes atboth ends along the circumfarance so as to seal in event of leak through thread.
5. All field weld should be tested cent percent radiographacally as pere IS1182.
6. Casingpipe should be capable of withstanding pressure equal to that of main carrier pipe with safety factor of 3 carrier pipes line should be pressure tested to $110 \%$ designed pressure.
7. Casing pipe should be provided with minimum 50 mm dia vent pipe (GI) extending not less than 1.2 m above ground level as shown in drawing. The vent pipe atlow end of the casing pipe should be connected with the side or bottom of the casing and the vent pipe atthe high end should be connceted with top of the casing. The top of vent pipe should be fitted with a down turned elbow screw. The screw end of casing pipe should be suitably sealed.
8. Carrier pipe and joints shold be of approved type of material and construction .joints for carrier pipe should be mechanical or welded type. Reinforced presure pipe conforming to is 458 may be used as carrier pipe for pressure below $7 \mathrm{~kg} / \mathrm{cm} / 2$. rcc pipes of NP-4 standard shall be used.
9. Casing pipes and jointsshould be of leak proof constructioncapable of withstanding MBG loading or any other current Rly. loading as defined in irs bridge rules.the section should also be checked for construction load i.e stresses which will arised during pushing the pipe.
10. The sluice valves should be provided away from Rly. land to facilitate the closer of flow of water supply where ever required.
11. To protect casing pipe as well as carrier pipe against corrosion, following action will be taken :-
a - outer surface of casing pipe as well as carrier pipe will be coated with poly ethylene tape system.
b- inside surface of carrier pipe as well as of casing pipe shall be painted with
high build epoxy to rdso specification no m\&c / pcn / 111 /88 to a dry field of thickness of 250 microne.
c - suitable size spacers of high density polyethylene or other similarmaterial shall be installed in between carrier and casing pipe to prevent carrier pipe from farming metallic contact with casing pipe
12. The alignment of pipe line shall be so that it crosses track nearest to right angle
13. Pipe line crossing shall not be located in close vicinityof existing bridge or any other type of structure.

### 3.3 In addition to common notes following notes are to be written on Type Plan No. 5.

1. Design of casing pipe and carrier pipe should be in accordance with the provision contained in the American petroleum institute (api) code no. 1102 \& ansi/ asme code B-31-8 / 1982, as amended till date. casing pipe thickness shall be checked w.r.t.external loads as per api 1102 / armea manuals pt.5(2002).
2. The carrier pipe should be tested 1.5 times the maximum operating pressure in the field \& 3 times in the factory (for diesel/ crude oil 1.25).
3. The casing pipe should extended min. length 15.00 m from the centre line of nearest track.
4. Suitable speed restriction will be imposed by SSE (P.Way) and which will be relaxed gradually to normal after the completion of the works.
5. Temporary Engineering indicators will be provided as per GR.15.09 (i) (d) SR.15.09 (ii).
6. For details of vent pipes, refer drawing no. 337 of ONGC, C \& M Division, Vadodara.
7. Permission from Director of Mines, Udaipur \& Chief Inspector of Explosive, Nagpur should be obtained for laying gas pipe line below the track.
8. It should be ensured that representative of telecom \& signalling department made available before work is commenced in vicinity of signalling and telecom cable to avoid any demmage.
9. Installation of carrier pipe inside the casing pipe under railway track shall follow approved construction practice, which shall be the same on railway land as for pipe lines on either side of the railway land.
10. The casing pipe should be so manufactured so as to prevent leakage of any material inside railway boundary except at ends where the ends are left open. The pipe should be installed with sufficient slack so that its not in tension. Expansion joints are not recommended.
11. Pipeline crossing should not be located in close vicinity of existing bridges, buildings \& other type of structure and should be minimum 15 m away from these care should be taken to isolate the pipe line crossing installation from aerial electrical wires and it should be suitably insulated from under ground conducts carrying electrical wires. pipelines and vent pipe should be atleast 1.2 m away ( vertically) from aerial electrical wires.
12. Casing pipe should be provided with minimum 50 mm dia vent pipe (GI). The vent
pipe at low end of the casing pipe should be connected with the side or bottom of the casing pipe and the vent pipe at the high end should be connected with the top of the casing. The top of ventpipe should be fitted with the down turned elbow screw. The end of casing pipe should be suitably sealed.
13. Shut off valve on either sides of railway land boundary is not recommanded. Installation of these valves introduces hazards not consistence with good pipe line operating practices.
14. Casing pipe should be capable to withstanding pressure equal to that of main carrier pipe with a safety factor of 3 , however safety factor of 3 may not be required if the pipeowing organization agrees for the following tests.
(a) - all welds of carrier pipes are $100 \%$ tested by x-rays.
(b) - carrier pipe hydro tested pre \& post instalation.
(c) - carrier pipe is again tested along with test of main pipe.
15. Casing pipe and joints should be of leak proof constructioncapable of withstanding latest approved railway loading as defined in irs bridge rules. The section should also be checked for the construction load i.e.stresses which will arise during pushing of the pipe.
16. Casing pipe should be of approved manufacturing practice. For steel pipes (both casing \& carrier) the pipes should be of mild steel fabricated as per IS:3587 from steel plates conforming to IS:226 or IS:2062. where screwed and coupled joints are used. The joint should be welded to the pipes at both ends along the circumferance as a seal to prevent leak through the threads. All joint be electrically weled and the weld should be tested cent percents radiographically as per IS :1182
17. Pipe line crossing under the track will be carried out by using auger pipe boring device with cutting head to drill horizontal bores.the holes drill will be of size to accommodate the casing pipe and casing pipe will be pushed in the bore as it progress to keep the formation supported and pervent any settlement.
18. The pipe owning organisation shall submit the detail specification for the pipe line in document from each zonal railway. This shall include the enumeration of monitoring system with scada \& detail of pipe line integraty management system. This will also enumerate the system of periodic testing and submission of certificate of inspection \& integraty of pipe line crossing annaully to railway for each crossing. A sysatem of annaul joint inspection sharing of monitoring data \& allowing asses to railway to the monitoring facility shall be enumerated by the pipe owning orgainsation. This amount will be part of agreement \& the pipe owning organisation will bear all costs,
19. In casing pipe, two component epoxy coating for internal surface will be used.
20. Carrier pipe to have external three layers high performer poluthene coating. Internal coating can be solvent free epoxy coating.
21. The pipe line will be coated with polyethylene \& will be protected against corrosion by impressed current cathodic protection system. Galvanic and or rebbons anodes would be cased crossing to suppliments impressed current facility.
22. The pipe owning organisation will take suitable third party comprehaensive liability insurance at its own cost indemnify railways against any claims arising out of
demmage/ loss of life or property railway man/ railway users and others due to mishaps on account of faulty during laying or oprtation of pipe line crossings. This will also be part of agreement.
23. The pipe owning organisation will be allowed to lay pipe line under railways supervision as per extension rules within railway areas using their own equipments passing of pipeline by pipe pushing / auger borring / directional drilling would also be done under suitable speed restriction of 20 kmph and observe all safety precaution, protection of track is to be provided in accoradance with para 801 to 808 of IRPWM till casing pipe is fully inserted. when at the end of the days work pushing of casing pipe is not complete, the soil at pushing of the pipe should be suitably protected. the track formation should be kept under carefull observation even after pipe pushing is complete and suitable sr may be continued, if required more stringent SR may be imposed if track gets disturbed.
24. The thickness of Casing / Carrier pipe in different cases is as under.

The thickness of the casing / Carrier pipe for all the categories shall be as under

| Carrier Pipe Dai (mm) | Thickeness of Carrier Pipe (mm) |
| :---: | :---: |
| 250 | 5 |
| 300 | 5 |
| 350 | 5 |
| 400 | 6 |
| 450 | 7 |
| 500 | 8 |
| 600 | 8 |
| 700 | 10 |
| 800 | 12 |
| 900 | 12 |
| 1000 | 14 |
| 1100 | 16 |
| 1200 | 16 |
| 1300 | 18 |
| 1400 | 20 |
| 1500 | 20 |
| 1600 | 22 |
| 1700 | 22 |
|  |  |
|  |  |

## Appendix A '(Sheet-1)'


PIPE LINE CROSSING - TYPE PLAN NO. 1

## Appendix A '(Sheet - 2)’


PIPE LINE CROSSING - TYPE PLAN NO. 2

## Appendix A '(Sheet-3)'



PIPE LINE CROSSING - TYPE PLAN NO. 3

Appendix A '(Sheet - 4)'

|  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
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PIPE LINE CROSSING - TYPE PLAN NO. 4


PIPE LINE CROSSING - TYPE PLAN NO. 5

## CONCEPTS OF ENGINEERING MECHANICS

1.0 Introduction: There are some basic concepts of Engineering Mechanics like center of gravity, centroid, moment of inertia, radius of gyration of plane surfaces as well as solids, and concepts of bending moment, shear force etc. which are required by all engineers in day to day work.
2.0 Centroid of surfaces OR Centre of gravity of bodies: Centre of gravity of a body is an imaginary point at which its whole mass may be assumed to be concentrated. For any body to be stable, the center of gravity should fall within its base.

In case of homogenous bodies having a constant thickness, weight of the body is proportional to the area. Hence center of gravity can be interpreted as an imaginary point at which the whole area of cross section is imagined to be concentrated. Centre of gravity of a plane figure is known as centroid. The centroid is denoted by co-ordinates ( $\mathrm{x}, \mathrm{y}$ ) about two perpendicular axes.

Let us begin with centroid of common geometrical sections:-


Centroid of rectangle from the base
Centroid of triangle from the base
Centroid of circular area $=$ center of circle $=(D / 2, D / 2)$
Centroid of semicircle area, $R$ is radius $=(D / 2,4 R / 3)$
To find centroid ( $\bar{x}, \bar{y}$ ) of any section, the section is divided into elementary sections and centroid of the section is calculated as under:-
$\overline{\mathrm{x}}=\frac{\Sigma \mathrm{ax}}{\Sigma \mathrm{a}} \quad$ and $\quad \overline{\mathrm{y}}=\frac{\Sigma \mathrm{ay}}{\Sigma \mathrm{a}}$
$\Sigma$ First moment of area
$\Sigma$ Area

Where $\mathbf{a}$, is areas of elementary sections and $(\mathrm{x}, \mathrm{y})$ is the centroid of elementary sections. The example shown below will explain it better.
2.1 Problem : Find the centroid ( $\bar{x}, \bar{y}$ ) of quadrilateral below about its vertical face \& top i.e. X and Y axes.

The above quadrilateral can be divided into two elementary shapes viz. rectangle \& a triangle whose area and centroid are tabulated below:-


| Elementary area | Area of elementary shape, rectangle | Centre of gravity of elementary area triangle |  |
| :---: | :---: | :---: | :---: |
|  |  | Along $x$-axis | Along Y -axes |
| Rectangle | $\mathrm{a} \times \mathrm{h}$ | a/2 | $\mathrm{h} / 2$ |
| Triangle | (b-a) $\times(\mathrm{h} / 2)$ | $a+[(b-a) / 3]$ | $\mathrm{h} / 3$ |

Note: Distance of centroid of each elementary area has to be measures from the chosen axes of reference (See X -axis \& Y -axis marked in sketch above)

Sum of moment of area of elementary shapes about $x$ axis divided by the total area of elementary shapes will give the centroid along $x$ axis as calculated below:-


Similarly sum of moment of area of elementary shapes about y axis divided by total area of elementary shapes will give the centroid along y axis as calculated below:-

$$
\bar{y}=\frac{(a h \times h / 2)+(b-a) \times(h / 2) \times(h / 3)}{a h+\{(b-a) \times(h / 2)\}}=\frac{2(a+b) h}{3(a+b)} \text { (on simplification) }
$$

## NOTE:

(a) The sections which an engineer comes across may not be basic geometrical shapes, but built up sections or composite sections. In such case as seen above, the centroid of composite sections about two perpendicular axes is calculated by moment of area of each sections divided by total area of sections.
(b) In some cases the built up sections may comprise of one or more basic sections with portions removed off. In such cases the area removed is to be treated as negative area and centroid found out as in case of following section where a circle has been cut out inside a circle.

### 3.0 Moment of Inertia (I)

The moment of inertia of the body about an axis denotes the internal resistance of the body against rotation about the axis.
Moment of inertia of a solid body about an axis = $\Sigma m r^{2}$, where ' $m$ ' is the mass \& ' $r$ ' ' is the square of the distance from the axes.


Similarly moment of inertia of a plane sectional area about an axis $=\Sigma$ ar'$^{2}$, where 'a' is the area of cross section $\& r^{2}$ ' is the square of the distance from the axes.

Moment of inertia of a section is the second moment of area.

| Figure <br> notations with | Condition | Moment <br> inertia |
| :--- | :--- | :---: |

Moments of inertia of some elementary shapes about an axis are shown below which is derived by system of integration (which is not explained in detail now).
3.1 When the moment of Inertia ( $2^{\text {nd }}$ Moment of area) is known about one axis and it is required to find the same about any other axis, either parallel to it or perpendicular to it, following theorems are applied.

The parallel axis is very useful to calculate the moment of inertia of any axes parallel to the centroidal axes from a known moment of inertia about it centroidal axes and therefore saves us lot of time in calculations.

Similarly the perpendicular axes theorem helps us to find the moment of inertia of an axis which is perpendicular to two mutually perpendicular axes for which moment of inertia are known.

## (a) Parallel axis theorem:

Moment of inertia of an area about any required axis is the sum of moment of inertia of that area about an axis passing through the centroid which is parallel to the required axis and the product of area and square of the distance between the two axes. It is denoted as

$$
I_{x x}=I_{G G}+A x^{2}
$$

Let us apply this to the moment of inertia of rectangle which we had learnt earlier.


We know that moment of inertia of a rectangle passing through centroidal axis parallel to the base

$$
\mathrm{I}_{\mathrm{GG}}=\mathrm{bd}^{3} / 12
$$

Now let us find out the moment of inertia of a rectangle passing through the base $(\mathrm{XX})$ which as can be seen in figure above is parallel to $G G$ by using the parallel axis theorem.

$$
I_{x x}=\left\{I_{G G}+A x^{2}\right\}=\frac{B d^{3}}{12}+\left\{b d x(d / 2)^{2}\right\}
$$

$$
=\frac{b d^{3}}{12}+\frac{b d^{3}}{4}=\frac{b d^{3}}{3}
$$

(b) Perpendicular axis theorem:

If $I_{x x} \& I_{y y}$ are moment of inertia of a section about two mutually perpendicular axes xx \& yy, then moment of Inertia of the same section through an axis perpendicular to both these axes is as under:-
$I_{z z}=I_{x x}+I_{y y}$
Let us apply find out the moment of inertia of a circular section perpendicular to its plane (zz) using the perpendicular axes theorem.


We know that moment of inertia of a circle about X axis/ Y axis $=\mathrm{pd}^{4} / 64$
Therefore $\mathrm{I}_{\mathrm{zz}}=\mathrm{I}_{\mathrm{xx}}+\mathrm{I}_{\mathrm{yy}}=\frac{\pi \mathrm{d}^{4}}{64}+\frac{\pi \mathrm{d}^{4}}{64}=\frac{\pi \mathrm{d}^{4}}{32}$
$\mathrm{I}_{z z}$ is also known as 'polar moment of inertia'.

### 3.2 Radius of gyration (K)

Sometimes, mainly in problems relating with circular motion of bodies, a radius of gyration, K is required to be found out. After knowing the moment of inertia of an area or a body about an axis, the radius of gyration can be calculated as below,
$\mathrm{I}=\Sigma \mathrm{ar}^{2}=A K^{2}$
Where ' $K$ ' is known as radius of gyration
$K=\sqrt{\frac{1}{A}}$

### 4.0 Shear force and bending moments in beams

(a) Beam: Beam is a component in civil Engineering construction which is subjected to lateral forces. The lateral forces are the forces acting perpendicular to the longitudinal center line of the member or forces having components normal to the longitudinal center line of the member.

Types of beams based on support conditions are detailed below:

| Type | How supported | Denotation of supports |
| :---: | :---: | :---: |
| Simply supported beam | Ends are freely supported |  |
| Cantilever beam | One end of beam is fixed and other end is free | 弐 |
| Overhanging beam | Freely supported on two points, but leaving some space on one side or both sides unsupported i.e. cantilever | $7 \quad \uparrow$ |
| Fixed beam | Both ends are rigidly fixed | 才—— |
| Continuous beam | Beam supported on more than two points | $\uparrow \uparrow \uparrow$ |

First three cases are statistically determinate structures and later two are indeterminate beams/structures.
(a) Loads:-

Three types of loads normally encountered are shown below:-

| Type | How loaded | Diagram of loads |
| :--- | :--- | :---: |
| Point load | They are loaded at certain points of <br> the beam and is also known as <br> concentrated load. | The load is uniformly distributed and <br> expressed as $\mathrm{N} / \mathrm{m}$ |
| Uniformly <br> distributed <br> load (UDL) | The load is uniformly varying from |  |
| Uniformly <br> varying load <br> (UVL) | The $1 \mathrm{~N} / \mathrm{m}$ to $\mathrm{W} 2 \mathrm{~N} / \mathrm{m}$ |  |

### 4.1 Shear force \& bending moment

## i. Shear force

Shear force at any point on a loaded beam is the algebraic sum of forces (loads) either to the left or right of the section. We have to follow a sign convention for the forces. We can consider all upward forces to the left of the section as positive and downward forces to the left of the section as negative. For the right of the section, then upward forces will be negative and downward forces will be positive.
ii. Bending moment

Bending moment at any section of a loaded beam is the algebraic sum of moment of the forces either to the left or right of the section. Here also we have to follow a sign convention. We can consider clockwise moments to the left of the section as positive and anticlockwise moments to the left of the section as negative. For right side of the section clockwise moments are negative and anticlockwise moments are positive.

## iii. Shear force \& bending moment diagram

A closed figure obtained by connecting the plot of bending moment or shear force at various locations along length of the beam with center line of the beam is known as shear force diagram (SFD) or bending moment diagram (BMD) as the case may be. Once the diagram is drawn with ordinates at salient points, then shear force or bending moment can be obtained by knowing the respective ordinates.
4.2 To understand the concept stated above, following example will be useful.

Example: A simply supported beam ABCD of length 10 m , supported at $A$ and $D$ is loaded with 2-point loads of 2 KN at B and C , also the length BC is loaded with a uniformly distributed load of $1 \mathrm{KN} / \mathrm{M}$. The distance $\mathrm{AB}=3 \mathrm{~m}, \mathrm{BC}=4 \mathrm{~m}$ and $\mathrm{CD}=3 \mathrm{~m}$. We have to find the S.F. and B.M. distribution along the length of the beam.

## Solution:

Total load = [Point Load 2 N , at B+ UDL (1 $\times 4$ ) 4 N on BC+ Point load 2 N , at C] $=8 \mathrm{~N}$
a) REACTIONS AT SUPPORT: The loads being symmetric on the beam and Total upward forces = total downward forces, the two supports will take equal load i.e. $R a=R b=8 / 2=4 N$.
However as a general rule, even when loads are not symmetric, the reactions in a simply supported beam can be found from basics. In S.S. beam the moments at the supports is zero, therefore, taking moment about A (support),

$$
\begin{aligned}
& 0=3 \times 2+(3+2) \times(1 \times 4)+(3+4) \times 2+10 \times(-R b) \text {, or } R b=4 \mathrm{~N} \\
& \text { and } \mathrm{Ra}=\mathrm{Total} \text { load }-\mathrm{Rb}=8-4=4 \mathrm{~N} \\
& \text { \{Note: }(-\mathrm{Rb}) \text { as it is upward direction while other loads are in down ward direction\} }
\end{aligned}
$$

b) SHEAR FORCE: Shear force at a section say xx just to the right of ' $A$ ' considering forces left of section $x x=R a=4 K N$. Therefore between $A$ \& $B$ the shear force will be 4KN.

Shear force at a section just to the right of ' $B$ ', considering forces left of the section is Ra $-2 K N=2 K N$. Similarly just to the left of $C$ the loads $=4-2-(1 \times 4)=-2 N$

Thus due to the UDL of $1 \mathrm{KN} / \mathrm{m}$, the shear force will decrease from 2 KN at B to -2 KN at C .

Shear force just to the right of point ' $C$ ' considering forces at the right of the section will be $-4 K N$ as per the sign convention defined in the definition of shear force above.


## c) BENDING MOMENT:

Bending moment at $\mathrm{A}=0$
Take moment at a point just left of point B,
$\mathrm{Mb}=\operatorname{Ra} \times 3=4 \times 3=12 \mathrm{~N} . \mathrm{m}$
From A to B , the bending moment will increase uniformly from 0 KN .m to 12
KN.m since there is no load or any constraint in between.
Take moment just left of point C,
$\mathrm{Mc}=\operatorname{Ra} \times(3+4)-4 \times 2-(1 \times 4) \times(4 / 2)=4 \times 7-4 \times 2-4 \times 2=12 \mathrm{~N} . \mathrm{m}$.
(UDL acts at c.g. of load i.e. at center point of loaded length)
From B to C the B .M. will be different from either B or C , since there is a UDL of $1 \mathrm{~N} / \mathrm{m}$ load between B and C . Then B.M. at four intermediate points @ 1 m interval should be found out. ( $\mathrm{B} 1, \mathrm{~B} 2, \mathrm{~B} 3$ and B 4 )
$\mathrm{Mb} 1=\operatorname{Ra} \times(3+1)-2 \times 1-(1 \times 1) \times(1 / 2)=4 \times 4-2-0.5=13.5 \mathrm{~N} . \mathrm{m}$
$\mathrm{Mb} 2=\operatorname{Rax}(3+2)-2 \times 2-(1 \times 2) \times(2 / 2)=4 \times 5-4-2=14.0 \mathrm{~N} . \mathrm{m}$
$\mathrm{Mb} 3=\operatorname{Ra} \times(3+3)-2 \times 3-(1 \times 3) \times(3 / 2)=4 \times 6-6-4.5=13.5 \mathrm{~N} . \mathrm{m}$
$\mathrm{Mb4}=\operatorname{Rax}(3+4)-2 \times 4-(1 \times 4) \times(4 / 2)=4 \times 7-8-8=12.0$ (B4 is same as C)
From B to C , the bending moment diagram will be in form of a parabola, with maximum value being $14.0 \mathrm{~N} . \mathrm{m}$ at center of BC .

From C to D , the bending moment diagram will be a straight line, reducing from $12.0 \mathrm{~N} . \mathrm{m}$ to 0 at the support D .
A
B
C
D
0
(
$\begin{array}{llll}13.5 & 14.0 & 13.5 & \text { B.M. Diagram }\end{array}$

### 4.3 Important Hints Related to SFD and BMD

| Shear force diagram | Bending moment diagram |
| :--- | :--- |
| Shear force diagram between two point <br> loads will be a straight line parallel to the <br> base having vertical drops at points of <br> loads. | Bending moment diagram in a region <br> between two point loads will be <br> a sloping straight line. |
| Shear force diagram in the region of <br> UDL will be a sloping straight line. | Bending moment diagram in the <br> region of UDL will be a parabola. |
| Where a point load acts in the region <br> of UDL, the shear force diagram will <br> have two sloping lines divided by a <br> vertical drop at the point load. | When a point load acts in the <br> region of UDL, the equation of <br> parabola on either side of the <br> section where the point load acts <br> will be different. |
| In case of simply supported beams, <br> shear force will have maximum value <br> at the supports. | In case of simply supported <br> beam, bending moment will be <br> zero at both the supports and <br> maximum somewhere within the <br> supported length depending on the <br> loads. |
| In simply supported beams, bending moment will be maximum where shear force will <br> be zero. Therefore if there are more than one point where shear force is zero, bending <br> moments at both these points have to be calculated to find the maximum bending <br> moment. |  |

### 4.4 Max Shear Force \& Bending Moments for some Standard Cases

\begin{tabular}{|l|c|c|}
\hline Standard cases \& Max shear force \& Max bending moment <br>

\hline \begin{tabular}{l}
SSB of span `L' with central <br>
point load

 \& 

W <br>
(At supports)
\end{tabular} \& <br>

<br>
\hline
\end{tabular}

### 5.0 Theory of bending in beams

The load on a beam causes it to bend and cause stress \& strain in the member. As can be seen in the sketches below, in case of simply supported beam, the fibers on the top layers undergo shortening i.e. compressive stresses and fibers at the bottom undergo lengthening i.e. tensile stresses. In case of cantilever it is opposite as top fibers undergo tension and bottom fibers undergo compression. But somewhere in the center of the beam in both cases, the fibers do not undergo any stress or strain i.e. stress free or neutral point and is called the neutral axis of the section. Neutral axis is always passing through the centroid of the cross section of the beam. In Simply supported beams, cross section of beam above the N.A. will be in compression(C) and below in tension ( T ). In cantilever beams the position is reversed i.e. compression below the N.A. and tension above the N.A. The stress and strains at any point of a cross section is proportional to the distance it is away from the neutral axis. The maximum strain thus stress in a cross section will be at extreme fibers and proportionately less at points away from the extremes. This holds true within elastic behavior of the material of beam.


The following relation is a very important for understanding the theory of simple bending,

$$
\begin{aligned}
& \text { M f E } \\
& -=-=- \\
& \text { I y R }
\end{aligned}
$$

where $M=$ moment of resistance which should be equal to Max bending moment
I = moment of inertia of the cross section about neutral axis
$f=$ stress in the fiber at a distance of $y$ from neutral axis
$\mathrm{E}=$ Modulus of elasticity of the material of the beam
$R=$ Radius of curvature of neutral axis

### 5.1 Section modulus (Z)

In structural design and analysis, it is normally required to know the maximum stresses and strains in the structure, which are at extreme fibers. In this case ' $y$ ' is the distance of top or bottom of beam from N.A. For convenience, a parameter known as Section Modulus $(Z)$ is defined as $I / Y$, where $I$ is the moment of Inertia of the cross section and ' $Y$ ' is the distance of N.A. from extreme fiber i.e. $Y_{b}$ or $Y_{t}$ depending upon if one is interested in bottom fiber or top fiber.

Sectional modulus $\left(Z_{b}\right.$ or $\left.Z_{t}\right)=\square$ and this a sectional property of the section and

$$
Y_{b} \text { or } Y_{t}
$$

members with higher value of $Z_{b}$ and $Z_{t}$ will have higher load carrying capacity in bending.

### 5.2 Application of the Concepts in Drawing Office:

a) The concepts explained above are very essential for designing any structure and understanding the codal provisions.
b) For drawing the reinforcement details in a R.C.C. structure, the SE (Drawing) should have clear understanding as to the differentiation between compression zone and tension zone of a member of structure and distribute steel reinforcement accordingly.
c) The anchorage lengths and lap lengths for splices of reinforcement in compression zone and tension zone need different treatment and understanding the concepts even when drawing a RCC structure are essential.
d) The Concrete is week in tension and as such steel reinforcement is provided to take care of the tension in the structure. The farther the reinforcement from neutral axis the more advantage and economy, but if for some reason the reinforcement has to be brought closer to the N.A., it may require extra steel to be provided and the SE (Drg.) should do it only after consulting the Design Engineer or scrutinizing the design.

## CHAPTER X

## CALCULATION OF QUANTITIES

### 1.0 Introduction

The calculation of quantities from the records of the field and or from the drawings is an important step in preparing an estimate. The calculations normally involve working out Length, area, Volume or number of pieces required for the work. While, length and number of pieces is a direct measurement, the area and volume have to be calculated using some formulas or derivations.

Some of the uses of calculation of area \& volume are as under:-
(a) To calculate the area of land from the plan
(b) To calculate the cross sectional area and based on that the volume of earthwork.
(c) To decide the area of cut \& fill for economy in earthwork in ghat/ hilly sections
(d) To calculate the volume of foundation in footings which are in form of a truncated prism

### 2.0 Calculation of area \& volume of some regular shapes

Area and volume for standard shapes have standard formulas as below:-
AREA:

| S. No. | Shape | Area |
| :--- | :--- | :--- |
| 1 | Rectangle (L, length and B, breadth | Lx B |
| 2 | Square ( L is the side length) | $\mathrm{Lx} \mathrm{L} \mathrm{or} \mathrm{L}^{2}$ |
| 3 | Triangle (B is base and H, height) | $1 / 2 \mathrm{~B} \times \mathrm{H}$ |
| 4 | Circle ( Diameter D or Radius, r ) | $\pi \mathrm{r}^{2}$ or $\pi \mathrm{D}^{2} / 4$. |
| 5 | Trapezium (L1 \&L2 length of parallel sides <br> and H, is height) | $(\mathrm{L} 1+\mathrm{L} 2) \times \mathrm{H} / 2$ |
| 6 | Surface area of sphere, Radius, r | $4 \pi \mathrm{r}^{2}$ |
| 7 | Arc Segment of a Circle Radius, $\mathrm{r} \&$ Height, h | -As given below |



$$
\text { Area }=2 / 3 \times b \times h
$$



Area $=1 / 3 \times b \times h$

## VOLUME:

| S. No. | Shape \& Dimension | Volume |
| :--- | :--- | :--- |
| 1 | Cuboids of sides L, B \&H | $\mathrm{L} \times \mathrm{B} \times \mathrm{H}$ |
| 2 | Cube of side L | $\mathrm{LxL} \times \mathrm{L}$ or $\mathrm{L}^{3}$ |
| 3 | Cone Base radius, $\mathrm{r} \&$ Height, H | $1 / 3 \times \pi \mathrm{r}^{2} \times \mathrm{H}$ |
| 4 | Sphere Radius, r | $4 / 3 \times \pi \mathrm{r}^{3}$ |
| 5 ($\left.^{*}\right)$ | Frustum of Cone/ Pyramid A1 \&A2 <br> are area of base and top with <br> Hheight | $(\mathrm{H} / 3) \times\left(\mathrm{A}_{1}+\mathrm{A}_{2}+\sqrt{(\mathrm{A} 1 \mathrm{XA2}))}\right.$ |


Where $A_{1}$ is area at top \& $A_{2}$ is area at bottom and ' $h$ ' is the perpendicular distance between the two area the planes of which are parallel to each other. This formula should be used for calculation of concrete in footings of columns.


Area of top $=\mathrm{L} 1 \times \mathrm{B} 1$ Area of bottom $=\mathrm{L} 2 \times \mathrm{B} 2$

### 3.0 Calculation of area \& volume of irregular shapes

While the area of definite shapes like triangle, square, rectangle, polygon etc. are very easy to calculate, there may be cases where shapes are irregular which have to be calculated in parts. There are several methods of calculation of the area and volume of irregular shapes.

Some of the methods of calculation of area are as under:-

- By division into triangles
- By division into squares
- By division into trapezoids
- By measuring ordinates

Computation of area by ordinates
(i) By using mid-ordinates
(ii) By using mean-ordinates
(iii) Trapezoidal formula
(iv) Simpsons' rule

Some of the methods of calculation of volume are
(a) By cross sections by taking
(b) By method of contouring

### 3.1 Calculation of areas

The various methods of calculation of area are explained as under:-

## (a) Computation of area by division into triangles

The method is to drawn lines between the vertices so as to divide the area into a number of triangles and area will be the sum of area of these triangles. An example is illustrated below:-


In the above example we have divided the area into four triangles and the arrow lines are marked to denote the height of respective triangles and area of each triangle will be equal to $1 / 2 \mathrm{x}$ its base x its height. The sum of the area of these triangles will give the total area.
(b) Computation of area by division into squares

This is a graphical method in which a piece of tracing paper divided into a number of squares each square representing a definite area as per the scale of the plan is placed on the plan from which area is to be calculated. The complete squares within the boundary are counted and the incomplete squares are counted as fractions. The squares more than half are counted as one and that less than half are neglected. Smaller the square more is the accuracy.


## (ii) By using mean ordinates

In this method the ordinates are drawn and scaled off at each point of the division of the base line instead of that at the mid-point of the division. The average of these ordinates multiplied by the length of the base line gives the required area (see fig below)


Area $\mathrm{A}=\frac{\mathrm{O}_{0}+\mathrm{O}_{1}+\mathrm{O}_{2}+\ldots \ldots+\mathrm{O}_{\mathrm{n}}}{\mathrm{n}+1} \times \mathrm{L}$
where $\mathrm{O}_{0}, \mathrm{O}_{1}, \mathrm{O}_{2}$ etc are the ordinates at each of the divisions, ' L ' is the length of the base line and ' $n$ ' is the number of parts into which the base line is divided.

$$
\text { Area } A=\frac{\text { (Sum of ordinates) }}{(\text { No of ordinates }+1)} \quad x \text { length of base line }
$$

(iii) By Trapezoidal formula:-

In this method, the whole area is divided into a series of trapezoids and the area is calculated as sum of individual trapezoids. It is assumed that the boundaries between the ends of the ordinates are straight lines and the area between the base line and the boundary is divided into trapezoids as shown in figure below:-


Area of first trapezoid $\quad=\frac{O_{0}+O_{1}}{2} x d$

Area of second trapezoid $=\frac{O_{1}+O_{2}}{2} x d$

## (ii) By using mean ordinates

In this method the ordinates are drawn and scaled off at each point of the division of the base line instead of that at the mid-point of the division. The average of these ordinates multiplied by the length of the base line gives the required area (see fig below)


Area $\mathrm{A}=\frac{\mathrm{O}_{0}+\mathrm{O}_{1}+\mathrm{O}_{2}+\ldots \ldots+\mathrm{O}_{\mathrm{n}}}{\mathrm{n}+1} \times \mathrm{L}$
where $\mathrm{O}_{0}, \mathrm{O}_{1}, \mathrm{O}_{2}$ etc are the ordinates at each of the divisions, ' L ' is the length of the base line and ' $n$ ' is the number of parts into which the base line is divided.

$$
\text { Area } A=\frac{\text { (Sum of ordinates) }}{(\text { No of ordinates }+1)} \quad x \text { length of base line }
$$

(iii) By Trapezoidal formula:-

In this method, the whole area is divided into a series of trapezoids and the area is calculated as sum of individual trapezoids. It is assumed that the boundaries between the ends of the ordinates are straight lines and the area between the base line and the boundary is divided into trapezoids as shown in figure below:-


Area of first trapezoid $\quad=\frac{O_{0}+O_{1}}{2} x d$

Area of second trapezoid $=\frac{O_{1}+O_{2}}{2} x d$

Area of third trapezoid $=\frac{\mathrm{O}_{2}+\mathrm{O}_{3}}{2} x \mathrm{~d}$
Area of fourth trapezoid $=\frac{\mathrm{O}_{3}+\mathrm{O}_{4}}{2} x \mathrm{~d}$

Area of fifth trapezoid $\quad=\frac{O_{4}+O_{5}}{2} x d$
Area of last trapezoid $=\frac{O_{n-1}+O_{n}}{2} x d$
Total area of all trapezoids $=\frac{d}{2} X\left(\mathrm{O}_{0}+2 \mathrm{O}_{1}+2 \mathrm{O}_{2}+2 \mathrm{O}_{3}+2 \mathrm{O}_{4}+\ldots \ldots \ldots .2 \mathrm{O}_{\mathrm{n}-1}+\mathrm{O}_{\mathrm{n}}\right)$
Sum of first and the last ordinates plus twice the total sum of intermediate ordinates is multiplied by the common distance between the ordinates. Half of this product gives the total area. On further simplification we get

Total area of all trapezoids $=d x\left\{\frac{0}{2}+\left(\mathrm{O}_{1}+\mathrm{O}_{2}+\mathrm{O}_{3}+\mathrm{O}_{4}+\mathrm{O}_{\mathrm{n}-1}\right)\right\}$

Area $=\mathrm{dx}$ (average of first and last ordinates + sum of remaining ordinates)

On Indian Railways for calculating cross sectional areas of embankment or cutting in comparatively flatter terrains, Trapezoidal Formula is used, which gives quite acceptable level of correctness in calculations.

This is more accurate than the trapezoidal rule as instead of
(iv) By Simpson rule
 ends of the ordinates being assumed as straight lines as in trapezoidal formulas, here the ends of ordinates are assumed to be parabolic arcs. However, this should be used only in very hilly and up and down terrain and not in flatter terrain. The derivation of the formula is as under:-

Let ' $A 1$ ' be the area of BCEFGHB which is equal to the area of trapezoid BCFGB plus the area of the enclosed between the parabolic arc and the base line CF.

Area of Trapezoid BCFGB $=\frac{O_{0}+O_{2}}{2} \times 2 d$
or $\quad a_{1}=\left(O_{0}+O_{2}\right) x d$
Area enclosed by parabola CEF and base line CF $=2 / 3$ of area of parallelogram Cc'f'F denoted in dotted line $=2 / 3 \times C F \times E e^{\prime}$

CF can be considered to be equal 2d
$\mathrm{Ee} e^{\prime}=\mathrm{EH}-\mathrm{e}^{\prime} \mathrm{H}=\mathrm{O}_{1}-\left\{\left(\mathrm{O}_{0}+\mathrm{O}_{2}\right) / 2\right\}$
Area enclosed by parabola CEF and base line CF $\left(a_{2}\right)$

$$
\begin{aligned}
& =(2 / 3 \times \text { CF } \times \text { Ee' }) \\
& =2 / 3 \times 2 d \times\left[\mathrm{O}_{1}-\left\{\left(\mathrm{O}_{0}+\mathrm{O}_{2}\right) / 2\right\}\right] \\
\mathrm{a}_{2} & =2 / 3 \times \mathrm{d} \times\left[2 \mathrm{O}_{1}-\left(\mathrm{O}_{0}+\mathrm{O}_{2}\right)\right]
\end{aligned}
$$

## Area A1 $=\mathrm{a}_{1}+\mathrm{a}_{2}$

$$
\begin{aligned}
& =\left\{\left(\mathrm{O}_{0}+\mathrm{O}_{2}\right)^{2} \times \mathrm{d}\right\}+\left\{2 / 3 \times \mathrm{dx}\left[2 \mathrm{O}_{1}-\left(\mathrm{O}_{0}+\mathrm{O}_{2}\right)\right]\right\} \\
& =\mathrm{d} / 3\left[3 \mathrm{O}_{0}+3 \mathrm{O}_{2}+4 \mathrm{O}_{1}-2 \mathrm{O}_{0}-2 \mathrm{O}_{2}\right] \\
& =\mathrm{d} / 3\left[\mathrm{O}_{0}+4 \mathrm{O}_{1}+\mathrm{O}_{2}\right]
\end{aligned}
$$

Similarly area for next two divisions

$$
\text { Area } \mathrm{A} 2=\mathrm{d} / 3\left[\mathrm{O}_{2}+4 \mathrm{O}_{3}+\mathrm{O}_{4}\right]
$$

Adding all partial areas, total area $A=\Sigma \mathrm{A} 1+\mathrm{A} 2+\ldots$.

$$
\begin{aligned}
& =\frac{d}{3} \times O_{0}+4 O_{1}+2 O_{2}+4 O_{3}+2 O_{4}+\ldots . .+2 O_{n-2}+4 O_{n-1}+O_{n} \\
& =\frac{d}{3} \times\left\{\left(O_{0}+O_{n}\right)+4\left(O_{1}+O_{3}+\ldots O_{n-1}\right)+2\left(O_{2}+O_{4}+\ldots . . O_{n-2}\right)\right\}
\end{aligned}
$$

d
Areaa $=-x[($ Ist ordinate + Last ordinate $)+(4 x$ sum of odd ordinates $)+(2 x$ 3 sum even ordinates)]

## NOTE

Simpson rule is applicable only for odd number of ordinates i.e. total number of odd ordinates should be one more than the total no of even ordinates. For even no. of ordinates, Simpson's rule should be applied for whole area except for the area between last two ordinates which is calculated by average ordinate method and added to the rest of the area calculated by Simpson's formula. Similarly the length 'd' between the two ordinates should be the same. If it is different, then it can be calculated by parts by taking in groups with same value of ' $d$ '.

### 3.2 Calculation of volumes

Calculation of volume of earth work in embankment or in cutting or to find out the volume of water in a dam is as explained. This is just an extension of method of calculating areas, except that in place of height as the ordinate, area is taken as the ordinate. One of the common methods adopted is by cross sections by taking levels. The method is explained below,

## a) By cross sections by leveling

This is useful for calculation of earthwork in embankment or cutting. A chain line is drawn approximately through the center of the area with station $A_{0}, B_{0}, C_{0} \ldots$ at fixed distances of say 30 m . In case of road/railways, the center line will be the

center line of the proposed alignment Cross sections are drawn across these stations at intervals of say 5 m .
Initial levels are taken at stations along the center line as well as on the cross sections before commencement of earth work. Final levels are first chosen along the center line and final levels of other points along the cross section are determined based on the slopes required to be given in sub grade. Earthwork is done up to the predetermined final levels duly compacted. After completion of earth work final levels are taken finally.

From the initial and final levels, cross sections are plotted to scale showing both initial and final levels. A sample cross section along $\mathrm{A}_{0}$ is shown as under:-


The cross sectional area between the two dotted lines gives the cross sectional area along $A_{0}$. The cross sectional area can be determined by choosing a datum line below the lowest of initial \& final levels. Let the area above the datum line up to final level be ' $X$ ' and the area above the datum level up to the initial levels be $Y$, then difference between ' $X$ ' \& ' $Y$ ' will give the cross sectional area along $A_{0}$. The graphical method explained in para. 2 b above can also be used to determine the cross sectional area. This will be approximate and therefore it is better to adopt the former method.

The cross sectional areas of other sections passing through B0, C0, D0 etc are determined. The volume of earth work can be calculated using the Simpson rule in same way area was calculated (ordinates are replaced by cross sectional area) as under:-

> Vol $=\frac{D}{3} x[$ Area of first section + Area of last section $+\{4 x$ area of odd $)+(2 x$ area of even secs $)\}$ where ' $D$ ' is the distance between two cross sections. In the above example it is 30 m.

## Note :-

As stated already Simpson rule is applicable only to odd number of cross sections. For even no of cross sections, Simpson's rule should be applied to odd number of cross sections and for volume between last two cross sections, average area method can be used. If value of $D$, inter distance between 2-ordinates is not equal the volume is calculated in parts as stated in calculation of area by Simpson's rule.
3.3 EXAMPLE: Estimate the quantity of earth work required in Railway embankment 150 m long and 6.85 m wide. The longitudinal gradient at the location is $1: 60$ and the Lsection is as shown in sketch below. The Initial cross section levels have been taken at every 30 m longitudinally and in the transverse direction at Centre line, edges of bank ( 3.425 m on either side), and at further 5m intervals. Use Trapezoidal Rule. The levels at different locations are given in table below,


CALCULATION OF QUANTITIES

| X-SECT. <br> LOCATION | FINAL <br> LEVEL | INITIAL LEVELS ON CROSS SECTIONS (M) |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  |  | $3(13.425 \mathrm{~m})$ | $2(8.425 \mathrm{~m})$ | $1(3.425 \mathrm{~m})$ | $0 \leftrightarrow$ | $4(3.425 \mathrm{~m})$ | $5(8.425 \mathrm{~m})$ | $6(13.425 \mathrm{~m})$ |
|  |  | In. L | In. L | In. L | In. L | In. L | In. L |  |
| A |  | 97.5 | 97.0 | 99.0 | 98.0 | 99.2 | 98.1 | 97.7 |
| B |  | 98.5 | 98.0 | 99.9 | 98.5 | 99.0 | 98.8 | 98.5 |
| C |  | 98.5 | 98.0 | 98.8 | 98.0 | 99.2 | 99.0 | 98.7 |
| D |  | 99.5 | 98.0 | 98.9 | 98.5 | 99.0 | 98.8 | 99.0 |
| E |  | 99.8 | 99.0 | 99.0 | 98.5 | 99.2 | 99.0 | 99.3 |
| F | 104.5 | 100.0 | 99.0 | 99.9 | 98.5 | 99.0 | 98.8 | 100.5 |

## SOLUTION:

Step-1 Draw the above initial levels at locations A, B, C, D, E and F on a sheet of graph paper or drawing sheet.

Step-2 Draw the formation level and the formation width of 6.85 m with center line ( 0 ) as the base, equally distributed 3.425 m (Half of 6.85 m ) on either side.

Step-3 Draw the side slopes at 2H: 1V to meet the initial level line, say at T1 and T2.
Step-4 Measure out distances T1-2, 2-1, 1-0, 0-4, 4-5, 5-T2 and the heights A2, A1, A0, A4, A5 (The height at T1 and T2 is zero) for the cross sections at A and similarly for cross sections at $B, C, D, E$ and $F$.

| $\begin{array}{\|l} \hline \text { X-SEC } \\ \text { A } \\ \hline \end{array}$ | INTER DISTANCE | INL. LEVEL | FL LEVEL | HT (m) | $\begin{array}{\|l\|} \hline \text { X-SEC } \\ \mathrm{B} \end{array}$ | INTER DISTANC | INL. LEVEL | FL LEVEL | HT (m) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (T1) | 2-T1 $=4.0 \mathrm{~m}$ | 97.5 | $\begin{aligned} & 102-(5+4) / 2 \\ & =97.5 \end{aligned}$ | 0 | (T1) | $\begin{aligned} & \text { 2-T1= } \\ & 4.0 \mathrm{~m} \end{aligned}$ | 98.5 | $\begin{array}{l\|} \hline 102.5- \\ (5+4) / 20 \\ =100.2 \\ \hline \end{array}$ | 0 |
| A2 | 2-1 $=5.0 \mathrm{~m}$ | 97.0 | $\begin{aligned} & \text { 102-(5.0/2) } \\ & =99.5 \end{aligned}$ | 2.5 | B2 | $\begin{aligned} & 2-1= \\ & 5.0 \mathrm{~m} \end{aligned}$ | 98.0 | $\begin{aligned} & \hline 102.5- \\ & 5 / 2=0 \\ & 100 . \end{aligned}$ | 2.0 |
| A1 | 1-0 =3.425m | 99.0 | 102.0 | 3.0 | B3 | $\begin{aligned} & \hline 1-0= \\ & 3.425 \mathrm{~m} \end{aligned}$ | 99.9 | 102.5 | 2.6 |
|  | 0 | 98.0 | 102.0 | 4.0 |  | 0 | 98.5 | 102.5 | 4.0 |
| A4 | 0-4 = 3.425m | 99.2 | 102.0 | 2.8 | B4 | $\begin{aligned} & \hline 0-4= \\ & 3.425 \mathrm{~m} \end{aligned}$ | 99.0 | 102.5 | 3.5 |
| A5 | $4-5=5.0 \mathrm{~m}$ | 98.1 | 102.0(5.0/2) | $\begin{array}{\|l\|} \hline 1.4 \\ =99.5 \end{array}$ | B5 | $4-5=$ | $\begin{array}{\|l\|} \hline 98.8 \\ 5.0 \mathrm{~m} \end{array}$ | $\begin{aligned} & \hline 102.5 \\ & -2.5 \\ & =100.0 \end{aligned}$ | 2.5 |
| (T2) | $5-\mathrm{T} 2=3.6 \mathrm{~m}$ | 97.7 | $\begin{aligned} & \hline 102.0- \\ & (5+3.6) / 2 \\ & =97.7 \end{aligned}$ | 0 | (T2) | $\begin{aligned} & \text { 5-T2= } \\ & 3.0 \mathrm{~m} \end{aligned}$ | 98.5 | $\begin{aligned} & \hline 102.5- \\ & (5+3) / 2 \\ & =98.5 \\ & \hline \end{aligned}$ | 0 |


| $\begin{aligned} & \mathrm{X}-\mathrm{SEC} \\ & \mathrm{C} \end{aligned}$ | INTER DISTANCE | INL. LEVEL | FLHT (m) LEVEL | HT (m) | $\begin{aligned} & \text { X-SEC } \\ & \mathrm{D} \end{aligned}$ | INTERINL. | INL. LEVEL | FL LEVEL | HT (m) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (T1) | 2-T1 $=4.0 \mathrm{~m}$ | 98.5 | $\begin{aligned} & 103.0- \\ & (5+4) / 2= \\ & 98.5 \end{aligned}$ | 0 | (T1) | $\begin{aligned} & \text { 2-T1= } \\ & 3.0 \mathrm{~m} \end{aligned}$ | 99.5 | $\begin{array}{l\|} \hline 103.5- \\ (5+3.0) / 2 \\ =99.5 \end{array}$ | 0 |
| C2 | $2-1=5.0 \mathrm{~m}$ | $\begin{array}{\|l\|} \hline 98.0 \\ 100.5 \end{array}$ | 103.0-(5/2) $=$ | 2.5 | D2 | 2-1=5.0m | $\begin{aligned} & \hline 98.0 \\ & (5) / 2 \end{aligned}$ | $\begin{aligned} & 103.5 \\ & =101.0 \end{aligned}$ | 3.0 |
| C1 | 1-0 =3.425m | 98.8 | 103.0 | 4.2 | D3 | $\begin{aligned} & \hline 1-0= \\ & 3.425 \mathrm{~m} \end{aligned}$ | 98.9 | 103.5 | 4.6 |
|  | 0 | 98.0 | 103.0 | 5.0 |  | 0 | 98.5 | 103.5 | 5.0 |
| $\begin{array}{\|l\|} \hline C 4 \\ 3.425 \end{array}$ | $0-4=$ | 99.2 | 103.0 | 3.7 | D4 | $\begin{aligned} & 0-4= \\ & 3.425 \mathrm{~m} \end{aligned}$ | 99.0 | 103.5 |  |
| C5 | $4-5=5.0 \mathrm{~m}$ | $\begin{array}{\|l\|} \hline 99.0 \\ 100.5 \end{array}$ | 103.0-(5/2) $=$ | 1.5 | D5 | 4-5=5.0m | $\begin{aligned} & \hline 98.8 \\ & (5 / 2) \end{aligned}$ | $\begin{gathered} 103.5- \\ 101.0 \end{gathered}$ | 2.2 |
| (T2) | 5-T2=3.6m | 98.7 | $\begin{aligned} & \hline 103.0- \\ & (5+3.6) / 2= \\ & 98.7 \\ & \hline \end{aligned}$ | 0 | (T2) | $\begin{aligned} & \text { 5-T2= } \\ & 3.0 \mathrm{~m} \end{aligned}$ | 99.0 | $\begin{aligned} & 103.5- \\ & (5+4)= \\ & 99.0 \end{aligned}$ | 0 |


| $\begin{array}{\|l\|} \hline \text { X-SEC } \\ \hline \end{array}$ | INTER DISTANCE | INL. LEVEL | FLHT (m) LEVEL | HT (m) | $\begin{array}{\|l\|} \hline \mathrm{X} \text {-SEC } \\ \mathrm{F} \\ \hline \end{array}$ | INTERINL. DISTANCE | INL. LEVE | FL LEVEL | HT (m) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (T1) | $2-\mathrm{T} 1=3.4 \mathrm{~m}$ | 99.8 | $\begin{aligned} & 104-(5+3.4) / \\ & 2=99.8 \end{aligned}$ | 0 | (T1) | $\begin{aligned} & \hline 2-\mathrm{T} 1= \\ & 4.0 \mathrm{~m} \end{aligned}$ | 100.0 | 104.5$(5+4) / 2$ $=100.0$ | 0 |
| E2 | 2-1=5.0m | 99.0 | $\begin{aligned} & \hline 104-2.5= \\ & 101.5 \end{aligned}$ | 2.5 | $\begin{aligned} & \hline \text { F2 } \\ & \text { F3 } \end{aligned}$ | $\begin{array}{\|l\|} \hline 2-1=5.0 \mathrm{~m} \\ 5.0 \end{array}$ | 99.0 | $\begin{aligned} & \hline 104.5- \\ & (5 / 2)= \\ & 102.0 \end{aligned}$ | 3.0 |
| E1 | 1-0=3.425m | 99.0 | 104.0 | 5.0 | F3 | $\begin{array}{\|l\|} \hline 1-0= \\ 3.425 \mathrm{~m} \\ \hline \end{array}$ | 99.9 | 104.5 | 4.6 |
| $\mathrm{E}^{\mathrm{E} 0} \uparrow$ | 0 | 98.5 | 104.0 | 5.5 |  | 0 | 98.5 | 104.5 | 6.0 |
| E4 | 0-4=3.425m | 99.2 | 104.0 | 4.8 | F4 | $\begin{array}{\|l\|} \hline 0-4= \\ 3.425 \mathrm{~m} \\ \hline \end{array}$ | 99.0 | 104.5 | 5.5 |
| E5 | $4-5=5.0 m$ | 99.0 | $\begin{aligned} & 104.0-2.5 \\ & =101.5 \end{aligned}$ | 2.5 | F5 | $4-5=5.0 \mathrm{~m}$ | 98.8 | $\begin{aligned} & 104.5- \\ & 2.5= \\ & 102.0 \end{aligned}$ | 3.2 |
| (T2) | $5-\mathrm{T} 2=4.8 \mathrm{~m}$ | 99.3 | $\begin{aligned} & 104-(5+4.8) \\ & / 2= \end{aligned}$ | 0 | (T2) | $\begin{aligned} & \hline 5-\mathrm{T} 2 \\ & =3.0 \mathrm{~m} \end{aligned}$ | 100.5 | $\begin{aligned} & 104.5- \\ & (5+3) / 2 \end{aligned}$ | 0 |

Step-5 Calculate the areas of $X$ - sections at all the locations i.e. at $A, B, C, D, E, A N D$ $F$. Trapezoidal rule is commonly used in Railways.
C.S. Area $(A)=1 / 2\{(0+2.5) \times 4.0+(2.5+3.0) \times 5.0+(3.0+4.0) \times 3.425+(4.0+2.8) \times$

$$
3.425+(2.8+1.4) \times 5.0+(1.4+0) \times 3.6\}=55.40 \text { sqm }
$$

C.S.Area $(B)=1 / 2\{(0+2.0) \times 4.0+(2.0+2.6) \times 5.0+(2.6+4.0) \times 3.425+(4.0+3.5) x$

$$
3.425+(3.5+2.5) \times 5.0+(2.5+0) \times 3.0\}=58.40 \text { sqm }
$$

C.S.Area $(C)=1 / 2\{(0+2.5) \times 3.4+(2.5+5.0) \times 5.0+(5.0+5.5) \times 3.425+(5.5+4.8) x$ $3.425+(4.8+2.5) \times 5.0+(2.5+0) \times 4.8\}=82.87$ sqm
C.S.Area $(D)=1 / 2\{(0+3.0) \times 3.0+(3.0+4.6) \times 5.0+(4.6+5.0) \times 3.425+(5.0+4.5) x$ $3.425+(4.5+2.2) \times 5.0+(2.2+0) \times 3.0\}=76.26$ sqm
C.S.Area $(E)=1 / 2\{(0+2.5) \times 3.4+(2.5+5.0) \times 5.0+(5.0+5.5) \times 3.425+(5.5+4.8) \times$

$$
3.425+(4.8+2.5) \times 5.0+(2.5+0) \times 4.8\}=82.67 \text { sqm }
$$

C.S.Area $(F)=1 / 2\{(0+3.0) \times 4.0+(3.0+4.6) \times 5.0+(4.6+6.0) \times 3.425+(6.0+5.5) x$
$3.425+(5.5+3.2) \times 5.0+(0+3.2) \times 3.0\}=89.40 \mathrm{sqm}$
Step 6 Calculate the volume in the given chain age ( 150 m from A to F) using trapezoidal rule

The inter distance between cross sections is 30 m . As per trapezoidal rule
Volume $=\mathrm{dx}\{(\mathrm{OA}+\mathrm{OF}) / 2+\mathrm{OB}+\mathrm{OC}+\mathrm{OD}+\mathrm{OE})\}$

$$
=30.0\{(55.40+89.4) / 2+58.40+82.87+76.26+82.67\}=11178 \text { cum }
$$

4.0 Balancing Earth work Quantity: The above example shows the method of calculating earth work quantities without reference to lead, the earth has to be carried. In a hilly terrain it will be advantageous to choose the alignment and formation level such that the volume of filling is more or less equal to volume of cutting. This gives an economic way of executing earthwork. Since the cut spoils from the cutting are to be led to the area where filling is to be done, it becomes necessary to find out the 'lead' i.e. the distance required to carry the spoils along with the quantity. This is achieved by drawing a 'Mass Haul Diagram'. The concept is explained under. However detailed treatment to work out the lead and optimize the cost is given in Appendix IV.


In the above case of cutting \& filling we should find the ordinates of point of intersection of initial \& final level $(X)$ as well as the base line $(Y)$ by interpolation or graphical method and once it is found we can calculate the area of cutting \& filling between these two ordinates as under:-
(a) Area of cutting is area above base line between ordinates of $A_{x}$ and $A_{6}$ up to initial levels minus the area of same ordinates with final levels.
(b) Area of filling is the area above the base line between ordinates of $A_{3} \& A_{x}$ up to final levels minus the area of same ordinates up to initial levels.

### 5.0 Building Work:

For estimating quantities for a building, the dimensions of length, breadth and depth are to be taken from the drawings - plans, elevations \& sections. Special care should be taken at the junctions of the members taking care that there is no duplication in the quantities. Two methods are used in estimation of buildings
(a) Longer wall shorter wall method
(b) Center line method

### 5.1 Longer wall-shorter wall method

In this method, the longer walls running in one direction are measured "out to out" and other walls running in traverse directions are measured "in to in". The same rule applies to calculating the quantities of earthwork in foundation, concrete in foundation \& masonry. Care should be taken to note the difference in dimensions at different heights due to offsets/footings. It is required to imagine the plan at different levels / heights as foundation trench plan, foundation concrete plan, plan of each footings of masonry etc.and dealing each plan \& part separately. When offsets are equal on both sides, the center line of wall,
footings foundations, trenches etc. remain the same. This can be used to advantage in longer wall shorter wall method. Normally this method is used in estimating quantities of brick work etc. Length of longer walls being center to center length of wall plus width and length of shorter walls is center to center length of walls less one width as shown in the Figure below:-


### 5.2 Centre line method:-

In this method, sum of total length of center line of walls - long and short having same cross section through out are calculated. To this length width \& depth are multiplied as available at different levels/depths to get respective quantity. However a deduction for junctions has to be made as per following formula:-
Deduction for junctions $=\mathrm{n} x \mathrm{~b} 2 \times$ depth where $\mathrm{n}=$ total number of junctions and b is the width of wall. Tee junctions are to be counted as $1 / 2$ junctions and cross junctions as one. This is explained with sketches below:-


Tree junction
Cross junction

Volume duplicated in the Tee junction $=\frac{b}{b}-\frac{--. d}{2}=$| $---b^{2} d$ |
| :--- |
| 2 |

Volume duplicated in cross junction $\quad=b \times b \times d \quad=b^{2} d$
5.3 EXAMPLE: Estimate the quantities of a masonry water tank using long and short wall method. The specifications are as below,

Foundation: Lime concrete, Masonry: $1^{\text {st }}$ class brick in 1:6 cement mortars, inside cement plaster, 12 mm thick, $1: 2$ and outside $12 \mathrm{~mm}, 1: 4$, Flooring C.C.1:1.5:3, 5 cm thick

over 30 cm lime concrete. Inside dimensions of tank are $7 \mathrm{~m} \times 5 \mathrm{~m} \times 1.5 \mathrm{~m}$. Other dimensions are as per figure given below.
Solution: The portion below ground level is symmetric but above ground inside dimension is constant but outer dimension is varying at 3 locations and as such for masonry above G.L. the $\mathrm{c} / \mathrm{c}$ distance is variable.

1. For portion below ground level: For excavation in all footings $\mathrm{c} / \mathrm{c}$ length of long wall $=7.0+(1.00 / 2)=7.5 \mathrm{~m}$ and for short wall= $5+(1.00 / 2)=5.5 \mathrm{~m}$.
2. For portion above ground Level: For 30 cm wall, $\mathrm{c} / \mathrm{c}$ of long wall $=7.3 \mathrm{~m}$ and for short wall $=5.3 \mathrm{~m}$. Similarly for 40 cm wall it is 7.4 m and 5.4 m . For 50 cm wall, it is 7.5 m and 5.5m.

The quantities are calculated as per table below.

| S.no | Description | Nos. | Dimension (m) |  |  | Qty | Total Qty | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | L | B | D |  |  |  |
| 1 | E.W. in excavation in foundation |  |  |  |  |  |  |  |
|  | Long wall | 2 | 8.5 | 1.0 | 1.95 | 33.15 |  | $\mathrm{L}=7.5+1.0=8.5$ |
|  | Short Wall | 2 | 4.5 | 1.0 | 1.95 | 17.55 |  | $\mathrm{L}=5.5-1.0=4.5$ |
|  | Central portion | 1 | 6.5 | 4.5 | 1.25 | 36.56 |  | $\mathrm{L}=7.5-1.0=6.5$ |
|  |  |  |  |  |  |  |  | $\mathrm{B}=5.5-1.0=4.5$ |
|  |  |  |  |  | (Total Cum) |  | 87.26 |  |
| 2 | Lime conc. in foundation /floor |  |  |  |  |  |  |  |
|  | Foundations |  |  |  |  |  |  |  |
|  | Long Wall | 2 | 8.5 | 1.0 | 0.30 | 5.12 |  |  |
|  | Short wall | 2 | 4.5 | 1.0 | 0.30 | 2.70 |  |  |
|  | Under floor | 1 | 7.0 | 5.0 | 0.20 | 7.00 |  |  |
|  |  |  |  |  | Total (Cum) |  | 14.80 |  |
| 3 | $1^{\text {st }}$ class brick in 1:6 cement mortar, below G.L. |  |  |  |  |  |  |  |
|  | Long Wall |  |  |  |  |  |  |  |
|  | $1^{\text {st }}$ footing | 2 | 8.20 | 0.70 | 0.20 | 2.29 |  | $\mathrm{L}=7.5+0.70=8.20 \mathrm{~m}$ |
|  | $2^{\text {nd }}$ footing | 2 | 8.10 | 0.60 | 0.20 | 1.94 |  | $L=8.20-0.10=8.10 \mathrm{~m}$ |
|  | 50 cm wall | 2 | 8.00 | 0.50 | 1.25 | 10.00 |  | $\mathrm{L}=8.10-0.10=8.0 \mathrm{~m}$ |
|  | Short wall |  |  |  |  |  |  |  |
|  | $1^{\text {st }}$ footing | 2 | 4.80 | 0.70 | 0.20 | 1.34 |  | $\mathrm{L}=5.50-0.70=4.8 \mathrm{~m}$ |
|  | 2nd footing | 2 | 4.90 | 0.60 | 0.20 | 1.18 |  | $\mathrm{L}=4.80+0.10=4.90 \mathrm{~m}$ |
|  | 50 cm wall | 2 | 5.00 | 0.50 | 1.25 | 6.25 |  | $\mathrm{L}=4.90+0.10=5.0 \mathrm{~m}$ |
|  | Above G.L. |  |  |  |  |  |  |  |
|  | Long wall |  |  |  |  |  |  |  |
|  | 40 cm wall | 2 | 7.80 | 0.40 | 1.00 | 6.24 |  | $\mathrm{L}=7.40+0.40=7.80 \mathrm{~m}$ |
|  | 30 cm wall | 2 | 7.60 | 0.30 | 0.50 | 2.28 |  | $\mathrm{L}=7.30+0.30=7.60 \mathrm{~m}$ |
|  | Short wall |  |  |  |  |  |  |  |
|  | 40 cm wall | 2 | 5.00 | 0.40 | 1.00 | 4.00 |  | $\mathrm{L}=5.40-0.40=5.00 \mathrm{~m}$ |
|  | 30 cm wall | 2 | 5.00 | 0.30 | 0.50 | 1.50 |  | L=5.30-0.30=5.00m |
|  |  |  |  |  | Total (Cum) |  | 37.02 |  |
| 4 | 12 mm th. Cement plaster 1:2 inside |  |  |  |  |  |  |  |
|  | Long wall | 2 | 7.00 | - | 2.50 | 35.00 |  | Length can also be taken as perimeter $2 \times 2.5(5+7)\}=60 \mathrm{Sam}$ |
|  | Short wall | 2 | 5.00 | - | 2.50 | 25.00 |  |  |
|  |  |  |  | Total (Sqm) |  | 60.00 |  |  |


| S.no | Description | Nos. | Dimension (m) |  |  | Qty | Total Qty | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | L | B | D |  |  |  |
| 5 | 12 mm th. Cement plaster 1:4 outside |  |  |  |  |  |  |  |
|  | 40 cm wall |  |  |  |  |  |  |  |
|  | Long wall | 2 | 7.80 | - | 1.25 | 19.50 |  | Ht . including 10 cm offset and 15 cm below ground |
|  | Short wall | 2 | 5.80 | - | 1.25 | 14.50 |  |  |
|  | 30 cm wall |  |  |  |  |  |  |  |
|  | Long wall | 2 | 7.60 | - | 0.60 | 9.12 |  | Ht. including 10cm offset |
|  | Short wall | 2 | 5.60 | - | 0.60 | 6.72 |  |  |
|  | On top of walls |  |  |  |  |  |  |  |
|  | Long walls | 2 | 7.60 | 0.30 | - | 4.56 |  |  |
|  | Short wall | 2 | 5.00 | 0.30 | - | 3.00 |  |  |
|  |  |  |  | Total (Sqm) |  | 57.40 |  |  |
| 6 | C.C. 1:11/2:3 on floor ( 5 cm ) | 1 | 7.00 | 5.00 | - | 35.0 | $\begin{aligned} & 35.0 \\ & \text { Sqm } \end{aligned}$ |  |

### 6.0 R.C.C. Work:

R.C.C. is estimated under 2 items, namely concrete work including centering and shuttering and reinforcement steel including bending binding fabrication and placement including binding wire. The quantity of steel used is very small compared to volume of concrete and as such is not subtracted from the total volume of concrete. Many times, the supply of steel reinforcement and bending, binding and placement are taken separate items for the convenience of payment and working out price variation of store item. In some organizations the item of shuttering and centering is also kept separate from concrete. This has been observed that the quality of concrete work is directly proportional to quality of form work and when the item of form work is separately kept the site engineer can strictly enforce the quality of the form work and obtain good quality of concrete. In Railways however, the item of form work is integral with the item of concrete and form work is not estimated separately.
The reinforcement should be assessed on actual basis from the bar bending schedule provided in the drawings of structures. However, in the absence of detailed drawing abstract estimate can be prepared based on the percentages, by volume given in the table below,

| S.No. | Description of element | Approximate \% by volume of concrete |
| :--- | :--- | :--- |
| 1 | Lintels/ slabs etc | $0.7-1.00 \%$ |
| 2 | Chajja/sunshade | $0.5 \%$ |
| 3 | Beams | $1.0-2.0 \%$ |
| 4 | Columns | $1.0-5.0 \%$ |
| 5 | Foundation raft footing etc. | $0.5-0.8 \%$ |

The shorter the span the steel \%ge on the lower limit, should be taken and for longer spans upper bound values be taken. Short span is about 3.1 m and long span is above 6.1 m . The interim values may be adopted for spans in-between. For bent hooked or cranked bars the length of bar required needs to be worked out as given in Chapter-VI.
The specific gravity of steel reinforcement is 7.85 and for concrete 2.4.
6.1 Example: An R.C.C. shelter, 3 m high, with 4 -columns and a roof slab supported on edge beams covering an area of $3.3 \mathrm{~m} \times 4.0 \mathrm{~m}$ is to be constructed. Estimate approximate quantities of concrete and reinforcement steel for an abstract cost.

Cement Concrete used is grade 1:2:4. Reinforcement- Fe 415


It may be noticed that R.C.C. quantity has been worked out individually for footings, columns, beams and slab under different items as it is required to not only work out proportionate quantity of steel reinforcement in each member but also the rate of RCC in these items will be different due to shuttering component being different in footing, column, beam and slab. If however the rate for formwork is to be paid separately, the quantity of the same should be worked out separately and the qty of RCC could be worked out in a combined manner, if of same grade. If the detailed drawing and reinforcement schedule are available, the bar lengths and their weight should be worked out and an allowance of $5 \%$ by weight should be added to the steel reinforcement to account for lap lengths. Normally, the wastage allowance about another $5 \%$, for cut pieces is not added and the rate of fabrication of steel is to account for the same. However, if department has to supply steel reinforcement, the wastage allowance should be added to the required steel reinforcement for procurement purpose.
6.2 Shuttering and centering: The shuttering is the surface area of the element of structure which is to be cast with concrete less the area required to be kept open/uncovered for pouring and vibrating the concrete. For example, in case of a i) simply supported beam the two ends and 3 sides would be required to be covered and the top face is to be kept open, thus the shuttering requirement is for total surface area less the top surface of beam ii) for slab again the top surface is not covered but sides and the bottom are to be covered, iii) for footing, the sides are to be covered but the bottom and top are not covered, iv) for columns the sides are covered but the bottom and top are not covered. There would be minor variations to the above depending on the structural details and sequence of casting but normally no consideration is given to the sequence of working which may require less or more formwork.

| S.No. | Element | Shape | Shuttering area (Sqm) |
| :---: | :---: | :---: | :---: |
| 1 | Beam |  | 2(BxD $+L \times D)+L x B$ |
| 2 | Slab |  | $2(L x D+B x D)+L x B$ |
| 3 | Column (Rectangular) |  | 2(Hx B+ HxD), $H$ is measured between the beams. |
| 4 | Column (Circular) | -- -do--- column) (d is diameter of | $\pi$. d. H |
| 5 | Isolated footing |  | $\begin{aligned} & \text { 4-Slopeed areas }+4 \text { sides }= \\ & 2\left(\mathrm{~B} 2 \times \mathrm{H} 1+\sqrt{\mathrm{H} 2^{2}+(\mathrm{B} 2-\mathrm{B} 1)^{2}} \mathrm{x}\right. \\ & (\mathrm{B} 1+\mathrm{B} 2) / 2) \\ & +2\left(\mathrm{~A} 2 \times \mathrm{H} 1+\sqrt{\mathrm{H}^{2}+/(\mathrm{A} 2-\mathrm{A} 1)^{2}} \times\right. \\ & (\mathrm{A} 1+\mathrm{A} 2) / 2) \end{aligned}$ |

The cost of form work and centering may vary between 20-35\% of cost of concrete depending on the intricacy of the shape and structure.

### 7.0 Steel Structures:

Quantity of steelwork has to be worked out for the structures like bridge girders, FOBs, Platform shelters and sheds etc. The work may either be done through contractual agency or in the Railway workshops. In some cases we also go for work with contractor's labor and machinery, bolts and rivets except for steel sections and plates which may be supplied by the Railway. The material to be indented can not be on the finished dimensions of the members as there would be cut pieces arising which may not be usable in the fabrication of the structure. In the case where the steel has to be procured by the department then it has to be indented and for indent purposes not only the quantity of each type of section or plate is to be given but the sizes of the sections/plates has to be specified in the indent. The structurals and plates are produced in the steel plant in some specified sizes and it is available in their product catalogue (ANNEXURE- A). Wastage of $5 \%$ is the acceptable norm, as has also been stipulated in the IRS B1 (Railway code dealing with fabrication). If indents are not made; taking into the desired lengths into account, wastage as high as $30 \%$ has been known to occur in the field. This can be achieved by making a 'TAILORING PLAN'.
7.1 Tailoring Plan: It is like a tailor does for stitching a shirt to ensure that the wastage is least. In some cases the tailoring plan may tell us that the wastage would be more than $5 \%$ and then indent has to be done considering higher percentage of wastage. And after the tailoring plan, it is required that the range of length for indenting is specified in the indents, e.g. for angle ( $100 \times 100 \times 10 \mathrm{~mm}$ ) suppose we require pieces of 1.85 m length we will indent for angles of length 11.5 m , as $6 x(1.85+0.025 \mathrm{~m}$, for cutting of ends=11.25 m ) or with multiples of 1.85 m . This will ensure minimum wastage. The maximum wastage can occur in case of plates which not only have specified length but width also. Similarly, if plate of length 10 m and width 1.20 m is required and we get a plate of length 12 m and width 2.50 m , there will be wastage of $33 \%$, by cutting 2 plates of size $10.0 \times 1.20$, if the same plate is not required for some small members like gussets, packing pieces etc.
A sample sheet for calculation of the quantities for indent for 18.3 m welded girder as per RDSO drawing is given in Annexure - B.
7.2 Contractors Fabrication including Supply of material: In the case the estimate is to be prepared considering steel also to be supplied by the contractor, the estimation of the quantity is done based on the finished drawings (Center line dimensions) and $3 \%$ is added for the rivets or $1 \%$ is added for the welds. Quantities of the gussets have to be calculated or these can be taken as $6-8 \%$ of the total weight of structure.
In case of bridge girders where the detailed drawings issued by RDSO is there and the total weight is mentioned in the drawings. Same is the case with Platform shelters if executed as per RDSO drawings, no wastage or allowance for rivets or welds is to taken.

In case of non-standard platform shelters and FOB, for which no RDSO drawings are available nor any detailed plan has been prepared, normally $5 \%$ wastage is considered
over the finished weight as per drawing (based on the finished lengths) of the members. The weight for rivets and weld is normally added by taking $3 \%$ and $1 \%$ respectively. If gusset plate also is to be assessed in case of FOB as well as platform shelter, then it would be of the order of 6 to $8 \%$.
8.0 Water Supply works: - Water supply works mainly consist of pipe lines and fittings. The pipeline including sockets bends, elbows, tees, clamps etc. is measured and estimated in linear meter and the fittings like stop cocks, bib cocks, ferrules etc. are estimated in nos. as an separate item. The choice of pipe lines and fittings depends upon the water requirement and location where they are to be used. Details are given in R.E.T.'s publication 'Plumbing and Pipeline work'. Wherever the pipes are to be laid under ground, the item for making the trench and filling back as also any requirement of sub grade etc is estimated in a separate item
8.1 Tube well with hand pump: The construction of a tube well with hand pump is given in R.E.T.S. Publication 'Plumbing and pipeline work'. One should first design the depending upon the depth of water table etc. Normally Mark-II or Mark -III hand pumps are used for lift of 15 m or more. But for lesser lift ordinary hand pumps (hand suction pumps) may be used as given in example below,
8.2 Example: Estimate for an ordinary Tube well with hand pump as per soil strata below. Dia of bore is 150 mm dia \& depth 30 m . Dia of Gl pipe \& strainer is 40 mm
The item for boring of bore well has different rates as per the strata ie all soils, soft rock \& hard rock and different rates for different depths. The rate for boring is per $m$ depth per cm dia. The items for boring of hole for above strata will be as under:-


| No | Depths | All soils | Soft rock | Hard rock | Total |
| :--- | :--- | ---: | ---: | ---: | ---: |
| 1 | 0 m to 6 m | $4+2=6$ | 0 | 0 | 6 |
| 2 | 63 to 12 m | 0 | 6 | 0 | 6 |
| 3 | 12 m to 18 m | 4 | 0 | 2 | 6 |
| 4 | 18 m to 24 m | 4 | 2 | 0 | 6 |
| 5 | 24 m to 30 m | 4 | 2 | 0 | 6 |

Gl pipe is provided for entire length of bore with a bail plug at bottom \& the strainer is provided in water bearing strata. The casing pipe is removed after filling it with sand so that water gets into the GI pipe and not the soil surrounding and sand acts as a filet media
Quantity sheet for bore well for above case

| Item No. | Particulars of items | Unit | Quantity | Remarks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | Boring for tube well 150 mm dia |  |  |  |
|  | (a) All soils up to 6 m below GL | Rm | 6 Rm |  |
|  | (b) Soft rock from 6 m to 12 m below GL | Rm | 6 Rm |  |
|  | (c) All soils from 12 m to 18 m below GL | Rm | 4 Rm |  |
|  | (d) Hard rock from 12 m to 18 m below GL | Rm | 2 Rm |  |
|  | (e) All soils from 18 m to 24 m below GL | Rm | 4 Rm |  |
|  | (f) Soft rock from 18 m to 24 m | Rm | 2 Rm |  |
|  | (g) All soils from 24 m to 30 m below GL | Rm | 4 Rm |  |
|  | (h) Soft rock from 24 m to 30 m | Rm | 2 Rm |  |
| 2 | 40 mm dia Gl pipe |  |  |  |
|  | strainer+0.6m |  |  |  |
|  | above GL | Rm | 24.6m | 30m-6m |
| 3 | 40mm strainer |  |  |  |
|  | Rm | 6m |  |  |
| 4 | Hand pump ordinary (No. 4 Hand pump) | No | 1 no |  |
| 5 | Bail plug | No | 1 No |  |
| 6 | Coarse sand around |  |  |  |
| 7 | Cement platform of 1.8 m dia with drains all around as per standard drawing | No | 1 no | We can take quantities item wise like concrete, brick work, plastering etc. |
| 8 | Pumping out water till clean water is obtained | LS |  |  |

If however the depth of well is higher, say 30 m then different design of pump is used in which the casing/ housing pipe of larger dia is taken below G.L. about 6 m deep and a gun metal cylinder and plunger and valve is placed below it. All items as shown in above example remain same but the plunger\& valve and 6 m GI pipe of higher dia (dia equal to
casing pipe) are additionally required. The design of different requirements of hand pumps is explained in R.E.T.S's book on 'Plumbing and Pipe line work'.
9.0 Roads: For roads and pavements, some of the factors to be considered are,
i) The stone metal when compacted in layers measures about 30-50\% less than the metal measured loose. Normally, 30\% extra supply over the compacted measurement is taken.
ii) A cross slope of 1 in 30 known as camber is to be given right from the sub-grade and measurements are taken along the sloped surface for sub-grade, soling, metalled surface and premix carpet as such no separate allowance is required o be made for the camber.
iii) The quantities for soling, metalling and premix carpet are calculated in Sq. $m$ however earth work required to prepare the formation is measured in Cum.
A typical cross section of a road is shown below


| No | Item | Details |
| :--- | :--- | :--- |
| 1 | Carriage way | 3.6 m for single lane, 7.20 m for double lane (excluding <br> width of divider if provided) |
| 2 | Side slope of formation | $2: 1$ |
| 4 | Road camber | 1 in 36 |
| 5 | Soling | $230 \mathrm{~mm} / 150 \mathrm{~mm} / 100 \mathrm{~mm}$ thick (consolidated thickness) |
| 6 | Metalling | $150 \mathrm{~mm} / 100 \mathrm{~mm} / 75 \mathrm{~mm}$ thick (Consolidated thickness |
| 7 | Surfacing | 68 mm premixed asphalt macadam+12mm seal coat <br> (precoated/liquid) after bitumen priming of base course <br> and two coats of bituminous painting over two layers of <br> metalling |
|  | For heavy vehicles |  |
|  | For light vehicles | $48 m \mathrm{~m}$ premixed asphalt macadam+12mm seal coat <br> (precoated/liquid) after bitumen priming of base course <br> and followed by two coats of bituminous painting |

Quantities for 1 Km of road of formation width 10 m , carriage way of 3.6 m and average height of bank of 1 meter and side slopes of $2: 1$ with 230 mm soling, 150 mm metalling \& 50 mm bitumen concrete.

| No | Items | No | Length <br> in m | Breadt <br> h in m | depth <br> in m | Quantity |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1 | Surveying | 1 | 1 Km |  |  | 1 Km |
| 2 | Land acquisition | 1 | 1000 | 30 |  | 30000 Sqm |
| 3 | Earthwork in embankment | 1 | 1000 | $\left(\mathrm{Bd}+\mathrm{sd}^{2}\right)$ <br> $=(10 \times 1)+\left(2 \times 1^{2}\right)$ | 20000 Cum |  |
| 4 | Plantation of grasses on side <br> slope | 2 | 1000 | $\sqrt{\left(\mathrm{d}^{2}+\mathrm{sd}^{2}\right)}$ <br> $=\sqrt{\left(1+2^{2}\right)}=2.24$ | 4480 Sqm |  |
| 5 | Preparation of sub grade <br> including dressing to camber <br> \& compaction by 10 tonne <br> roller | 1 | 1000 | $3.6+0.3$ | 3900 Sqm |  |

### 10.0 Permanent Way

(i) Rails per track Km-2000 Rm x Sectional weiqhtain $\leqslant \mathrm{Eg} / \mathrm{m}=$ Total weight of rail\$ in Kg

(b) 52 Kg Rails $-2000 \mathrm{Rm} \times 52 \mathrm{Kg} / \mathrm{Rm}$
(c) 90 lbs Rails $-2000 \mathrm{Rm} \times 45 \mathrm{Kg} / R m \pm 190698 \mathrm{Rm}$ bitugaqnfoncrete
(d) 69lbs Rails $-2000 \mathrm{Rm} \times 35 \mathrm{Kg} / \mathrm{Rm}=70000 \mathrm{Kg}=70 \mathrm{MT}$
(Thumb rule - If sectional weight is in $\mathrm{Kg} / \mathrm{Rm}$, multiply sectional weight by 2 to get weight of rails in MT per track Km and if sectional weight is in lbs/rm, multiply sectional weight by 1 to get weight of rails in MT per track Km ).
(ii) Fish plates in pairs per track Km(one pair - 2 fish plates \& four bolts with nuts)
(a) For free rails $-2000 \mathrm{Rm} / 13 \mathrm{~m}=154$ pairs
(b) For three rail panels $-2000 \mathrm{Rm} / 39 \mathrm{~m}=52$ pairs
(c) For five rail panels $-2000 \mathrm{Rm} / 65 \mathrm{~m}=32$ pairs
(d) For ten rail panels - $2000 \mathrm{Rm} / 130 \mathrm{~m}=16$ pairs
(e) For twenty rail panels - $2000 \mathrm{Rm} / 260 \mathrm{~m}=8$ pairs
(f) (Length of one free rail taken for calculation purposes is 13 m )
(g) For concrete sleepers on SWR track, one metre long fish plates are to be used with clamps to avoid drilling in rails and to have normal sleeper spacing at rail joints.

These fish plated joints can be eliminated thereafter by welding by AT welds to convert SWR to LWR/CWR.

## (iii) Flash butt joints per track Km

Free rails are welded as three rail panels/five rail panels/ten rail panels/twenty rail panels either in flash butt welding depot in workshop or using mobile flash butt welding. Flash butt welding is a fusion welding of rails where high voltage electricity is passed through rail and rail ends are joined by heat \& pressure.
(a) No of flash butt joints = 154 - no of fish plated joints
(b) No of flash butt joints for free rails

- 154-154 = Nil
(c) No of flash butt joints for three rail panels - 154-52 = 102 Joints
(d) No of flash butt joints for five rail panels
- 154-32 = 122 joints
(e) No of flash butt joints for ten rail panels -154-16=138 joints
(f) No of flash butt joints for 20 rail panels -154-8=146 Joints


## (iv) AT welds per track km

There is a limit to which the rails can be welded at flash butt welding plant in depot due to difficulties in transportation of longer welded panels. AT weld is done after laying of rails in the track to convert $1 / 3 / 5 / 10 / 20$ rail panels into long welded track/ continuous welded track. This is done in the field either on running track in traffic block or on cess it is a field weld. Calculation of quantity per track Km is same as done in item. 2 (ie. 154 pairs for free rails, 52 rails for three rails, 32 pairs for five rails, 16 pairs for 10 rails \& 8 pairs for 20 rail panels per track km).

## (v) Sleepers per track Km

The sleeper density is defined as the number of sleepers per rail length and denoted by $M+` n$ ' where ' $m$ ' denotes one rail length ie $13 m$ and ` $n$ ' denotes a numeric. Sleeper density of $M+4$ denotes that $13+4=17$ sleepers per rail length of 13 m
The quantity of sleepers per track Km required for different sleeper densities are as under:-
(a) $\mathrm{M}+0-(1000 / 13) \times 13=77 \times 13=1001$ sleepers $/ \mathrm{Km}$
(b) $\mathrm{M}+1-(1000 / 13) \times 14=77 \times 14=1078$ sleepers $/ \mathrm{Km}$
(c) $\mathrm{M}+2-(1000 / 13) \times 15=77 \times 15=1155$ sleepers $/ \mathrm{Km}$
(d) $\mathrm{M}+3-(1000 / 13) \times 16=77 \times 16=1232$ sleepers $/ \mathrm{Km}$
(e) $\mathrm{M}+4-(1000 / 13) \times 17=77 \times 17=1309$ sleepers $/ \mathrm{Km}$
(f) $\mathrm{M}+5-(1000 / 13) \times 18=77 \times 18=1386$ sleepers $/ \mathrm{Km}$
(g) $\mathrm{M}+6-(1000 / 13) \times 19=77 \times 19=1463$ sleepers $/ \mathrm{Km}$
(h) $\mathrm{M}+7-(1000 / 13) \times 20=77 \times 20=1540$ sleepers $/ \mathrm{Km}$
(Note :- 1000/13 = 76.92 but rounded off to 77 )

## (vi) Sleeper fittings per sleeper

In any estimate, the cost of sleeper is including its fittings. However to work out the cost of sleeper inclusive of fittings, it is necessary to know the quantity and rate of the sleepers as well as fittings.

The fittings required for each sleepers are:- 4 Elastic Rail Clips, 4 metal/insulated liners \& 2 grooved rubber pads(GRSP). Sleepers in track circuited are provided with insulated GFN liners instead of metal liners. The type of fittings to be used for different rail sections are as under:-

| Ordinary PRC <br> Sleeper | Rail | Sleeper fittings for concrete sleepers |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  |  | ERC | Metal liners | GFN liners | GRSP |
| 52 Kg | 52 Kg | $\mathrm{T}-3701$ | T-3738 | T-3702 | T-3703 |
| 60 Kg | 60 Kg | $\mathrm{T}-3701$ | T-3740 | $\mathrm{T}-3706$ | T-3711 |
| 60 Kg | 52 Kg | $\mathrm{T}-3701$ | T-3741 <br> T-3742 | T-3707 <br> T-3708 | T-3711 |

(vii) Switch expansion joints (in set with rails, sleepers \& fittings)

Switch expansion joints are provided at ends of LWR/CWR for allowing expansion of rails in breathing length. Two switch expansion joints are to be taken for each stretch of LWR/ CWR track - one on either side. However if LWR/CWR plans are still not finalized four SEJs can be taken for track 4 Kms ie 1 number per Km and rounded off to nearest decimal.

| S. No. | Rail section and gap | Drawing No. |
| :--- | :--- | :--- |
| 1. | 52 Kg 80 mm straight | $\mathrm{T}-4160$ |
| 2. | 60 Kg 80 mm straight | $\mathrm{T}-4165$ |

## (viii) Glued joints (G-3L or G-3S)

Glued joints are required for insulation in track circuited portion and their quantity depends on the number of circuits the track is to be divided into. In the yard more glued joints will be required due to number of points \& crossings. Six glued joints will be required for each points \& crossings. Approximately 100 nos. glued joints are required for a station having two loop lines one siding on a double line section. Now-a-dyas all glued joints are laid with G-3L type only.

## (ix) Points \& crossings

Though in estimate the points \& crossings are taken as a complete set. The different components and rates of different components are required to arrive at the rate per set of points \& crossings.
(a) Switch assembly complete - one pair of tongue rails with stock rails, along with stretcher bar
(b) Crossing assembly complete - Crossing with check rails.
(c) Free rails for lead rails, stock rail \& one rail on either side of $\mathrm{P} \& \mathrm{C}$ to have same rail section

| S. <br> No. | Type of <br> P \& C | Items <br> with <br> fitting |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Switch <br> with <br> fitting | Rish <br> Plate | Bolts <br> 140 x <br> 25 mm | Single coil <br> spring <br> washer |  |  |  |
| 1 | 1 in 8-1/2 | 1 set | 1 Set | 70 RM | 16 pairs | 64 Nos. | 64 Nos. |
| 2 | 1 in 12 | 1 set | 1 set | 110 RM | 19 pairs | 76 Nos. | 76 Nos. |
| 3 | Derailing <br> switch | $1 / 2$ <br> set | - | 26 RM | 3 pairs | 12 Nos. | 12 Nos. |

11.0 METHOD OF MEASUREMENTS: The method of measurements of different item of works covering the following aspects have been laid down in IS:1200
(a) Degree of accuracy of measurements
(b) Deductions \& additions not to be made.
(c) Measurement of different members
(d) Extant of lead \& lift considered in the item

### 11.1 Degree of accuracy in measurements:

All linear dimensions will be correct to a $\mathrm{cm}(0.01 \mathrm{~m})$, all area to be calculated correct to Sq.Cm ( 0.01 Sqm ) and volume correct to 0.01 cum except for the following
(a) Thickness of RCC slabs shall be measured correct to 5 mm i.e. 0.005 m
(b) Steel members shall be measured to finished work correct to mm

### 11.2 No deductions/additions to be made for following:-

(i) In case of concreting no deductions shall be made for the following
(a) Ends of dissimilar materials for example beams, posts, girders, rafters, purlins, trusses, corbels and steps up to 500 sqcm in cross sections.
(b) Opening up to 0.1 sq.metre ( 1000 sq.cm.)
(c) Volume occupied by pipes, conduits, sheathing etc.not exceeding $100 \mathrm{sq} . \mathrm{cm}$ each in cross sectional areas in plain concrete and not exceeding 25 sq.cm in RCC and nothing shall be paid for making leaving and finishing such cavities and holes.
(d) Small voids when these do not exceed 40 sq.cm each in cross section.
(e) In calculating area of opening, the thickness of any separate lintel or sill shall be included in the height. Nothing extra shall be payable for forming such openings or voids.
(f) The volume occupied by reinforcements.
(ii) In case of brick work no deductions shall be done and no extra payment for the following:-
(a) Ends of dissimilar materials (that is, joists, beams, lintels, posts, girders, rafters, purlins, trusses, corbels, steps etc.,) up to 0.1 m 2 in section.
(b) Opening up to 0.1 m 2 in area. In calculating area of an opening, any separate lintel or sills shall be included with the size of the opening but end portions of lintel shall be excluded. Extra width of rebated reveals, if any, shall also be excluded. Where minimum area is defined for deduction of an opening, void or both, such areas shall refer only to opening or void within the space measured.
(c) Wall plates, bed plates and bearing of slabs, chhajjas and the like, where thickness does not exceed 10 cm . and bearing does not extend over the full thickness of walls
(d) Cement concrete blocks as for hold fasts and holding down bolts.
(e) Iron fixtures, such as wall ties, pipes ups to 300 mm diameter and hold fasts for doors and windows.
(f) Chases of section not exceeding 50 cm in girth; and
(g) Bearing portion of drip course, bearing of moulding and cornice.
(iii) In case of stone work no deductions shall be done and no extra payment for the following:-
(a) Ends of dissimilar materials (that is joists, beams, lintels, posts, girders, rafters, Purlins, trusses, corbels, steps etc.,) up to 0.1 sqm. in section.
(b) Openings up to 0.1 sqm in area. In calculating the area of opening, any separate lintels or sills shall be included along with the size of the opening but the end portion of the lintels shall be excluded and extra width of rebated reveals, if any, shall also be excluded.
(c) Wall plates and bed plates and bearing of chhajja and the like, where the thickness does not exceed 10 cm and the bearing does not extend over the full thickness of the wall.
(d) The bearing of floor and roof slabs shall be deducted from wall masonry.
(e) Drain holes and recesses left for cement concrete blocks to embed hold-fasts for doors and windows.
(f) Building in the masonry iron fixture and pipes up to 300 mm diameter.
(g) Forming chases in masonry each up to section of 360 sq.cm.
(h) Stone walling in chimney breasts, chimney stacks, smoke or air flues not exceeding 0.20 sqm. in sectional area shall be measured as solid and no extra measurement shall be made for pargetting and coring such flues. Where flues exceed 0.20 sqm. in sectional area, deduction shall be made for the same and pargetting and coring flues paid for separately.
(iv) In case of steel work no deductions shall be done and no extra payment for the following:-
(a) No deduction shall be made for rivet/or bolt holes (excluding holes for anchor or holding down bolts). Deduction in case of rivet or bolt hole shall however be made if its area exceeds 0.02 sqm.

### 11.3 Measurement of members

(a) In concrete, measurement shall be taken before any rendering is done in concrete members. Measurement will not include rendering
(b) RCC Slabs shall be taken as running continuously through except when slab is monolithic with the beam. In that case it will be from the face to face of the beam.
(c) RCC beams shall be measured from face to face of columns and shall include haunches, if any, between columns and beam. The depth of the beam shall be from the bottom of slab to the bottom of beam if beam and slab are not monolithic. In case of monolithic construction where slabs are integrally connected with beam, the depth of beam shall be from the top of the slab to the bottom of beam.
(d) For RCC columns measurement shall be taken through.
(e) RCC Chajas along with its bearing on wall shall be measured in cubic metre nearest to two places of decimal. When chaija is combined with lintel, slab or beam, the projecting portion shall be measured as chajjas; built in bearing shall be measured as per item of lintel, slab or beam in which chajja bears.
(f) Where the band and lintel are of the same height and the band serves as lintel, the portion of the band to be measured as lintel shall be for clear length of opening plus twice the overall depth of band.
(g) In case of arches, the length of the arch shall be calculated as mean of extrados \& intrados.
(h) Where it is stipulated that the form work shall be paid for separately, measurements shall be taken of the area of shuttering in contact with the concrete surface.
(i) Where half brick wall is joined to the main walls of one brick or greater thickness, measurements for half brick wall shall be taken for its clear length from the face of the thicker wall.
(j) For stonework the thickness of wall shall be measured at joints excluding the bushing.
(k) In wood work \& steel work, measurements should be made to finished dimensions. Finished dimensions shall be taken as the sides of the smallest square or rectangle from which such a section can be cut.
(I) In case of steel work in riveted/bolted sections, an addition of 3 per cent of the weight of structure shall be made for shop and site rivet heads in riveted steel structures and for bolts in bolted sections.
(m) In wood work, no payment shall be made for overlapping of members in joints
( $n$ ) Length and width of the shutters shall be measured in closed position covering the rebate of the frames but excluding the gap between the shutters and the frame. Overlap of two shutters shall be measured. All work shall be measured net as fixed \& no deduction shall be made for providing venetian opening and opening for glazing.
(o) The partitions shall be measured within the rebates of the frames
(p) The weight of steel sheets, plates and strips shall be taken from relevant Indian Standards based on $7.85 \mathrm{~kg} / \mathrm{m} 2$ for every millimetre sheet thickness. For rolled sections, steel rods and steel strips, weight given in relevant Indian Standards shall be used.
(q) For roofing covering in slopes, the superficial area in general plane of the roof shall be measured on the flat without allowance for laps and corrugations. Portion of roof covering overlapping the ridge, hip or flashing pieces etc. shall be included in the measurement. Roof with curved sheets shall be measured along the curvature.
(r) For gutters mmeasurements shall be taken for the finished work along the centre line of the top width of the gutter. The hooked lap portion in the junctions and gutter lengths shall not be measured.

### 11.4 Painting

For painting, the measurements are taken flat for one side and multiplied by the coefficient of painting for different types of works as per IS 1200 (Part-15) as under:-

| No | Type of work | How measured | Coefficient for painting |
| :--- | :--- | :--- | :--- |
| 1 | Panelled or framed and <br> braced or ledged and <br> battened or ledged, <br> battened and braced <br> joinery | Measured flat (not girthed) <br> including CHOWKAT or <br> frame. Edges, chocks, <br> cleats, etc, shall be <br> deemed to be included in <br> the item | 1.30 (for each side) |
| 2 | Flush joinery | Measured flat (not girthed) <br> including CHOWKAT or <br> frame. Edges, chocks, <br> cleats, etc, shall be deemed <br> to be included in the item | 1.20 (for each side) |
| 3 | Flush shutter | Measured flat overall | 1.20 (for each side) |
| 4 | Fully glazed or gauzed <br> joinery | Measured flat (not girthed) <br> including CHOWKAT or <br> frame. Edges, chocks, <br> cleats, etc. shall be deemed <br> to be, included In the item | 0.80 (for each side) |
| 5 | Partly panelled and <br> partly glazed or gauzed <br> joinery | Measured flat (not girthed) <br> including CHOWKAT or <br> frame. Edges, chocks, | 1 (for each side) |

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|  |  | cleats, etc, shall be deemed to be included in the item |  |
| :---: | :---: | :---: | :---: |
| 6 | Fully venetian or louvered joinery | Measured flat (not girthed) including CHOWKAT or frame. Edges, chocks, cleats, etc, shall be deemed to be included in the item | 1.80 (for each side) |
| 7 | Weather boarding | Measured flat (not girthed) supporting frame-work shall not be, measured separately | 1.20 (for each side) |
| 8 | Wood shingle roofing | Measured flat (not girthed) | 1.10 (for each side) |
| 9 | Boarding with cover fillets and match boarding | Measured flat (not girthed) | 1.05 (for each side) |
| 10 | Tile and slate battening | Measured flat overall; no deduction shall be made for open spaces | 0.80 (for painting all over) |
| 11 | Trellis (or JAFFRI) work | Measured flat overall; no one-way or two way deduction shall be made for open spaces; supporting members shall not be measured separately | 2 (for painting all over) |
| 12 | Guard bars, balustrades gates, gratings, grills, expanded metal and railings | Measured flat overall; no deduction shall be made for open spaces: supporting members shall not be measured separately | 1 (for painting all over) |
| 13 | Gates and open palisade fencing including standards, braces, rails, stays, etc | Measured flat overall; no deduction shall be made for open supporting members spaces; Supporting members shall not be measured separately ( see Note 1 ) | 1 ( for painting all over) |
| 14 | carved or enriched work | Measured flat | 2 ( for each side ) |
| 15 | Steel roller shutters | Measured flat ( size of opening ) overall; jamb guides, bottom rails and locking arrangement, etc, shall be included in the item | 1.10 ( for each side ) |


|  |  | (top cover shall be <br> measured separately ) |  |
| :--- | :--- | :--- | :--- |
| 16 | Plain sheet steel doors <br> and windows | Measured flat ( not girthed) <br> including frame, edges, etc | 1.10 ( for each side ) |
| 17 | Fully glazed or gauzed <br> steel doors and windows | Measured flat ( not girthed ) <br> including frame edges, etc | 0.50 ( for each side ) |
| 18 | Partly panelled and <br> partly glazed or gauzed | Measured flat ( not girthed ) <br> including frame edges, etc <br> steel doors | 0.80 ( for each side ) |
| 19 | Collapsible gate | Measured flat (size of <br> opening ) | 1.50 ( for painting <br> all over ) |

## NOTES

1. The height shall be taken from bottom of lowest rail, if palisades, do not go below it or from lower end of palisades, if they project below lowest rail, up to top of palisades, but not up to top of standards if they are higher than palisades.
2. Where doors, windows, etc, are of composite types other tha $n$ those included in this table, different portions shall be measured separately with their appropriate coefficients, centre line of common rail being taken as the dividing line between the two portions.
3. Measurement of painting of doors, window, collapsible gates, rolling shutters, etc, as given in this table shall be deemed to include painting, if required, of all iron fittings in the same shade.
4. When two faces of a door, window, etc, are to be treated. with different specified finishes, measurable under separate items, edges of frames and shutters shall be treated with the one or the other type of finish and measurement thereof shall be deemed to be included in the measurement of the face treated with that finish.
5. In case where shutters are fixed on both faces of a frame, measurement for the door frame and shutter on one face shall be taken in the manner already described. while the additional shutter on the other face shall be measured exclusive of the frame.
6. Where shutter is provided with clearance exceeding 15 cm at top and/or at bottom, such openings shall be deducted from the overall measurement and relevant coefficients applied.

ANNEXURE - A

## 1. Bhilai Steel Plant

## Plates

Rationalised sizes of Plates from Plate Mill

| Length(mm) <br> Thickness <br> $(\mathrm{mm})$ | Width (mm) |  |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | 1600 | 1800 | 2000 | 2200 | 2500 | 2800 | 3000 | 3200 |
| 8 |  |  |  |  | 6300 |  |  |  |
|  |  |  |  |  | 9300 |  |  |  |
|  |  |  |  |  | 12500 |  |  |  |
| 10 |  |  |  | 9300 | 6300 |  |  |  |
|  |  |  |  |  | 9300 |  |  |  |
|  |  |  |  |  | 12500 |  |  |  |
|  |  |  | 6300 | 6300 | 6300 | 7100 |  |  |
|  |  |  | 9300 | 9300 | 8000 | 10000 |  |  |
|  |  |  |  |  | 9500 | 12500 | 12500 |  |


| Length(mm) Thickness | Width (mm) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1600 | 1800 | 2000 | 2200 | 2500 | 2800 | 3000 | 3200 |
|  |  | 7100 | 8000 | 10000 | 9300 | 9300 |  |  |
|  |  | 9000 | 9000 |  | 10000 |  |  |  |
|  |  | 9300 | 12500 |  |  |  |  |  |
|  |  | 12500 |  |  |  |  |  |  |
| 22 | 5000 | 5000 | 5600 | 5000 | 5600 | 5000 |  |  |
|  | 5600 | 5600 | 7100 | 6300 | 6300 | 5600 |  |  |
|  | 6300 | 6300 | 8000 | 7100 | 8000 | 7100 |  |  |
|  | 7100 | 8000 | 10000 | 9300 | 9000 | 8000 |  |  |
|  | 9000 | 9000 |  | 10000 | 9300 | 9300 |  |  |
|  | 9300 | 12500 |  |  |  |  |  |  |
|  | 12500 |  |  |  |  |  |  |  |
| 25 | 5000 | 5000 | 5000 | 5600 | 5000 | 6300 | 6300 | 5600 |
|  | 5600 | 5600 | 6300 | 6300 | 5600 | 7100 | 12500 | 6300 |
|  | 6300 | 7100 | 9000 | 8000 | 7100 | 12500 |  | 12500 |
|  | 8000 | 10000 | 9300 | 9000 | 8000 |  |  |  |
|  | 12500 |  | 1000 | 9300 |  |  |  |  |
|  | 1600 | 1800 | 2000 | 2200 | 2500 | 2800 | 3000 | 3200 |
| 28 | 5000 | 5000 | 56000 | 5000 | 6300 | 5600 | 5600 | 5000 |
|  | 5600 | 6300 | 8000 | 5600 | 7100 | 6300 | 6300 | 5600 |
|  | 7100 | 9000 | 9000 | 7100 | 12500 | 12500 | 10000 | 9300 |
|  | 10000 | 9300 | 9300 | 8000 |  |  | 12500 | 10000 |
|  |  | 10000 |  |  |  |  |  |  |
| 32 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 |
|  | 6300 | 5600 | 7100 | 6300 | 6300 | 5600 | 9000 | 8000 |
|  | 9000 | 8000 | 8000 | 7100 | 12500 | 9300 | 9300 | 9000 |
|  | 9300 | 9000 |  | 12500 |  | 10000 | 10000 | 9300 |
|  | 10000 |  |  |  |  |  |  | 10000 |
| 36 | 5000 | 5000 | 6300 | 5600 | 5000 | 5000 | 8000 | 7100 |
|  | 5600 | 7100 | 7100 | 6300 | 5600 | 8000 | 9000 | 8000 |
|  | 8000 | 8000 | 12500 | 12500 | 9300 | 9000 | 9300 | 9000 |
|  | 9000 |  |  |  | 10000 | 9300 |  |  |
| 40 | 5000 | 6300 | 5600 | 5000 | 5000 | 7100 | 7100 | 6300 |
|  | 7100 | 7100 | 6300 | 5600 | 9000 | 8000 | 8000 | 7100 |
|  | 8000 | 12500 | 12500 | 10000 | 9300 | 9000 |  | 8000 |
|  |  |  |  |  | 1000 | 9300 |  |  |
|  |  |  |  |  |  | 10000 |  |  |

CALCULATION OF QUANTITIES

| $\begin{array}{\|l\|} \hline \text { Length }(\mathrm{mm}) \\ \text { Thickness } \end{array}$ | Width (mm) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1600 | 1800 | 2000 | 2200 | 2500 | 2800 | 3000 | 3200 |
| 45 | 6300 | 5600 | 5000 | 5000 | 8000 | 7100 | 6300 | 6300 |
|  | 7100 | 6300 | 5600 | 9300 | 9000 | 8000 | 7100 | 7100 |
|  | 12500 | 12500 | 10000 | 10000 | 9300 |  |  |  |
| 50 | 5600 | 5000 | 5000 | 8000 | 7100 | 6300 | 5600 | 5600 |
|  | 6300 | 5600 | 9000 | 9000 | 8000 | 7100 | 6300 | 6300 |
|  | 12500 | 9300 | 9300 | 9300 |  |  | 7100 |  |
|  |  | 10000 | 10000 |  |  |  |  |  |
| 56 | 5000 | 5000 | 8000 | 7100 | 6300 | 5600 | 5000 | 5000 |
|  | 5600 | 9300 | 9000 | 8000 | 7100 | 6300 | 5600 | 5600 |
|  | 9300 | 10000 | 9300 |  |  |  |  |  |
|  | 10000 |  |  |  |  |  |  |  |
| 63 | 4500 | 8000 | 7100 | 6300 | 5600 | 5000 | 4500 | 4500 |
|  | 5000 | 9300 | 8000 | 7100 | 6300 | 5600 | 5000 | 5000 |
|  | 9000 |  |  |  |  |  |  |  |
|  | 9300 |  |  |  |  |  |  |  |
|  | 10000 |  |  |  |  |  |  |  |
| 75 | 7100 | 6300 | 5600 | 5000 | 4500 | 4500 | 4500 |  |
|  | 8000 | 7100 | 6300 | 5600 | 5000 | 5000 |  |  |
| 80 | 6300 | 5600 | 5000 | 4500 | 4500 |  |  |  |
|  | 7100 | 6300 | 5600 | 5000 | 5000 |  |  |  |
|  | 8000 | 7100 | 6300 | 5600 |  |  |  |  |
| 90 | 6300 | 5600 | 5000 | 5000 |  |  |  |  |
|  |  | 6300 | 5600 |  |  |  |  |  |
| 100 | 5000 | 5000 | 5000 |  |  |  |  |  |
|  | 5600 | 5600 |  |  |  |  |  |  |
|  | 6300 |  |  |  |  |  |  |  |
| 110 | 5000 | 5000 |  |  |  |  |  |  |
|  | 5600 |  |  |  |  |  |  |  |
| 120 | 4500 |  |  |  |  |  |  |  |
|  | 5000 |  |  |  |  |  |  |  |

\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline \& \& \multicolumn{6}{|l|}{Drawing (DQ)} \& \multicolumn{5}{|l|}{Indent (IQ)} \& Westage \\
\hline S
N
1 \& Component
2 \& Section
3 \& Unit Weight 4 \& Length \& \begin{tabular}{l}
Nos. \\
6
\end{tabular} \& Weight in Kg 7 \& \[
\begin{gathered}
\hline \text { For } 6 \text { spans } \\
\text { of } 18.3 \\
8
\end{gathered}
\] \& Section

9 \& Unit Weight 10 \& Length

11 \& Nos.
12 \& Weight in Kg 13 \& <br>
\hline 1 \& Web Plate \& $1790 \times 14$ \& 196.72 \& 11210 \& 2 \& 4411.00 \& 26466.00 \& $2000 \times 14$ \& 219.80 \& 12500 \& 12 \& 32970.00 \& <br>
\hline \& \& $1790 \times 14$ \& 196.72 \& 8460 \& 2 \& 3329.00 \& 19974.00 \& \& \& \& \& \& <br>
\hline \& Web Cover Plate \& $360 \times 14$ \& 39.56 \& 1090 \& 4 \& 173.00 \& 1038.00 \& $2000 \times 14$ \& 219.80 \& 9000 \& 12 \& 23738.40 \& <br>
\hline \& Web Splice Plate \& $325 \times 14$ \& 35.71 \& 660 \& 8 \& 189.00 \& 1134.00 \& \& \& \& \& \& <br>
\hline 2 \& Top Flange Plate \& $580 \times 32$ \& 145.7 \& 11210 \& 2 \& 3267.00 \& 19602.00 \& $2500 \times 32$ \& 628.00 \& 12500 \& 6 \& 47100.00 \& <br>
\hline \& \& $580 \times 32$ \& 145.7 \& 8460 \& 2 \& 2466.00 \& 14796.00 \& \& \& \& \& \& <br>
\hline \& Bottom Flange \& $580 \times 32$ \& 145.7 \& 11210 \& 2 \& 2958.00 \& 17748.00 \& $2500 \times 32$ \& 628.00 \& 9000 \& 6 \& 33912.00 \& <br>
\hline \& Plate (Flare cut) \& $580 \times 32$ \& 145.7 \& 8460 \& 2 \& 2858.00 \& 17148.00 \& \& \& \& \& \& <br>
\hline 3 \& End Stiffner Plate \& $220 \times 20$ \& 34.5 \& 1790 \& 8 \& 495.00 \& 2970.00 \& $1800 \times 20{ }^{*}$ \& 282.60 \& 5000 \& 3 \& 3118.50 \& <br>

\hline 4 \& Inner Flange Cover Plate \& $260 \times 22$ \& 44.9 \& 1720 \& 8 \& 618.00 \& 3708.00 \& $1800 \times 22$ \& 310.86 \& 9000 \& 3 \& 8393.22 \& $$
\begin{gathered}
\text { 14.6 } \\
\%
\end{gathered}
$$ <br>

\hline \& Outer Flange Cover Plate \& $580 \times 22$ \& 100.2 \& 1720 \& 4 \& 690.00 \& 4140.00 \& \& \& \& \& \& <br>
\hline 5 \& Stiffning Plate \& $300 \times 25$ \& 58.9 \& 480 \& 4 \& 113.00 \& 678.00 \& $1600 \times 25 *$ \& 314.00 \& 5000 \& 1 \& 900.90 \& <br>
\hline \& Location Strip \& $65 \times 25$ \& 12.76 \& 365 \& 4 \& 19.00 \& 114.00 \& \& \& \& \& \& <br>
\hline \& Location Strip \& $65 \times 25$ \& 12.76 \& 205 \& 4 \& 11.00 \& 66.00 \& \& \& \& \& \& <br>
\hline 6 \& Bearing Plate \& $210 \times 50$ \& 82.5 \& 420 \& 4 \& 139.00 \& 834.00 \& $1600 \times 50$ * \& 628.00 \& 5300 \& 3 \& 3773.70 \& <br>
\hline \& Bed Plate \& $390 \times 50$ \& 153.1 \& 750 \& 4 \& 460.00 \& 2760.00 \& \& \& \& \& \& <br>
\hline 7 \& End x -frame top Gusset Plate \& $406 \times 10$ \& 31.8 \& 431 \& 4 \& 55.00 \& 330.00 \& \& \& \& \& \& <br>
\hline \& End x-frame bottom gusset plate \& $413 \times 10$ \& 32.6 \& 424 \& 4 \& 55.00 \& 330.00 \& \& \& \& \& \& <br>
\hline
\end{tabular}

|  |  | Drawing (DQ) |  |  |  |  |  | Indent (IQ) |  |  |  |  | Westage |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| S $N$ 1 | Component $2$ | Section $3$ | Unit Weight 4 | Length $5$ | Nos. $6$ | Weight <br> in Kg <br> 7 | For 6 span\$ of 18.3 8 | Section $9$ | Unit Weight 10 | Length $11$ | Nos. $12$ | $\begin{gathered} \text { Weight } \\ \text { in } \mathrm{Kg} \\ 13 \\ \hline \end{gathered}$ |  |
|  | Int. x-frame top Gusset Plate | $296 \times 10$ | 23.2 | 315 | 8 | 59.00 | 354.00 |  |  |  |  |  |  |
|  | Int. x-frame bottom gusset plate | $303 \times 10$ | 23.8 | 308 | 8 | 59.00 | 354.00 |  |  |  |  |  |  |
| 8 | Int. / End x-frame Centre gusset In. Stiffner Angle | $\begin{aligned} & 200 \times 10 \\ & 100 \times 100 \times 10 \end{aligned}$ | $\begin{aligned} & 15.7 \\ & 14.9 \end{aligned}$ | $\begin{array}{r} 206 \\ 1790 \end{array}$ | $6$ $56$ | $\begin{array}{r} 20.00 \\ 1494.00 \end{array}$ | $\begin{array}{r} 120.00 \\ 8964.00 \end{array}$ | $2500 \times 10$ | 196.25 | 6300 | 2 | 2472.75 |  |
|  | (inner \& outer) Joint Stifffner | $100 \times 100 \times 10$ | 14.9 | 1754 | 4 | 105.00 | 630.00 |  |  |  |  |  |  |
|  | angle Top | $100 \times 100 \times 10$ | 14.9 | 2251 | 11 | 369.00 | 2214.00 |  | 14.90 | 11000 | 74 | 12128.60 |  |
| 9 | Lateral Bracing angle x-frame horizontal | $90 \times 90 \times 10$ | 13.4 | 1800 | 12 | 290.00 | 1740.00 |  |  |  |  |  |  |
|  | angle <br> End x-frame | $90 \times 90 \times 10$ | 13.4 | 1788 | 4 | 96.00 | 576.00 |  |  |  |  |  |  |
|  | diagonal angle Int. x-frame | $90 \times 90 \times 10$ | 13.4 | 2108 | 8 | 226.00 | 1356.00 |  | 13.40 | 11500 | 24 | 3698.40 |  |
|  | Diagonal angle |  |  |  |  | 25024.00 | 150144.00 |  |  |  |  | 172206.47 |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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## CHAPTER XI

## TYPES OF ESTIMATES

1.0 GENERAL: The dictionary meaning of the word Estimate is 'to guess', 'to opine' or 'to judge' tentatively the approximate cost of work. The accuracy of the estimates has to differ depending on the purpose for which it is to be used. Engineers are asked to provide quantities, duration, and cost estimates as a primary part of their jobs. The estimation process is partly an art and partly a science. However, once one learns good estimating processes and techniques, one will be able to move more toward the "science" side of estimating and rely less on the "art" side. In Indian Railways, a Civil Engineer has to do this exercise as a regular measure for several purposes,
i) For construction or purchase of new works or assets
ii) For the renewal or replacement of existing assets or works.
iii) For scrapping, dismantling or abandonment of existing works or assets.
iv) For repairing or reconditioning of assets or works costing Rs. 1Lakh or more.
v) For temporary or experimental works
vi) For comparing two or more options for expenditure.
vii) For preparing face value/cost of for tendering/ contracting part work to an agency.
viii) For justifying expenditure over the sanctioned cost of work.
ix) For introducing new items in existing contracts.
x) For finding out actual cost incurred on any work.
xi) For asking a party to deposit money with the railway for rendering any service, way leave facilities or carrying work for an outside party.
xii) For acquiring or relinquishing a piece of land, etc.
xiii) Others not listed above.
2.0 LEVEL OF ACCURACY: The main purpose to which the estimate is going to be finally used is to be clearly understood by the framer of the estimate and in-build accordingly the level of accuracy in the estimate. When one is asked to estimate a piece of work, the urge to jump right into it should be resisted. If you spend just a little time planning, you will find that the entire estimating process will be quicker and will result in a more accurate estimate. If you're getting ready to prepare an estimate for a work, you should know enough so that you can estimate the work to within plus or minus of a reasonable limit required for the work. If you can't estimate the work to this level of confidence, you should spend more time investigating and understanding the work. If the work is just too large to be able to estimate at that level of confidence, one should consider breaking the project/ work into smaller pieces so that one can estimate each smaller project to within $10 \%$.
3.0 BOTTOM UP APPROACH: The most accurate way to estimate is usually to build a work breakdown structure (WBD Structure) and to estimate all of the lowest level, individual work components.

For the work breakdown technique, the work has to be broken down in smallest detail into different activities and one needs to estimate each activity. Activities that have been done before can be estimated reasonably well. New activities are more difficult to estimate, but the work breakdown structure, which defines activities at a smaller level, should help produce estimates that are reasonably close. The work break down structure will form a pyramid like structure, with complete item at highest level and sub-activities at lower level. There may be 4-5 levels to fully break up the activity. The figure below shows a 5 level break down structure, the elements in each level represent the work to be done in the level below. The WBD structure in the figure represents only 2 or 3, sub-tasks representing the higher task, which could be several nos. The lowest level (level V) items finally go to form the main item at level I. Sometimes there may be only 2 levels and sometimes many more. The numbering of the elements can be adopted as per ones convenience but the numbering as suggested below is helpful especially if one is using computer for preparing an estimate. The nos. may or may not be with separation by dots. The no. of digits in any element will indicate the level of the activity hierarchy.


Example: As an illustration of the 'Work Break down Structure' of a work in the Pyramid shape for 'Detailed Estimate of Complete track Renewal' is given below,
(LEVEL-I).1.0- Complete track renewal
(LEVEL-II) 1.1- sleeper, 1.2-rail, 1.3- Ballast, 1.4-P\&C
For 1.1-Sleepers
(LEVEL-III) 1.1.1 Dismantling, 1.1.2- Sleeper and fittings
(LEVEL-IV) 1.1.1.1- Labor 1.1.1.2 - Carting and stacking 1.1.1.3- Disposal by auction
1.1.2.1- Material 1.1.2.2- Carting and spreading, 1.1.2.3-insertion of sleeper

## For 1.2-Rails

(LEVEL-III) 1.2.1- Dismantling, 1.2.2- Rails and fittings, 1.2.3- Welding, 1.2.4 OHE bonds 1.2.5 S\&T Track circuit works
(LEVEL-IV) 1.2.1.1- labor, 1.2.1.2- Carting and stacking 1.2.1.3- Disposal by auction
1.2.2.1- Materials, 1.2.2.2- Carting and spreading, 1.2.2.3- Rail insertion
1.2.3.1-Leveling and lining, 1.2.3.2- Welding and grinding
1.2.4.1- Material 1.2.4.2 Labor
1.2.5.1- Materials 1.2.5.2 Labor

## For 1.3 - Ballast

(LEVEL-III)
1.3.1- Deep screening, 1.3.2-Supply\&collection 1.3.3- Spreading, 1.3.4- Packing and Dressing, 1.3.5 making up cess Final work break down required only up to Level III.

For 1.4- P\&C
(LEVEL-III) 1.4.1 Dismantling, 1.4.2 Deep screening 1.4.3 Sleepers 1.4.4 P\&C and fittings, 1.4.5 S\&T work
(LEVEL-IV) 1.4.1.1 Labor, 1.4.1.2 Carting and stacking, 1.4.1.3 disposal by auction
1.4.2.1 Labor, 1.4.2.2 Clearing site, 1.4.2.3 supply, spreading and packing ballast
1.4.3.1 Material, 1.4.3.2 Carting and spreading 1.4.3.3 Insertion of sleeper
1.4.4.1 Materials, 1.4.4.2 Carting and spreading, 1.4.4.3 Labor, 1.4.4.4 Rental charges of T-28 Machine

### 1.4.5.1 Materials 1.4.5.2 Labor

Here, the work has been broken down up to Level-IV for understanding the process. It would have sufficed to break down only up to Level-III, as the Level-IV breaking down has resulted in splitting to the level of specific items of work, which may not be required for an experienced Estimator. The W.B.D. structure as adopted on Railwars is given in Annexure A

This bottom-up approach is time consuming but pretty accurate. It is not appropriate for the initial estimating that one does early on in the funding and prioritization process, like an Abstract estimate. However this is to be used for preparing detailed estimates and the accuracy expected and achievable in this approach is within 10\%.
4.0 TOP DOWN APPROACH: As against this there is 'Top down approach' where one looks for past experience and works executed of similar nature. This approach is generally used for preparing initial (Abstract)estimates of the work and the accuracy of such estimates is required within $15-20 \%$ of the actual. Following different methods can be used in this approach,
a) Previous history: Most organizations have details of previous similar projects/ works, and this information may help to estimate new work. One can describe the project in the same terms of similar work done in the past. However it is to be remembered that no two works/projects are identical and will differ in site conditions, local issues etc which may not only affect the rates but also the quantities. This type of estimate is less accurate than the one based on 'Work Break Down' structure in the bottom up approach. This can be used for rough estimation only.
b) Partial work breakdown structure: In this approach, one breaks down a few major component of work into smaller activities and makes a good historical estimate of other activities. This is better than a) above and still less accurate than 'Bottom Up' approach.
c) Ratio: Ratio Method is where you have some basis for comparing work that has similar characteristics-but on a larger or smaller scale. For instance, you may find that the quantity and cost required for completing a bridge of $4 \times 30.5 \mathrm{~m}$ PSC girder with pile foundations may be about double for a bridge of $2 \times 30.5 \mathrm{~m}$ on pile foundations. Thus one may work out the cost of bridge per meter length of bridge and use it as a unit to assess the cost of any other bridge of similar configuration. This may be quite approximate as the depth of foundation, nature of strata encountered could affect the cost appreciably. However, in many cases of initial estimates, much accuracy is not required and this estimate may serve the purpose.
5.0 ESTIMATES ON INDIAN RAILWAYS: On the Indian Railways, there is a distinct level of details required for different types of works namely Revenue works, works and projects.
Works costing above Rs.1.0 lakhs, required for maintenance of the existing assets are to be covered by Revenue works estimate. Here, the only justification is the condition of the asset or the periodic maintenance as per the laid down instructions.
Works such as New Line construction, Doubling, Gauge conversion etc. which are chargeable to Capital, come under the scope of Projects and Project Estimates are prepared. All these projects are to be investigated much more in detail, by carrying out field survey along with traffic survey to assess the financial remunerativeness of the investment decision. All projects have to be preceded with a survey report. However, in terms of Financial code Para 207, all works proposals which are intended to increase line capacity, traffic survey is essential requirement. Similarly, for works relating to yard remodeling and terminal facilities, workshops expansion, Rolling stock repair units, production units, microwave and telecommunication works, and major signaling schemes have to pass the test of financial remunerativeness of investment decision, even when these works may not be charged to Capital.
All other works charged to DRF, DF, Safety Fund etc. are covered under Works Estimates. Such works also require detailed justification but for other than the works listed in Para above financial remunerativeness is not required to be worked out.
The level of details required can be used to categorize the nature of estimates; however, the estimates are classified in the Indian Railways according to the purpose for which it has been prepared.
6.0 TYPES OF ESTIMATES: Following broad types/terminology of estimates are used in Indian Railways,
a) Abstract Estimate
b) Detailed Estimate
c) Project Estimate

- Rough Project Estimate
- Project estimate based on Preliminary Survey
- Construction estimate
d) Supplementary Estimate
e) Revised Estimate
f) Completion Estimate

7. ABSTRACT ESTIMATE: As the name suggests, an abstract estimate is a summary estimate prepared for assessing the reasonably accurate, likely cost of the work and the technical justification for the same. This is required for the competent authority to decide the necessity of taking up the work (Chargeable to DRF, DF, OLWR, Special safety fund and Safety Fund etc) in preference to many other such proposals. Abstract estimates avoid the expense and delay of preparing plans \& estimates for works in detail at a stage when the necessity or the general desirability of the works proposed has not been decided upon by competent authority
Abstract estimate while does not require detailed drawings, long and cross sections, plans structural or locational but forms the basis of all further process and can be termed as the "Mother Estimate"i.e. all variations if any while making a detailed estimate, while carrying out work etc. are compared over the Abstract estimate of work. It is therefore necessary that the abstract estimate is not considered as a rough estimate and given due consideration of all the technical requirements without omitting any part of the work which may be required for successful commissioning of the facility and special site conditions. It is to be remembered that any excess in quantities of work above $20 \%$ is considered abnormal and requires to be referred to Railway Board for sanction even for the works originally sanctioned by GM. However there is more flexibility in regard to cost revision due to escalation in rates which is up to $100 \%$.
7.1 Following must be ensured prior to preparing an abstract estimate,
i) Availability of encumbrance free land. If certain structures, facilities are required to be relocated, availability of land and the cost of such relocation. Approximate cost/work involved for reclaiming the land including relocation.
ii) Site verification with minor details like a) Spot levels b) Special sub-soil conditions as verified by local knowledge c) Flood proneness of site, and location of water table in the area which may effect excavation of foundations etc.
iii) Fixing of specifications of work.
iv) A concept outline plan of the facility proposed, with salient dimensions marked thereon. It is not necessary to prepare a dimensioned plan but dimensions should be demarcated on even an un-dimensioned plan. This plan should have acceptance of the requiring department and other concerned offices. Any changes in the concept scheme resulting increasing the cost may be termed as 'Change in scope
of work', which require even more stringent process for sanction and should be avoided at all costs.
v) Requirements of relocation of services like electric cables, S\&T cables, water pipelines etc., whatever can be ascertained by referring to available details and plans.
vi) Details on following factors should be collected, which are likely to impact the rates to be adopted for estimate,

- General information about soil strata gathered from any previous work done in the vicinity.
- Any special features of Govt. taxes, royalty, local levies etc which may affect the rates of work.
- Cost of stores like P.Way items as announced by Railway Board every year.
- Accessibility of site by road and railway.
- Limitations on working hours, due to proximity of colony, running track, secured area like goods shed, workshop, passenger platforms etc.
- Flood proneness of site, location of water table in the area which may effect excavation of foundations etc.
Items i) to v) have bearing on the quantities while item vi) has relationship with rates.


### 7.2 An abstract estimate should contain

(i) Brief report and justification for the work including inadequacy statement if for construction of new quarters showing \%age of staff provided with quarters
(ii) A rough sketch (not to scale) in A4 size showing the site \& scope of work.
(iii) The plan head to which it is to be charged in case of works proposed for Works Machinery and Rolling-stock Programmes (explained in para 3.0 of Appendix - III)
(iv) The allocation of each item as between Capital, Development Fund, Open Line Works-Revenue, Depreciation Reserve Fund and Revenue should be indicated. (Explained in Para 5.0 of Appendix - III )
(v) Funds required for the year for which it is programmed.
8.0 DETAILED ESTIMATE: On receiving administrative approval for the proposal for work through the Abstract estimate, a detailed estimate is framed to obtain technical sanction of the work. The administrative approval of work, through Abstract Estimate or appearance of work in Budget (Pink/Green/Orange book) is not an authority to start the work or incur any expenditure and such authority is available only after sanction of detailed estimate also called as Technical Sanction. Prior to starting preparing a detailed estimate following must be arranged,
i) The detailed drawings of all the structures and works
ii) Spot levels of the site
iii) Unit rate of vital stores item to be used in the work
iv) Organization's L.A.R.'s (Last accepted rates) for various items of work
v) Inflation \% of last 3-4 years.
vi) Cost of major machineries required to be procured for work.
vii) Unit cost of staff salaries and benefits payable for the works establishment
viii) Technical specifications of work/ part work, if not are done according to 'Works Hand Book'.
viii) Prepare work break down structure of the activities required for the work.
8.2 The detailed estimate of a work will comprise of
(i) Statement showing details of estimated cost with items of works, quantity, rate and amount in form E-704 based on approved plans for the work.
(ii) Variation statement showing the difference of cost of items /works in the detailed estimate with that of abstract estimate and the excess cost differentiated in to the heads as due to escalation and other than escalation and savings separately
(iii) An outer sheet giving the abstract of cost of work, the report, the financial 'justification and the allocation in form E-706.
9.0 PROJECT ESTIMATE: A project is a work for creation of new assets like, New Line, Doubling, and Gauge conversion etc. and charged to Capital. Decision regarding investments even for conducting Preliminary techno-economic survey for Major projects like new lines etc, most of the times, is preceded by a reconnaissance surveys. In reconnaissance survey, locations of major bridges, station locations, any tunnels etc are identified and a route length based on paper alignment is calculated. No leveling etc is carried out to estimate the quantities of earth work, minor bridges etc. More than 1 alternative alignment is drawn and rough costs worked out to find the cheaper alignment. This estimate is termed as Rough Project Estimate. Similarly Rough estimates are made for certain other purposes also, mainly to make a decision, if the expenditure for carrying out detailed investigation would be worth while or not. They are simply called rough estimates.
The Techno-Economic Survey Report based on preliminary survey has to contain an Abstract estimate of the project based on the details collected on preliminary survey and is referred to as 'Project Estimate'. The decision to carry out a project or not is taken by competent authority (Railway Board) based on the Techno-Economic Survey and Project Estimate. On approval of the work by Railway Board through Annual Budget. The estimate if based on Final location survey is normally referred to as 'Construction Estimate' or Project Estimate based on final location survey. The survey collects the details of ground level, gradients, curves, waterways, level crossings etc but detail design of structures, bridges etc. is not prepared at this stage, in the Preliminary Survey as this estimate is prepared for justifying the proposal. However, the estimate is to be prepared after the work break down of the project under at least 3-levels as discussed under 'Bottom up approach' Para 1.2 above. The different levels are given specific allocation no. in terms of accounting procedure on Railways. The WBD up to level-III and the allocation of expenditure assigned to it is given in Annexure-A. This is dealt in Appendix-III in detail. It is sufficient tio mention that the Project Estimate has to be prepared on a WBD structure, minimum to 3 levels. The third level tasks can be further broken down in lower levels Level-IV and LevelV , depending on convenience and for simplification of including all the items, without neglecting any part of the work required for framing a complete estimate
(a) Project Estimate based on Preliminary survey: The Techno-economic feasibility report based on Preliminary survey is to be submitted for the approval of the Railway Board along with the abstract cost of project on Form E. 554 (Engineering Code), Under Sub-heads i.e. Level-II WBD along with Abstract cost of the junction arrangements ( the yard from line takes off and terminate) and detailed cost estimate under different detailed head (Level-III,WBD structure) for following,
i) Land
ii) Tunnels
iii) Major Bridges
iv) Minor bridges
v) Detailed estimate of 1 Km of Permanent Way
vi) Rolling Stock
vii)General and Direction Charges

- Though the submission to board is under sub-heads except for the items listed above, but the practice is to prepare the estimate at detailed head level but submit as required by Board.
(b) Construction Estimate: When it is decided to undertake the execution of a new line, gauge conversion or doubling of lines etc, a final location survey is carried out and based on the information collected in that survey estimates of all the works included in the project as a whole are prepared. The estimate so prepared is called the "Construction Estimate" of the project. It should be prepared after a careful examination of the various details of construction involved in the project. And should be based on detailed drawings including given hereunder,
i) Detailed plans and sections
ii) Longitudinal sections and plan at center line of alignment
iii) Station yards
iv) Detailed drawings of structures and bridges
v) Plans of junction arrangements
- It should provide for the buildings and equipment of the railway up to a standard that will be sufficient for working such traffic as may be expected during the first year or two after opening of the line. It is the basis on which technical sanction of the detailed estimate after designing various elements/ works included in the construction of a project is accorded. Detailed estimates on Form E. 553 under various heads are to be prepared and submitted to Railway Board. It should be divided into convenient sections in accordance with the following principles.
(i) When, as is usually the case, certain works within the limits of a junction station are incidental to the project, these works should form a distinct section.
(ii) When a project comprises a "main line" and a "branch", the "branch" should form at least one distinct section;
(iii) Where the country traversed by a line is such that it may readily be divided into tracts of distinctive topographical character, the length through each class of country may comprise a section or a project may be divided into "engine runs" or into lengths suitable for "construction divisions".
(iv) Where there is likelihood of different sections of a project being opened to traffic at different intervals, the estimate for each such section should be kept distinct;
(v) When an estimate for any alternative alignment of importance is included, the estimate for the alternative alignment and for the length which it would supersede, if adopted, should each be comprised in a distinct section.

In both the cases of estimates based on Preliminary Survey and Final location survey, the term Abstract estimate only means a summary sheet as per the pro-forma given in Para 554E, but it has to be detailed estimate in all senses. Each rate adopted has to be fully analyzed and explained, all quantities are based on data collected and all parts of the project have to be covered. Detailed Drawings of Structures, etc.-Though many of them are not required for submission to the Railway Board with a construction estimate, drawings of all schemes should be prepared in order that sufficiently accurate estimates can be compiled. These drawings should be carefully recorded for future use.
The drawings which are usually required by the Railway Board are as follows:

- Type drawings of banks, cuttings and tunnels in cases only where the proposals differ from the prescribed maximum and minimum dimensions.
- Skeleton outlined drawings to small scale of all large bridges.
c) In special cases, mainly where the remunerativeness of project is not established based on Preliminary Survey or some other considerations, Railway Board has ordered for Final Location survey without approving the work for construction and the decision as to project is to be executed is taken on submission of the final location survey. In these circumstances, the Costruction Estimate so prepared is not considered as the Technical sanction, rather a detailed Project Estimate is to be prepared for obtaining the sanction of the same.
d) Where works are required to be commenced before the earliest date by which detailed estimates for the project as a whole could be prepared and sanctioned, part estimates for sub- works may be prepared. To enable the commencement of work on such works forming a part of the project, part estimates for the following sub-works may be sanctioned progressively by the authority competent to sanction the detailed estimate for the whole project.
10.0 REVISED ESTIMATE: In terms of Para E-708 of Engineering code, as soon as it becomes apparent that the expenditure on a work or Project (Work as a whole) is likely to exceed the amount provided there for in the detailed estimate or construction estimate, a revised estimate should be prepared and submitted for the sanction of the competent authority. It should, be prepared in the same form and the same degree of detail as the original estimate, and should be accompanied by a comparative statement showing the excess or saving under each sub-head of account against the latest sanction. In cases
where a supplementary estimate or a previous revised estimate has been sanctioned by the Railway Board, it should be made clear how the original sanction has been modified by such further sanctions. There are several changes that take place during execution of work, in individual items or minor heads, all of such changes do not call for preparing revised estimate, however whenever the revision is required on account of more than $10 \%$ in any sub-head as per good practice followed on some Railways or overall cost of work is expected to be increased is required, a revised estimate is to be prepared and necessary sanction obtained.
Further, stipulations of ParaE-1136 (Engineering Code) are as under,
i) Normally, the executive should not incur expenditure in excess of the sanctioned cost of the work.
ii) In case, during execution of work it is apparent that cost of the work as a whole, will be escalated, executive should take steps to restrict the expenditure as far as possible, till sanction for extra cost through a revised estimate is obtained.
iii) In case there has been no great modification in the scope of original estimate, an abstract only for the items affected with explanation and bringing out any changes in allocation can be prepared, instead of complete revision of detailed estimate. Whenever, the sanctioning authority is Railway Board, brief abstract should be prepared, showing the heads affected, the increase under each head and the reasons for the same. The increase should always be shown separately for price increase and other causes.
iv) The increase in cost of an estimate on account of price increase comes to notice much earlier, generally at the time of receipt of tenders. In such cases, an abstract revised estimate can be prepared and sent for sanction. In other cases, it should be prepared as soon as probability of excess is known.
v) If the work/Project is in advanced stage of progress and the time taken to prepare and obtain the sanction of Revised estimate is such that the completion of the work/project may be achieved earlier, the excess can be explained through the Completion estimate with the approval of the competent authority, empowered to revise the estimate and associate accounts advised of the same.
vi) Even if the cost has exceeded or likely to exceed the sanctioned cost, the following payments should not be withheld,
a. To liquidate the liabilities already incurred on the date of reporting the excess to the competent authority for sanction. This means that no new liabilities should be incurred after reporting the excess to the competent authority, without his approval.
b. Payments in respect to salaries, wages, and or other pressing claims.

The revised estimate is to be prepared in the same form and details as was done for original estimate. A variation statement giving the Variations on account of escalation in prices and other than escalation has to be shown in separate columns. The reasons for variations are to be clearly given.
11.0 COMPLETION ESTIMATE: When the work is completed or nearing completion an estimate comprising of actual amount spent against the sanctioned expenditure is to be prepared. All work estimates, Revenue estimates, construction estimates have to be closed by preparation of Completion estimate. A completion Estimate is prepared in super session of a sanctioned detailed Estimate as provided in paragraph E-1701(Engg. Code). It should show in a tabular form (E. 713) the following particulars in respect of all the works included in the sanctioned estimate:
(i) Amount of sanctioned estimate;
(ii) Actual expenditure on all works up to the date of the construction estimate;
(iii) Commitments on that date;
(iv) Anticipated further outlay;
(v) Total estimated cost; and
(vi) Difference between the sanctioned estimate and the estimated cost.

In regard to Projects i.e. Estimates sanctioned under Capital expenditure, an abstract of the completion estimate showing the above particulars against the various heads of capital classification should be submitted for information or sanction, to the Railway Board together with brief explanations for excesses occurring under any main head of account. Provision for further outlay if required should be made in completion estimate only for those works which are in progress or completed on the date of closing of the construction estimate. All works not started on that date should be dealt with separately as open line works both as regards estimate and expenditure. In forwarding, therefore, estimates for sanction for works in connection with new lines opened, it should be clearly indicated whether the cost of the work is chargeable to Capital Construction or Open Line Capital.

### 12.0 COMPETENT AUTHORITY OF SANCTION OF ESTIMATES

Cases where sanction of estimate by competent authority is necessary before liability or expenditure is incurred thereon is as under but subject to exceptions shown in foot note.
(a) Construction or purchase of new works or assets when estimated to cost above Rs.50,000/-.
(b) Renewals and replacements of existing works or assets chargeable to Depreciation Fund/Development Fund or Open Line works Revenue(OLWR) when estimated to cost more than Rs.50,000/-
(c) Renewals and replacement of existing works or assets chargeable to Revenue when estimated to cost more than Rs. 2 lakhs.
(d) Scrapping, dismantlement or abandonment of existing works or assets.
(e) Repairing or reconditioning of the existing works or assets, if estimated to cost more than Rs. 1 lakh and that of a single housing unit, if estimated to cost more than Rs. 20,000/-.
(f) Temporary and experimental works
(g) Renewals and replacements on worked lines, and
(h) Renewals of ballast.

Note:- Exceptions for prior sanctioning of estimates are as under:-
(i) Works commenced under urgency certificate which are considered to be urgently necessary to safeguard life or property or to repair damage to the line caused by flood, accident or other unforeseen contingency, so as to restore or maintain through communication. In this case liability or expenditure can be incurred prior to sanctioning of estimate.
(Ref:- para.1103E). The procedure for commencement of works under urgency certificate is prescribed in para.1104E.
(ii) In those cases of renewals of permanent way, which are essentially of the nature of repairs and maintenance and in respect of which there is no question of an improvement or a change in the type of materials, and it is impracticable to prepare estimates in advance, separate estimates need not be prepared, but the total cost of the renewals, which must be comparatively small (less the cost of released materials), may be charged to Depreciation Fund through the permanent-way returns, the estimate for track renewals for the division or system being operated upon for this purpose, and the possible credits to Capital on account of the difference between the original cost and the actual cost being neglected in such cases.

### 13.0 MATERIAL MODIFICATION (Para1109 to 1114E)

The following may be taken as material modifications on lines under construction and open line works estimated to cost rupees one crore and over:-.
(a) Any change in the alignment likely to affect the facilities offered to the public in the neighborhood or likely to increase or decrease the length of the line by over one kilometer.
(b) Introduction of any new station or omission of any station.
(c) Any alteration in the type or number of engines or vehicles provided in an estimate for rolling-stock.
(d) A change in the layout of a yard affecting the general method of working or increasing or reducing the number of trains that can be dealt with.
(e) Any departure from the standards of construction as prescribed in Chapter II of Engineering code or as accepted by the Railway Board in the Abstract Estimate or use of any second hand material, if it affects the speed of trains or the number of trains to be dealt with than contemplated originally.
(f) The introduction or omission of any work or facility involving a sum of Rs. 5 lakhs and over.
(g) Any modification of a sub-work provided for in the estimate of a sanctioned work involving an additional outlay on that sub-work of more than Rs. 5 lakhs.
(h) The introduction of the new sub-work not provided for in the estimate of a sanctioned work involving an outlay of more than Rs. 5 lakhs.
(i) Any alteration in the standards of interlocking.

No material modification in a work or scheme as sanctioned should be permitted or undertaken without the prior approval of the authority that sanctioned the estimate. In the
case of estimates sanctioned by the Railway Board or higher authority, instances of what will be considered to be a material modifications of a sanctioned project or work are given below:-.

With a view to ensure effective control over the execution of works within the powers of sanction of the General Manager, it will be open to him to expand the scope of the term "material modification" as defined in the preceding paragraphs and to prescribe what other instances will be regarded as material modifications by him.
Any modification other than a "material modification" in the scheme or project sanctioned by the Railway Board or a higher authority may be sanctioned by the General Manager or any lower authority, provided that the amount of additional expenditure, if any, necessitated by such modification, does not cause an excess beyond his powers of sanction.
If the introduction of a material modification becomes necessary in a project sanctioned by the Railway Board before the work is actually commenced, an amended abstract estimate should be prepared for the project and submitted for the approval of the Railway Board. When the introduction of a material modification in a project as sanctioned by the Railway Board or higher authority becomes necessary during the progress of the work, a revised abstract estimate should be submitted to the Railway Board, even when no excess in the amount of the sanctioned estimate is likely to result. No liability should be incurred on the modification, nor, if a saving is likely to be affected by its introduction, should the saving be utilized for any other purpose, until the proposed modification has received the approval of the Railway Board.

No material modification can be sanctioned by the General Manager, if as a result thereof, an excess over sanctioned estimate occurs beyond the sanctioning powers of the General Manager.

Executive Engineers need not ordinarily refer to higher authority for orders proposals for the introduction of any modification, which is necessitated by purely engineering consideration and which involve an outlay of less than Rs.10,000 provided the financial powers of the authority who sanctioned the estimate are not exceeded thereby.

### 14.0 OUT OF TURN SANCTIONS

When a work is not administratively approved in the Railways Works, Machinery and Rolling-stock Program for current year, out of turn sanction can be sought from the competent authority for the same year.
15.0 COMMON PITFALLS IN FRAMING ESTIMATES: One way to prepare good estimates is to recognize and avoid the common errors and biases that plague the estimating process today. These errors and biases include the following:

## a) Not taking all the work into account

This is perhaps the most common problem, especially with Abstract estimates. You may just miss some major work that you didn't understand to be a part of the project/work, such as electrical, S\&T or site development activities. Many a times you underestimate the size of deliverables that need to be completed or you do not include all of the activities required to complete the deliverable.

## b) Wishful thinking

Anyone who provides estimates of work knows that there can be pressure from your boss or user department to make the estimate as low as possible, and sometimes to be within local powers of sanction or funds available. Ultimately, the same people want to get what is actually needed for as little effort (and cost) as possible. In many cases, there is a tendency on the part of the estimator to get caught up in that mindset as well. The estimator ends up "wishing" the work ends up within the boss's expectations but seldom able to achieve it.

## c) Not recognizing estimating biases

Your personal biases can sneak into your estimates. Some are optimistic and some are pessimistic. Optimistic biases will result in underestimating the work and can include:

- Tending to think the work is simple without accounting for site difficulties or poor accessibility of site etc.(many things appear simple to a person not fully involved in execution).
- The lower the estimate, comparatively easier to get approval from associated finance and the approving authority without much queries.
Pessimistic biases will result in overestimating the work and can include:
- Overestimating the work because you had a bad experience on a similar project in the past
- Overestimating because you don't really want to do the work. You might estimate high and hope the work will not be approved.
- In a Divisional environment, the estimators depend on budgetary quotations from the regular contractors visiting the office. They many times give biased quotations, as they are also prospective participants in the work tender to be issued.

ANNEXURE-A
Allocation of work Expenditure under Demand No. 16

| Minorhead (LEVEL-I) | Sub-Heads (LEVEL-II) | Detailed Heads (LEVEL-III) | $\begin{gathered} \hline \text { LEVEL- } \\ \text { IV } \end{gathered}$ | $\begin{gathered} \text { LEVEL- } \\ \mathrm{V} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: |
| $1100$ <br> New <br> Lines <br> (Construc tion) | 1110 Preliminary expenses | 1111 Survey expenses. |  |  |
|  |  | 1112 Plant. |  |  |
|  |  | 1113 Establishment. |  |  |
|  |  | 1114 Miscellaneous. |  |  |
|  | 1120 Land | 1120 Land |  |  |
|  | 1130Structural Engineering Works - Formation. | 1131 Earthwork |  |  |
|  |  | 1132 Tunnels. |  |  |
|  | 1140 Structural Engineering Works-- Permanent Way. | 1141 Rails and fastenings |  |  |
|  |  | 1142 Sleepers and fastening |  |  |
|  |  | 1143 Points and crossings. |  |  |
|  |  | 1144 Ballast |  |  |
|  |  | 1145 Fencing. |  |  |
|  | 1140 Structural Engineering Works-- Permanent Way. | 1146 Road crossings including foot over/ under bridges at stations and other places |  |  |
|  |  | 1147 Miscellaneous. |  |  |
|  | 1150 Structural Engineering Works- bridges | 1151 Major bridges-Steel work |  |  |
|  |  | 1152 Major bridges-Masonry |  |  |
|  |  | 1153 Major bridges-Miscellaneous |  |  |
|  |  | 1154 Minor bridges-Steel works |  |  |
|  |  | 1155 Minor bridges-Masonry |  |  |
|  |  | 1156 Minor bridges-Miscellaneous |  |  |
|  | 1160 Structural Engineering <br> Works- Stations and Buildings | 1161 Offices |  |  |
|  |  | 1162 Stations. |  |  |
|  |  | 1163 Workshop and Stores <br> Buildings including Electric <br> Power Stations and sub- stations |  |  |
|  |  | 1164 Other Service Buildings. |  |  |
|  |  | 1165 Residential Buildings. |  |  |
|  |  | 1166 Buildings and other works in con-nection with staff welfare. |  |  |
|  |  | 1167 Station machinery. |  |  |
|  |  | 1168 Shore connection for ferry steamers. |  |  |


| Minorhead (LEVEL-I) | Sub-Heads (LEVEL-II) | Detailed Heads (LEVEL-III) | $\begin{gathered} \text { LEVEL- } \\ \text { IV } \end{gathered}$ | $\begin{gathered} \text { LEVEL- } \\ \mathrm{V} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: |
|  | 1170 Equipment, Plant and Machinery | 1171 Overhead Power lines and Traction Equipment. |  |  |
|  |  | 1172 Underground cables. |  |  |
|  |  | 1173 Electric Telegraphs and train control equipment including all Signal-ling and inter locking machinery. |  |  |
|  |  | 1174 Plant and equipment-Civil Engineering department |  |  |
|  |  | 1175 Plant and equipment Mechanical department. |  |  |
|  | 1180 General Charges- <br> Establishment | 1181 Direction and general |  |  |
|  |  | 1182 Audit and Accounts. |  |  |
|  |  | 1183 Civil Engineering. |  |  |
|  |  | 1184 Electric Department. |  |  |
|  |  | 1185Mechanical Department. |  |  |
|  |  | 1186 Traffic Department. |  |  |
|  |  | 1187 S. \& T. Department. |  |  |
|  |  | 1188 Stores Department. |  |  |
|  |  | 1189 Medical and Sanitation. |  |  |
|  | 1190 General Charges-other than Establishment | 1191 Plant construction. |  |  |
|  |  | 1192 Instruments. |  |  |
|  |  | 1193 Office expenses. |  |  |
|  |  | 1194 Temporary Residential Quarters. |  |  |
|  |  | 1195 General Charges on stores |  |  |
|  |  | 1196 Loss of cash and stores. |  |  |
|  |  | 1197 Operating expenses pending opening of the line for traffic. |  |  |
|  |  | 1198 Miscellaneous receipts. |  |  |
|  |  | 1199 Credits for released materials. |  |  |

## CHAPTER-XII

## UNIT RATES OF ITEMS OF WORKS

1.0 Adoption of Rates in Estimates: The basis of adoption of any rate in the estimate is to be on any rational method. The rate adopted should not only be reasonable and workable but also should be proved to be so. In terms of Para E-538 of Engineering Code, for all the project reports, based on preliminary survey or Final location survey it is essential to present the basis on which the rates and quantities in the estimate have been adopted. This is also true for any estimate be it abstract, detailed, Project or any other. Thus, working out unit rates of different items of work is the preparatory work for making any estimate.
2.0 Methods of Calculation of Unit Rates: Rates of items of work depend primarily on the following inputs,
i) Material cost
ii) Labor cost
iii) Machinery and fuel
iv) Temporary works required (Not paid separately)
v) Taxes, royalties' local imposts etc.
vi) Overhead costs of supervision, management etc.
vii) Contractors profit

In Civil Engineering works the typical break up of cost for different types of works as conventionally done are as under:

| S. No | Nature of Work | Fixed (\%) | Materials(\%) | Labor (\%) | Fuel (\%) |
| :--- | :--- | :---: | :---: | :---: | :---: |
| 1 | Steel Structures | 25 | 50 | 20 | 5 |
| 2 | Earthwork | 35 | 5 | 55 | 5 |
| 3 | Bridge work | 15 | 40 | 30 | 15 |
| 4 | Building | 15 | 40 | 30 | 15 |
| 5 | Road work | 25 | 50 | 20 | 5 |
| 6 | Ballast/ quarry prod | 25 | 50 | 15 | 10 |
| 7 | Track work | 25 | 10 | 60 | 5 |

Conventionally in railways as also in many other Government systems, weightage is not being given to use of heavy machinery in civil engineering works and this component is clubbed up under 'fixed costs' only, and the component of fuel is taken separately for consumables and transportation etc. It is also to be considered that if heavy machinery is used, the component of labor will correspondingly get reduced, the major component
being Materials, which primarily include steel, cement and quarry products like sand, stone chips, earth etc. The cost of materials like cement and steel normally can be taken as same for works without much influence of factors of location etc. The cost of quarry products can be quite different, at different locations depending on local demand, transportation, local duties and royalty etc. The temporary works required for completion of work but not separately paid can constitute a sizable proportion of the cost and differ significantly from site to site and from work to work. This is normally not given due weightage in departmental estimates. As an example, if a bridge is being constructed in a perennial river one will require to make islands or coffer dams for constructing foundation and jetties to reach the material, labor to the location i.e. payable work can be done only after considerable temporary works have been done, which may not at all be required for a bridge which flows during monsoon only. Similarly if the pier structure is only 5-6 meter high will require very different scaffolding compared to 20-25m high structure besides requiring additional labor. There can be big variations in local taxes, royalties and imposts from state to state and sometimes municipality to municipality. Then the minimum wages of workers skilled/unskilled can be different from one district to another district.

The underlying idea is that whatever method of working rates one uses, one must be aware of all these factors and collect the details of as many variables as one can gather for the specific requirements of a work to prepare a justifiable and reasonable rate analysis.
2.1 This is done by several methods, namely,
a) On Last accepted rates.
b) Modified Last accepted rates.
c) Modified Standard Schedule of rates
d) By Market survey
e) Basic Rate analysis.
f) By Work study

There are merits and demerits of each method and it is difficult to recommend any one method over another, generally it is the end use and the time available which governs the adoption of any particular method.
3.0 Last Accepted Rates: One of the very common methods of adopting rates in an estimate is to pick up the rates of similar work executed in the geographical jurisdiction of the same administration. Further the practice is that average rate of three similar works is used to arrive at what we call last accepted rate or LAR for short.. If the works in the past were done more than 1 year back a \%ge for increase in rates in the interim period is added to compensate for the inflation of rates in the intervening period. This is considered quite reliable method but before adopting such rates the estimator must confirm that the work now proposed is similar in nature and the conditions of site and work are generally identical. The factors that should be similar are,

- Scale of work- the L.A.R of a much smaller or much bigger work compared to the proposed work is likely to be not representative. The overhead costs of bigger works/ bigger contractors are much higher (up to $35 \%$ compared to about $15 \%$ for smaller works), there might be some rate difference due to scale of work also. Further the LAR of item should not have been accepted without detailed justification, e.g. being an insignificant item in the previous work; such rates can be sometimes unreasonably high or low.
- Accessibility of site- An unapproachable site by road where approach roads may be required to be constructed can increase the cost of materials by about $10 \%$ or the cost of work by $5 \%$.
- Law and order situation- The insurgency prone areas and other areas having unlawful activities by organized groups would increase the rates of work by about 10\%.
- Temporary works (not paid separately) - Temporary works include scaffolding, centering, shuttering, approach road, jetties, floating passages, survey towers etc.
- Lead and lift of material at site- with more lead and lift required for taller, bigger structures, the productivity of labor can reduce by $25-40 \%$ thus the rates will be lower by about ( $30 \times 25 / 100=$ ) $7.5 \%$ of the cost of work. ( for a work having labour component as $30 \%$ ) .Some organizations add a flat $1.5 \%$ for every additional storey of a building. If the rate for single storey building is Rs.100.00 (say) then the rate for higher storey can be worked out a below,

| Height of Building | Rate (Rs.) |
| :--- | :--- |
| Ground floor | 100.00 (say) |
| First floor | 101.50 |
| Second floor | $101.5 \times 1.015=103.02$ |
| Third floor | $103.20 \times 1.015=104.57$ |
| Fourth floor | $104.56 \times 1.015=106.13$ |
| Average Rate for <br> G+4 storey <br> building | $103.25 \%$ of the basic <br> rate for ground <br> floor work. |

- Working time constraints- In places like workshops, goods and passenger sheds/platforms, work in traffic blocks, in built up habitats etc the progress of work will be less with same inputs, due to restricted hours of working. The rates will be accordingly different depending upon the constraints over normal 8 hour working of labor (Generally the contractors labor works more than 8 hrs a day). More the labor content of work higher the cost difference.
- Statutory levies- Different taxes, duties and royalties etc would make difference in cost.
- Availability of water and electric power at site. Water and electricity are required not only for the work and machine operation but also for labor camps. The cost of water if arranged through tankers could be costlier by Rs. 20.00 per 1000 Its. And electric power if required be generated by diesel generators cost about Rs.4.00 per unit. For civil works where concreting is a major item of work, the difference could be as much as $2 \%$ of cost of work.
3.1 Modified Last accepted rates: The last accepted rates, if not available for similar work, but is available for work which is slightly different then rates can be worked out by adding/subtracting a reasonable percentage over the average LAR. This may be required on the factors as described in foregoing Para or minor changes in the technical specifications of work. A good example is of different grade of concrete. If we have LAR of ( $1: 2: 4$ ) concrete but we have to estimate the rate of ( $1: 1: 2$ ) concrete, where the consumption of cement will be double of requirement for (1:2:4) concrete, other things being almost same. The estimated rate of concrete (1:1:2) can be obtained by adding landed cost of extra cement on the rate of concrete (1:2:4).

Example: Available accepted rate in Aug 2007 for construction of a G+4-story building'RCC M30 in columns and beams with all materials including cement, shuttering, scaffolding, centering, temporary arrangements etc., labor, admixtures if required.'@ Rs.4500/Cum. Rate is required for similar item in Sept. 2009 but for a single story building.

In case of building work, the type and quantity of shuttering, scaffolding and centering (temporary works) will be same for all level of concreting in beams and columns but lift of materials cement, sand, stone, shuttering material, water etc will be different in two cases. (Material component - 40\%).Further there would be price escalation due to lapse of two years (Compounded @5\%p.a.). Thus the estimated rate for single story building would be as under,

| S. No. | Description of item | Unit | Rate (Rs) |
| :---: | :--- | :--- | :--- |
| 1 | For G+4 story bldg-'RCC M30 in columns <br> and beams with all materials including <br> cement, shuttering, scaffolding, centering, <br> temporary arrangements etc., labor, <br> admixtures if required.' | Per Cum | 4500.00 |
| 2 | (+) For inflation over 2 yr. @ 5\% p.a. <br> compounded (5+5.25=10.25\%) | Per Cum | $(+) 461.25$ |
| 3 | (-) Less for labor productivity component for <br> lifting all materials to 3-15m height <br> @ 3.25\% | Per Cum | $(-) 146.25$ |
|  | Total rate | Per Cum | $\mathbf{4 8 1 5 . 0 0}$ |

Note: The cost of carrying 1 Cum of concrete weighing 2.4 Ton (48 bags of 50kg) and shuttering centering material etc on head load, for an extra average lead of ( 3 m -
$12 m=7.5 \mathrm{~m}$ ) can be worked out from first principle which may be used instead of $3.25 \%$ for S.No.3.
3.2 Based on Standard Schedule of Rates: As per Board's Instructions, if rates of the item can be derived from the combination of items of works of the Standard schedule of rates, the rate for the same should be worked out as per these rates. These can be increased by the prevalent percentage, above or below, for SOR rates in the area. This is the best practice as the S.O.R. has been framed after due consideration of various elements constituting the item. If there are special factors relating to the work or the site, which may affect the rates, as described in Para-3.0 above, the same should also be considered.

A variation of the above approach can also be adopted, in case, the combination of several SOR rates do not fully represent the proposed item then the rate can be worked out by adding/subtracting the analyzed rate for the small component not covered/ required. The additional component of work can be separately analyzed and added to the rate obtained by modifying the SOR rates. However, it is to be ensured that percentage above or below SOR is not applied on the analyzed rate of the small component as we are doing new analysis for rate of of this component.
3.2.1 Example - As an illustration if Rate of 'Steel fabrication and erection with Railways steel but contractors labor, rivets, tool, equipment etc.' is to be estimated. The standard schedule of rates has two items namely, i) fabrication of steel structures (with steel and rivets to be supplied by Railway, Free of cost) and ii) Erection of fabricated work for Rly bridge girder in traffic block. The composite rate can be estimated as under,

| S. <br> No. | C.R.SOR <br> Item No. | Description of Item | Rate/ton |
| :--- | :--- | :--- | :--- |
| 1 | $x 1 y 1 z 1$ | Fabrication of steel work with all materials, labor, <br> consumables etc. (only steel and rivets to be <br> supplied by Rly. Free of cost) | 10000.00 |
| 2 | $x 2 y 2 z 2$ | Steel fabrication with Railways steel and rivets <br> but contractors labor, bolts, tools, equipment etc | 7000.00 |
| S.No1+2 |  | 17000.00 |  |
| \% Above/Below | $110 \%$ above | 18700.00 |  |
| Total |  | 35700.00 |  |
| (+) Extra for cost <br> of rivets | For rivets supply by contractor@ Rs 100/kg, <br> consumption (Assume, 30 Kg/ton i.e. 3\% by weight) | 3000.00 |  |
| Rate for proposed <br> Item | Steel fabrication and erection with Railways steel <br> but contractors labor, tool, equipment and rivets etc. | 38700.00 |  |

Note: The item description, rates etc are only for illustration of the concept, and are not for adopting in any estimate.

### 3.3 By Detailed Rate Analysis:

This method is adopted whenever the standard schedule of rates is to be revised, or there is no past history of having executed a similar work but can also be adopted when options under Para- 3.1 and 3.2 above are not found feasible.

Over a period of time, it is seen that the rates of various items do not increase in the market uniformly resulting into some items of standard schedule of rates becoming loss making items and some other items becoming profit-making items to contractor in the schedule, which affects the contract. This necessitates revision of standard schedule of rates to bring all the items on par with the current market trends.

The determination of unit rates of a particular item of work, from the cost of quantities of material, cost of labor and other miscellaneous expenses required for completion of work as per specifications is known as analysis of rates. A reasonable profit, normally $10 \%$ for the contractor is also included in the rate analysis.
(i) Material

A material analysis for calculating the quantity of materials required for unit work is done. The quantity of materials shall include wastage (normally 5\%) depending on nature of work. The rates of materials will be as per market rates enhanced by the taxes and freight applicable for the material component.

## (ii) Labor

This is calculated based on task work which is based on turnout of team of laborers under normal conditions in a day to calculate the man days of different type of labour required for unit outturn or 10 unit/100 units of work. The output of labour for general works is given in Annexure-A. The labour rates should normaly be based on market rates of different types of labour subject to minimum wages by them from time to time. The minimum wages can be obtained from the labour commissioner's office. But normally the minimum prescribed wages are adopted in the rate analysis especially at locations where there is no shortage of labour. Different organizations like National Building Organization,CPWD, and Railways etc. have worked out the task work for different items of works and are available in the confidential rate analysis of the organizations. Values of some typical items as adopted in CPWD and now also in indian Railways are given in Annexure-B. These can be adopted for working out the labour requirements of any similar item of work.

## (iii) Hire charges for plants \& machineries:

Most of the bigger works require plant and machinery to be employed for execution of work satisfactorily, however for small works of normal repair etc the M\&P employed may not be significant and this element is not considered and a lump sum \%age is adopted and this is usually $5 \%$ of cost of materials to be handled.

However for major works, M\&P is used quite extensively and the rate has to be assessed realistically by one of the two methods given below,
a) Many organizations like CPWD and others have worked out and published unit hire charges for normally used plant and the same can also be used without going in for detailed analysis as given above which however will be used for special plant not covered by standard published rates. The charges fixed by CPWD are given in Annexure - C.
b) Para S-1923 of Indian Railways, Code for stores department lays down the procedure for working out the departmental hire charges of M\&P hired to outside agencies. This has also been elaborated in IR Bridge Manual vide Para - 1215. It is the practice on Indian Railways to adopt the same procedure for working out hire charges of M\&P employed by contractor either on lease from market or purchased outright from market. The procedure is based on the cost of plant and machinery, which is worked out as under,

Cost of plant (C):-The M\&P is categorized (Para-1208 of IRBM) into three categories i) Light plant, ii) Heavy Plant or iii) Special plant. The life of light plant is considered as 6 years, heavy plant as 10 years and special plant as 15 years and accordingly the depreciation rate of the plant is taken as $16 \%$, $10 \%$ and $6 \%$ per annum respectively, depending on the age of the plant. The category of the plant is decided by the Chief Engineer of the Railway, however the general guideline is that special plant is used for few special works and is very expensive like Piling rigs, tunnel boring machines, compressors, cranes etc. The trucks, tippers, compressors, generators, heavy pumps and motors etc are considered as heavy plant and all others like vibrators, concrete mixers, small water pumps, power trowels etc are considered as light plants. The cost of plant is taken as the actual market rate duly depreciated at the percentage given above for the age of the plant. Since at the time of preparation of rate analysis, it is not known as to the age of plant, it is normally taken as the landed cost of new plant only. The cost of second hand $M \& P$ is worked out as under, $C$ (2nd Hand) $=R \times(N / L) \times(R-S)$, where $R$ is present day cost of new plant, $N$ is the no. of years from the date of purchase of plant. $L$ is the total codal life of plant and $S$ is the scrap value of plant as estimated. A 12.5\% supervision charges are added to obtain the cost of plant.
The hire charges per year ( 250 working days for 8 hours every day) are worked out as under,

1. Interest charges on the cost of plant at bank rate (Normally 10\% p.a.)
2. Ordinary repairs and maintenance charges @ $5 \%$ of cost of M\&P.
3. Special repairs and maintenance charges @ 10\% of cost of M\&P
4. Depreciation charges at $16 \%, 10 \%$ or $6 \%$ depending on type of plant.
5. Contingencies @ $10 \%$ over $1+2+3+4$

The total hire charges per day (8 Hours) would therefore be $(1+2+3+4+5) / 250$. The cost of operators and consumables has to be separately worked out. The output of the machinery per day (8Hours) is to be assessed and then pro-rata rate for unit quantity has to be worked out.

Example: - If the cost of M\&P (Heavy Plant) is Rs. 100,000/-. The hire charges per day would be

$$
=100,000 / 250(0.10+0.05+0.10+0.10) \times 1.10=\text { Rs. } 154 /- \text { per day }
$$

(iv) Overhead costs and Profit: The overheads of the contractor are 2-types namely
i) General overheads: to cover the office expenses, rents, stationary, telephone bills, traveling allowances, etc. which are indirect expenses and not directly productive and
ii) Job over heads: like salaries to engineers/supervisors, handling of materials, repairs and depreciation of machinery, interest on investment, amenities to labor/staff, workmen's compensation, insurance, costs of B.G. etc

These are varying from site to site and magnitude of work. For small works these are considered as negligible but for bigger works these can be as much as $10-12 \%$ of the cost of work and is generally not added while carrying out rate analysis and are considered to be part of contractors' profit which is added. The new Standard schedule of rates prepared by RITES for whole Indian Railways has therefore considered the profit percentage to $15 \%$ from $10 \%$ used in earlier Standard SOR's while carrying out the rate analysis.
(v) Water charges: A flat $1 \%$ is added, to cover the cost of water required for work as well as the requirement of labor etc., in the rate analysis.
3.4 The following example will explain the process of working out rate analysis of any item. For items contained Standard Schedule of Rates, analysis of rates has tobe done in detail and is maintained in HQ and Divisional and is called 'confidential Rate Analysis'

Example: Work out rate analysis of 'Cement concrete 1:3:6 with all materials labor, tools and plant, etc. (Cement and shuttering to be paid separately)
(i) up to plinth level and
(ii) From plinth level to 2-floors above.

## Solution:

(i) Up to plinth level

| Description | Unit | Rate (Rs.) | Quantity | Labour cost | Material cost |
| :---: | :---: | :---: | :---: | :---: | :---: |
| CEMENT CONCRETE (CAST-IN-SITU): <br> Providing and laying in position cement concrete of specified proportion excluding the cost of cement and of centering and shuttering - All work up to Plinth level: |  |  |  |  |  |
| 1:3:6 ( 1 cement: 3 sand: 6 graded stone aggregate 20 mm nominal size). <br> Details of cost for 1 cum of concrete |  |  |  |  |  |
| Material: |  |  |  |  |  |
| Stone Aggregate (Single size) : 20 mm nominal size | cum | 700.00 | 0.700 |  | 490.00 |
| Stone Aggregate (Single size) 10 mm nominal size | cum | 700.00 | 0.240 |  | 168.00 |
| Coarse sand (zone III) | cum | 600.00 | 0.470 |  | 282.00 |
| Carriage of Stone aggregate below 40 mm nominal size | cum | 53.21 | 0.940 |  | 0.00 |
| Carriage of Coarse Sand | cum | 53.21 | 0.470 |  | 0.00 |
| Carriage of cement | ton | 47.29 | 0.220 |  | 0.00 |
| Labor: |  |  |  |  |  |
| Mason (average) | Day | 146.55 | 0.100 | 14.66 |  |
| Beldar | Day | 135.25 | 1.630 | 220.46 |  |
| Bhisti | Day | 138.45 | 0.700 | 96.92 |  |
| Machinery |  |  |  |  |  |
| Hire charges of Concrete Mixer 0.14 cubic meter | Day | 400.00 | 0.070 | 28.00 |  |
| Vibrator (Needle type 40mm) | Day | 200.00 | 0.070 | 14.00 |  |
| Sundries | LS | 1.00 | 8.580 | 8.58 |  |
| Total |  |  |  | 382.62 | 940.00 |
| Add for water charges @ 1\% |  | 0.01 |  | 3.83 | 9.40 |
|  |  |  |  | 386.43 | 949.49 |
| Add for contractor's profit and overheads <br> @ 15\% |  | 0.15 |  | 57.97 | 142.41 |
| cost of 1 cum |  |  |  | $444.40 \quad 1091.81$ |  |
| TOTAL COST OF 1 Cum |  |  |  | 1536.21 |  |

## (ii) From plinth level to 2-floors above

| Description | Unit | $\begin{gathered} \hline \text { Rate } \\ \text { (Rs.) } \end{gathered}$ | Quantity | Labour cost | Material cost |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Providing and laying cement concrete, above plinth up to floor two level, in retaining walls, walls (any thickness) including attached pilasters, columns, pillars, posts, struts, buttresses, string or lacing courses, parapets, coping, bed blocks, anchor blocks, plain window sills, fillets etc, excluding the cost of cement and of shuttering, centering. 1:3:6 ( 1 cement: 3 sand: 6 graded stone |  |  |  |  |  |
| aggregate 20 mm nominal size). Details of cost for 1 cum of concrete |  |  |  |  |  |
| Material: |  |  |  |  |  |
| Stone Aggregate (Single size) : 20 mm nominal size | cum | 700.00 | 0.700 |  | 490.00 |
| Stone Aggregate (Single size) : <br> 10 mm nominal size | cum | 700.00 | 0.240 |  | 168.00 |
| Coarse sand (zone III) | cum | 600.00 | 0.470 |  | 282.00 |
| Carriage of Stone aggregate below 40 mm nominal size | cum | 53.21 | 0.940 |  | 0.00 |
| Carriage of Coarse Sand | cum | 53.21 | 0.470 |  | 0.00 |
| Carriage of cement Labour: | ton | 47.29 | 0.220 |  | 0.00 |
| Beldar | Day | 135.25 | 0.900 | 121.73 |  |
| Coolie | Day | 135.25 | 0.780 | 105.50 |  |
| Bhisti | Day | 138.45 | 0.700 | 96.92 |  |
| Mason 1st class | Day | 151.50 | 0.060 | 9.09 |  |
| Mason 2nd class | Day | 141.60 | 0.060 | 8.50 |  |
| Machinery |  |  |  |  |  |
| Hire charges of Concrete Mixer 0.14 cubic meter | Day | 400.00 | 0.070 | 28.00 |  |


| Vibrator (Needle type 40mm) | Day | 200.00 | 0.070 | 14.00 |  |
| :--- | :--- | ---: | ---: | ---: | ---: |
| Scaffolding (17.60 x 2.5 average) | LS | 1.00 | 72.600 | 72.60 |  |
| Sundries | LS | 1.00 | 9.070 | 9.07 |  |
| Extra Labor: for lifting Material: | Day | 135.25 | 1.130 | 152.83 |  |
| Coolie (0.75x1.50) |  |  |  |  |  |
| Total |  |  |  | 618.22 | 940.00 |
| Add for water charges @1\% |  | 0.01 |  | 6.18 | 9.40 |
|  |  |  |  | 624.41 | 949.40 |
| Add for contractor's profit and |  | 0.15 |  | 93.66 | 142.41 |
| overheads @ 15\% |  |  |  |  |  |
| cost of 1 cum |  |  |  | $\mathbf{7 1 8 . 0 7}$ | $\mathbf{1 0 9 1 . 8 1}$ |

3.4 By Work study: Several times during the progress of work, mainly of major works there are situations where the item given in the bill of quantities(Tender schedule) do not cover all the process or complete scope of work required to successfully execute the work and contractors demand for an extra item to be operated. In such cases the rate analysis of the extra work should be done using work study at the site of work in regard to the use of materials, labor and machinery plant for the additional work and the rate analyzed on the same manner as given in the 'Rate Analysis' above. The activities not covered in the item of 'BOQ' can thus be arrived at and included in the new item to be prepared.

## WAGES OF LABOR - AT NEW DELHI AREA (CPWD)

| Category of artisan/Labor | Unit | Rs./day |
| :---: | :---: | :---: |
| Bandhani | Day | 138.45 |
| Bhisti | Day | 138.45 |
| Blacksmith 1 st class | Day | 151.50 |
| Blacksmith 2nd class | Day | 141.60 |
| Carpenter 1 st class | Day | 151.50 |
| Carpenter 2nd class | Day | 141.60 |
| Chowkidar | Day | 135.25 |
| Beldar | Day | 135.25 |
| Coolie | Day | 135.25 |
| Fitter (grade 1) | Day | 151.50 |
| Assistant Fitter or 2nd class Fitter | Day | 141.60 |
| Glazier | Day | 141.60 |
| Mason (for plaster of Paris work) 1 st class | Day | 151.50 |
| Mason (brick layer) 1 st class | Day | 151.50 |
| Mason (brick layer) 2nd class | Day | 141.60 |
| Mason (for plain stone work) 2nd class) | Day | 141.60 |
| Mason (for ornamental stone work) 1 st class | Day | 151.50 |
| Driver (for Road Roller, Concrete Mixer, Truck etc.) | Day | 151.50 |
| Mate | Day | 138.45 |
| Mistry | Day | 151.50 |
| Painter | Day | 141.60 |
| Rock Excavator | Day | 135.25 |
| Rock Breaker | Day | 135.25 |
| Rock Hole Driller | Day | 135.25 |
| Stone Chiseller | Day | 138.45 |
| Sprayer (for bitumen, tar etc.) | Day | 138.45 |
| Skilled Beldar (for floor rubbing etc.) | Day | 138.45 |
| White Washer | Day | 138.45 |
| Mason (average) | Day | 146.55 |
| Carpenter (average). | Day | 146.55 |
| Operator (Pile driving/ Special machine) | Day | 166.00 |
| Skilled torch operator for laying tack | Day | 151.50 |

ANNEXURE-B
QUANTITY OF LABOR COMPONENT IN STANDARD TYPE WORKS:

| $\begin{aligned} & \text { S. } \\ & \text { No. } \end{aligned}$ | Description of work | Unit | Labor days ( 8 working hours) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | H.S | S/Skilled | U/Skilled |
|  | (A )Earthwork |  |  |  |  |
| 1 | Excavation in trenches for foundation up to 1.5 m width, and disposal up to life 1.5 m and lead up to 30 m |  |  |  |  |
| a | Ordinary soil | 10Cum |  | 1.76 | 1.41 |
| b | In dense or hard soil | 10Cum |  | 2.30 | 1.85 |
|  | Extra for every 30m lead | 10Cum |  |  | 0.4 |
| 2 | Re-Filling excavated earth in trenches, plinths, sides of foundations in layers of 15 cm in depth duly rammed | 10Cum |  | 1.1 | 0.9 |
| 3 | C.Concrete volumetric in foundation and upto plinth (Any grade) Shuttering to be paid separately | Cum | $\begin{gathered} 0.10 \\ \text { (Mason) } \end{gathered}$ | $\begin{gathered} 1.63 \\ \text { (Beldar) } \end{gathered}$ | 0.70 <br> (Bhishti) |
| 4 | C. Concrete Volumetric in superstructure above plinth and upto 2 -floors. Shuttering to be paid separately | Cum | $\begin{gathered} 0.12 \\ \text { (Mason) } \end{gathered}$ | $\begin{gathered} 1.68 \\ \text { (Beldar) } \end{gathered}$ | 0.70 <br> (Bhishti) |
|  | Extra for handling/lifting materials | Cum | - | - | 1.13 (Coolie) |
| 5. | C.C. Mix design in foundation and upto plinth (Any grade) Shuttering to be paid separately | Cum | $\begin{gathered} 0.17 \\ \text { (Mason) } \end{gathered}$ | $\begin{gathered} 2.0 \\ \text { (Beldar) } \end{gathered}$ | $0.9$ <br> (Bhishti) |
| 6 | C.C. Mix design in superstructure above plinth and up to 2-floors Shuttering to be paid separately |  | $\begin{gathered} 0.20 \\ \text { (Mason) } \end{gathered}$ | $\begin{gathered} 2.05 \\ \text { (Beldar) } \end{gathered}$ | 0.9 <br> (Bhishti) |
|  | Extra for material handling/lifting | Cum | - | - | 0.6 (Coolie) |
| 7 | Bending, binding and placing steel reinforcement in work | Qtl. | 1.0 | 1.0 | - |


| 8 | Centering/shuttering including propping, strutting etc (Steel plates and forms) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| a | Foundn., footing, base of column i.e. works below plinth level | 10Sqm | 0.75 | 1.50 |  |
| b | Retaining walls, walls, attached pilasters,buttresses,fillets etc | 10Sqm | 2.2 | 3.8 | - |
| c | Columns, pillars ,posts and struts etc | 10Sqm | 2.2 | 4.5 | - |
| d | Slabs and other flat surfaces | 10Sqm | 2.0 | 3.8 |  |
| 9. | Centering/shuttering etc (Wooden ly board etc) | The H.S. labor would be about double of nos. reqd for steel form but $\mathrm{S} /$ Skilled will be same as given in item 8. |  |  |  |
| 10 | Brick work | Cum | 0.8 | - | 1.75 |
| 11 | Random rubble Stone work | Cum | 1.1 | 1.1 | 0.8 |
| 12 | IPS flooring (40mm thick) | 10Sqm | 1.25 | 1.0 | 1.0 |
| 13 | Plastering any mortar 12 mm th | 10Sqm | 0.75 | - | 1.0 |
| 14 | White/ color washing 3 coats | 10Sqm |  | 0.17 | 0.17 |
| 15 | Painting wood or steel work- <br> 2 Coats | 10Sqm | 3.0 |  | 2.0 |

ANNEXURE - C

## HIRE CHARGES OF COMMON TOOLS AND PLANT (CPWD)

| Description | Unit | Rate |
| :--- | :--- | ---: |
| Hire charges of Coal tar Boiler 900 to 1400 liters | Day | 595.00 |
| Hire charges of Concrete Mixer 0.14 cubic meter | Day | 400.00 |
| Hire charges of Diesel Road Roller - 8 to 10 tonne | Day | 1000.00 |
| Production cost of concrete by batch mix plant. | cum | 200.00 |
| Hire charges of Diesel Truck - 9 tonne | Day | 1008.00 |
| Hire charges of Spraying machine including electric charges | Day | 173.00 |
| Hire charges of Coal tar Sprayer | Day | 250.00 |
| Hire charges of Barber green, drying, mixing and <br> Asphalt Plant, with accessories, capacity 30/45 tonne | Day | 7050.00 |
| Pumping charges of concrete including Hire charges of <br> pump, piping work \& accessories etc. | cum | 80.00 |
| Hire charges of Derrick monkey rope | Day | 500.00 |
| Hire charges of pump set of capacity 4000lit/hour | Day | 300.00 |
| Vibrator (Needle type 40mm) | Day | 200.00 |
| Machine for rubbing of floors | Day | 200.00 |
| Front end loader | Day | 6000.00 |
| Mastic Cooker | Day | 515.00 |
| Hire and running charges of tipper | Day | 1030.00 |
| Hire and running charges of loader. | Day | 800.00 |
| Hand Grinder For mirror polish | Day | 100.00 |
| Hydraulic Excavator ~3D) with driver and fuel. | Day | 6000.00 |
| Pin vibrator | Day | 288.00 |
| Surface Vibrator | Day | 330.00 |
| GUSMER (for spraying of chemical) | Day | 625.00 |
| Hire and running charges of hydraulic piling rig with power <br> unit etc. including complete accessories and shifting <br> at site. | per day | 28000.00 |
| Hire and running charges of light crane. | 2000.00 |  |
| Hire and running charges of bentonite pump. | 4000.00 |  |
| Hire and running charges of vibrating pile driving <br> hammer complete with power unit and accessories. | 28000.00 |  |


| Hire and running charges of crane 20 tonne capacity. | per day | 8000.00 |
| :--- | :--- | ---: |
| Carriage of concrete by transit mixer. | kmlcum | 18.00 |
| Generator 250 KVA. | per day | 1600.00 |
| Paint applicator. | per day | 680.00 |
| Mobile crane. | per day | 5000.00 |
| Tractor with ripper attachment. | per day | 1000.00 |
| Tractor with trolley. | per day | 1000.00 |
| Air compressor 250 cfm with two leads for pneumatic <br> cutters/hammers. | Day | 1600.00 |
| Joint cutting machine with 2-3 blades | per day | 800.00 |
| C.C .batch mix plant. | Day | 88000.00 |
| Road sweeper | Day | 480.00 |
| Slip form paver with sensor. | Day | 12000.00 |
| Water tanker. | Day | 800.00 |
| Concrete joint cutting machine. | Day | 800.00 |
| Texturing machine. | Day | 800.00 |

## QUANTITY OF MATERIALS FOR DIFFERENT WORKS

## 1. Quantity of Materials for Mortars

| No | Concrete | Cement | Lime | Surki | Sand |
| :--- | :--- | :---: | :---: | :---: | :---: |
| 1 | Cement mortar 1:1 <br> (1 cement, 1 sand) | 1020 kg | -- | - | 0.713 Cum |
| 2 | Cement mortar 1:2 <br> (1 cement, 2 sand) | 680 Kg | -- | -- | 0.95 Cum |
| 3 | Cement mortar 1:3 <br> (1 cement, 3 sand) | 510 Kg | -- | -- | 1.07 Cum |
| 4 | Cement mortar 1:4 <br> $(1$ cement, 4 sand) | 380 Kg | -- | -- | 1.07 Cum |
| 5 | Cement mortar 1:5 <br> (1 cement, 5 sand) | 310 Kg | -- | -- | 1.07 Cum |
| 6 | Cement mortar 1:6 <br> $(1$ cement, 6 sand) | 250 Kg | -- | -- | 1.07 Cum |

2. Quantity of materials for concrete

| No | Concrete | Cement | Fly ash | Sand | Metal |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 1:2;4 concrete with 20 mm nominal size graded metal | 318 Kg | - | 0.445 Cum | 20mm - 0.67 Cum $10 \mathrm{~mm}-0.22$ Cum |
| 2 | 1:3;6 concrete with 20mm nominal size graded metal | 220 Kg | - | 0.47 Cum | $20 \mathrm{~mm}-0.70 \mathrm{Cum}$ $10 \mathrm{~mm}-0.24$ Cum |
| 3 | 1:3;6 concrete with 40 mm nominal size graded metal | 220 Kg | - | 0.47 Cum | $40 \mathrm{~mm}-0.65 \mathrm{Cum}$ 20 mm - 0.24 Cum |
| 4 | 1:4;8 concrete with 40 mm nominal size graded metal | 170 Kg | - | 0.47 Cum | 40 mm - 0.65 Cum 20 mm - 0.24 Cum |
| 5 | 1:5;10 concrete with 40 mm nominal size graded metal | 130 Kg | - | 0.47 Cum | $40 \mathrm{~mm}-0.65 \mathrm{Cum}$ 20 mm - 0.24 Cum |
| 6 | 1: 2 : 3.5 :9 fly ash concrete | 144 Kg | 0.21 cum | 0.37 cum | $40 \mathrm{~mm}-0.65 \mathrm{Cum}$ 20 mm - 0.24 Cum |
| 7 | 1:2.5:4:11 fly ash concrete | 130 Kg | 0.21 cum | 0.34 cum | $40 \mathrm{~mm}-0.65$ Cum 20mm- 0.24 Cum |

3. Quantity of materials per cum of brick work.

| No | Brick work in cm | Bricks | Cement mortar | Cement | Sand |
| :--- | :--- | :--- | :--- | :--- | :--- |
| 1 | $1: 3$ | 0.75 cum | 0.25 cum | 128 Kg | 0.27 Cum |
| 2 | $1: 4$ | 0.75 cum | 0.25 Cum | 95 Kg | 0.27 Cum |
| 3 | $1: 5$ | 0.75 cum | 0.25 Cum | 78 Kg | 0.27 Cum |
| 4 | $1: 6$ | 0.75 cum | 0.25 Cum | 63 Kg | 0.27 Cum |

Note :- Calculation of no of bricks per cum of brick work 1 cum
(a) No of bricks without mortar joints in one cum =

| $0.23 \times 0.115 \times 0.075$ <br> 1 cum |
| :---: |
|  |  |

(c) Volume of cement mortar per cum of brick work $=(504.10-373.99) \times 0.23 \times 0.115 \times 0.075$

$$
=0.25 \mathrm{cum}
$$

(d) Volume of bricks in one cum of brick work set in cement mortar $=1-0.25=0.75 \mathrm{cum}$ (374 bricks)

## 4. Stone Masonry - Quantity of materials per cum

| No | Stone work | Stone | mortar | Remark |
| :--- | :--- | :--- | :--- | :--- |
| 1 | Random rubble masonry | 1.16 Cum*$^{*}$ | 0.33 Cum | For quantity of |
| 2 | Course rubble masonry | 1.37 Cum $^{*}$ | 0.30 Cum | cement \& sandper <br> 3 |
| Late rite stone masonry for different |  |  |  |  |
| ratio refer para. 1.00 Cum $^{* *}$ | 0.18 Cum |  |  |  |
| 4 | Ashlars stone masonry | 1.33 Cum | 0.30 Cum |  |

* 0.32 Cum extra for circular pillars
** 0.29 Cum extra for pillars \& 0.10 Cum extra for curved surfaces

5. Flooring work

| No | Flooring | Quantum of materials |
| :---: | :---: | :---: |
| 1 | Brick on edge per 10 Sqm with FPS bricks | Bricks -0.565 Cum <br> Cement mortar -0.434 Cum |
| 2 | Flat brick flooring per 10 Sqm with FPS bricks | Bricks -0.385 Cum <br> Cement mortar -0.366 Cum |
| 3 | Moorum flooring 10 cm thick | Moorum - 0.110 Cum |
| 4 | IPS flooring |  |
|  | For Base Concrete with 10 to 20mm metal per cum | Please refer para 2 for quantity of metal, Sand \& Cement per cum of concrete |
|  | For 15 mm thick hardened topping with 1 part of metallic floor hardener, 4 parts of cement \& 9 parts of 6 mm metal | Cement -76 Kg <br> Metallic floor hardner -27.5 Kg <br> Marble chips of $4-6 \mathrm{~mm}-14.0 \mathrm{Kg}$  |
| 5 | All types of tiles set in 20mm thick cement mortar 1:3 per 10Sqm | $\begin{array}{ll} \text { Tiles with } 10 \% \text { wastage } & =11 \mathrm{Sqm} / 10 \mathrm{Sqm} \\ \text { Cement mortar } & =0.224 \mathrm{Cum} / 10 \mathrm{Sqm} \end{array}$ |

## 6. Painting work

The covering capacity of paints varies according to the composition of paint, type of surface to be covered and skill of the painter. One painter can normally paint 45 Sqm to 65 Sqm of surface per day which can be up to 90 Sqm if the surface is of iron sheets and the paint is running freely. For most difficult \& careful works like doors \& windows the same painter can only paint about 20 Sqm.

## (a) Covering area for wood work

(i) Ready mix Primer

- 0.75litres /10 Sqm
(ii) Ready mix paint

First coat paint over primer
Second coat over primer
(iii) Oiling with double boiled linseed oil
(iv) Varnishing

First coat

- 0.80 litres/10Sqm

Second \& subsequent coat

- 0.65 litres/10Sqm
(v) Coal Taring - 1 litre/10Sqm for one coat \& 1.8 litres/10Sqm for 2 coats
(vi) Solignum painting-1 litre/10Sqm for one coat \& 1.7 litres/10Sqm for 2 coats
(b) Covering area for painting galvanized iron / steel works
(i) Red oxide zinc chromate primer
- 0.54 litres/ 10 Sqm
(ii) Synthetic enamel /Aluminum paint (2coats) - 0.80 litres/ 10 Sqm
(iii) Synthetic enamel paint on old work (1coat) - 0.46 litres/10 Sqm
(c) Covering area for white washing \& Color washing (pigment added for color wash)

For one coat (new work)
For two coats (new work)
For three coats (new work)
For one coat (old work)
Pigment for color wash
-1.2 Kg unslaked white lime per 10 Sqm

- 2.2 Kg unslaked white lime per 10 Sqm
- 3.2 Kg unslaked white lime per 10 Sqm
-1.0 Kg unslaked white lime per 10 Sqm
- 0.15 Kg per 10 Sqm
(d) Covering area for distempering

Primer $\quad-0.80$ litres/10 Sqm
Dry distemper $\quad-0.63 \mathrm{Kg}$ for first coat $\& 0.50 \mathrm{Kg}$ for second coat per 10 Sqm
(e) Covering area for snow-cem

Primer

- 0.80 litres/ 10 Sqm

Snow-cem $\quad-3 \mathrm{Kg}$ for first coat \& 2 Kg for second coat per 10 Sqm

## CHAPTER-XIII

## PREPARATION OF ESTIMATES

1.0 Preparation of Abstract Estimates: The Abstract estimate, as described in Chapter XI is mainly for the purpose of examining the justification of any work proposal with cost implications and obtaining the Administrative approval of the competent authority. For other than projects (New lines, doublings, gauge conversions etc. as defined in Chapter XI), the exercise of preparation need not be on a very detailed basis, however work break down structure of a preliminary nature is still required based on the requirement of work spelled out on a not-to-scale, dimensioned drawings. The WBD structure is required mainly to define various elements of the work, if it constitutes more than one element. For example, for construction of a building normally in addition to the civil works of building site development, water supply, drainage, electrification etc will be other elements and the scope of each should be identified.
1.1 For commonly used works the abstract estimate may be prepared on the following basis,
a) BUILDING WORKS: Plinth area rate should be prepared on the basis of any building works done in the nearby area in the past. CPWD and State PWD's also prepare and publish the Plinth Area Rate (PAR) duly update it with building cost index from time to time. These can also be used as the basis or working out the cost estimate of a building proposed. These rates would normally be for average specifications and if some superior specifications in regard to finish, flooring, fittings (Sanitary or otherwise) are to be provided which are not covered by these PAR, the same may be added. The foundations type required may also be confirmed and if it is different from the conventional open footing, additional cost for the same also needs to be incorporated.
b) RAILWAY BRIDGE WORKS: The cost of a major bridge is expected to be equally divided between foundations with sub-structure and super-structure. However, for bridges with open foundations, the cost of foundation with sub-structure is comparatively lesser. If one finds a previously executed work of similar specifications, namely i)type of foundation ii) Type of girders an estimate based on per unit linear length of bridge for each track would give quite acceptable figure. In case of different type of foundation or girders it would be better to follow the approach of Para 4.0 (b) Capter XI i.e. partial work break down method. The work being split in two major parts i) Foundation and ii) Superstructure and individual unit rates per meter of bridge length per track worked out to obtain the cost estimate. Cost of protection works, earth work in approaches and a percentage for whether the work will require diversion or floating equipment for various activities which may be different in the present case may be separately added.
c) MINOR BRIDGE WORKS: In major bridges the length of the bridge opening and type of foundation is the most important parameter, however in minor bridges and culverts like box culverts, Hume pipe culverts, slab culverts it is the width of the bridge (Dependent on the height of the bank) and the bridge opening which is important. Unit rates of culverts of different openings per unit width of barrel length, if available can be used to estimate the cost of minor bridges for preparation of Abstract estimate.
d) ROAD OVER BRIDGE WORKS: This is similar to Railway bridges except for long approaches compared to Railway Bridge. Unit rate per square meter of bridge and approaches should be worked out from past works and can be used to assess the abstract cost of the proposed work. These days some of the local authorities are insisting on fly-over type of ROBs and accordingly the cost of approaches from a similar work only should be used for unit rate for ROB spans to be done by Railway.
e) TRACK WORKS: The track works generally have a major component of stores items and as such it is necessary to adopt latest rates of P.Way stores as issued by Railway Board every year for the purpose of estimates. Ballast can be another major item of work, the rates for which should be taken from the area where the track work is proposed to be done. The rates of ballast are generally fluctuating from area to area and from time to time depending on the availability and demand. It is therefore necessary to take the most recent rates and not historical rates.

The labor rates for execution should be per Km as obtained from past rates of the area. Care should be taken to include the cost of work of Electrical Department for bonding wires in OHE territory and S\&T departments for track circuiting areas and for points and crossing works. Most Zonal Railways have an agreed amount per Km or per turnout with Electrical or S\&T department, and the same can be adopted.
f) WATER SUPPLY WORKS: Water supply works are not very often required to be carried out in the Railways and generally form small component of the building works. Based on experience $7.5 \%$ of the cost of building would be adequate to meet with the plumbing for water supply requirement of a building for normal fittings and fixtures. This percentage can go up to $10 \%$ with superior fittings and fixtures.

For major water supply schemes including pump houses, and other installations a unit cost of commissioning any system, per 1000 liters of water should be obtained from any previous work. This cost may not be available in the Railways as similar works in the recent past might not have been executed, however Building developers and colonizers, including city development authorities will have plenty of such works planned and executed, which can be used to estimate the cost for the proposed water supply scheme.
g) DRAINAGE WORKS: For building works normally no separate provision need be kept for drainage requirements and same can be clubbed with water supply requirements. However, if a separate system for 'Storm water disposal and sewerage disposal' is to be planned the same principle for working out unit rate per person required to be served can be obtained from developers, colonizers etc.

For improvement of drainage in a colony or area, specific survey should be done and requirement of specific areas has to be identified and the estimate has to be based on partial work break down structure as per Para 1.3(b) above. This will include estimated length and size of drains, open as well as covered at a slope giving self cleansing velocity of flow, any requirements of modification to outfall etc. to be designed.
1.2 Contingency Charges: Contingency charges are kept in the estimate to cater for the unforeseen items and situations of minor nature. These are provided for in each sub-head of estimate @ $3 \%$ of the cost of the work. This has been reduced to $1 \%$ now. The provision against contingencies can be used only with the approval of the authority that sanctioned the estimate.
1.3 Departmental Charges: Railway department is required to carry out certain works on behalf of other government departments, other bodies or even private parties and charges at the rate of $12.5 \%$ are levied on the estimated cost. Such works are called as deposit works. $2 \%$ on the cost of work is to be deposited by the party with the railway for preparation of plans and estimates and these are adjusted in the $12.5 \%$ once the work is decided to be executed. Works of ROB portion over Railway line, private sidings, pipeline and other crossings are examples of this. Earlier it was mandatory that deposit works are to be carried out by Railway only. Of late permission has been granted to NHAI for doing the work of ROB portion over track, some local government for construction of subways, pipeline and other crossings through railway track. The common condition in all these is that they should execute the work under the supervision of Railway approved consultants. RITES, KRCL etc. are examples of such supervising consultants.
1.4 HQ Overheads: Railway works including project work requires input as well as time and efforts of departments for successful execution. This may be in the form direct involvement in the project work as well as not so direct involvement like scrutiny of plans, financial scrutiny of proposals, maintaining of account books, procurement of stores, monitoring of works, overall management of project, reporting to Railway Board etc. Therefore provision for all the departments that are directly or indirectly involved in the project is provided in the General Charges including that of finance and vigilance, who have more of a regulatory role to play.

The general charges are broadly divided in two parts - Establishment and other than establishment and the former is further divided into the charges for the field organisation and HQ organisation. Considering the efforts in different kinds of works, the percentage of
each of the departments is fixed and conveyed by Railway Board vide letter No.2000/ E\&R/400/2 dated 20-12-2001. The summary of the charges is tabulated below.

| S. No. | Charges <br> type | Civil <br> (constr- <br> uction) | Civil (GC <br> /Doubling | RE <br> w/o <br> block | Electrica <br> with <br> block | Electrical <br> w/o <br> block | S\&T <br> w/o <br> block | S\&T <br> with <br> block |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1. | Establish - <br> ment | 7.83 | 5.13 | 8.37 | 8.73 | 12.11 | 9.54 | 13.58 |
| 2. | Other than <br> Establishment | 1.30 | 1.30 | 1.35 | 1.45 | 1.45 | 1.15 | 1.15 |
| Total | 9.13 | 6.43 | 9.72 | 10.18 | 13.56 | 10.69 | 14.73 |  |

The details can be seen in the circular. For track renewal estimates the charges are different.

### 1.5 Tools and equipment

Tools and equipment are required in two stages of the project. The first stage is the requirement for the execution of works. These are T \& P like vehicles, rollars, testing equipments etc. The second stage is for maintenance of works for the commissining of the section. The former are chargeable to general charges and from the part of percentage as explained in 1.3 above. The latter is chargeable to the proper head of works.
2.0 Approximate Abstract Cost of works: The table below gives unit abstract cost of some of the frequently used works in the Indian Railways, for guidance only. The rates may vary considerably depending on the area where work is proposed, the year when it is proposed, site peculiarities etc. and should not be adopted without specific verification. Such table should be prepared for the commonly used items, which will make the work of estimating easy and also gives knowledge for comparison of the different alternatives.

| S. <br> NO. | ITEM OF WORK | UNIT | APPX. <br> COST PER <br> UNIT (2008-09) |
| :--- | :--- | :--- | :--- |
| 1 | BUILDING WORK (PLINTH AREA) | SQ.M | Rs.15000 to <br> Rs.20000 |
| 2. | MAJOR BRIDGE(RLYS) \{Deck Area\} | Sqm | Rs.54000 |
| 3. | MINOR BRIDGES/CULVERTS\{Deck Area\} | Sqm | Rs.23000 |
| 4. | ROAD OVER BRIDGES |  |  |
| a | BRIDGE OVER TRACKS $\{D e c k ~ A r e a\}$ | SQ.M | Rs.50,000 |

PREPARATION OF ESTIMATES

| b | APPROACHES FOR MIN. LENGTH REQUIRED \{Deck Area\} | SQ.M | Rs.25,000 |
| :---: | :---: | :---: | :---: |
| 5 | CC APRON/ Ballast less track Rheda2000 | Rm | Rs.38,000 |
| 6. | TRACK WORK (Excl Materials \& Freight) |  |  |
| a | COMPLETE TRACK RENEWAL | Km | Rs.3,50,000 |
| b | DEEP SCREENING | KM | Rs.1,80,000 |
| c | THROUGH SLEEPER RENEWAL | KM | Rs.2,00,000 |
| d | THROUGH RAIL RENEWAL | KM | Rs.1,50,000 |
| e | THROUGH WELD RENEWAL | NO. | Rs. 3000 |
| f | THROUGH TURNOUT RENEWAL | NO. | Rs.1,00,000 |
| g | THROUGH BRIDGE TIMBER RENEWAL WITH STEEL CHANNEL SLEEPERS | No | Rs.20,000 |
| h | THROUGH FITTING RENEWAL (Incl greasing of ERC) | KM | Rs.70,000 |
| 7. | WATER SUPPLY WORKS |  |  |
| a | TUBE WELL WITH HAND PUMP | NO. | 40,000 |
| b | WATER TANK OVERHEAD WITH STAGING | LT. | Rs. 16 |
| c | WATER TANK UNDER GROUND | LT. | Rs. 6 |
| d | WATER TANK SYNTAX WITHOUT STAGING | LT. | Rs. 6 |
| e | WATER TANK PRESSED STEEL PANELS WITHOUT STAGING | LT. | Rs. 24 |
| 8. | Open DRAINS ( 0.6 m wide and 0.9 m deep) | rM | Rs. 4500 |
| 9. | BOUNDARY WALL (2.4M HIGH) | M |  |
| a | -DO- RANDOM RUBBLE MASONARY | M | Rs. 6500 |
| b | -DO- POST AND PANEL RCC | M | Rs. 4500 |
| 10. | FENCING (2.4M HIGH) |  |  |
| a | BARBED WIRE FENCING | M | Rs. 400 |
| b | WOVEN WIRE FENCING | M | Rs. 350 |
| c | TIE-BAR FENCING | M | Rs. 2200 |
| 11. | LEVEL CROSSINGS |  |  |
| a | New unmanned LC <br> (i) Single line <br> (ii) Double line | Eac hEach | Rs. 5 lakhs Rs. 8 lakhs |
| b | New manned LC <br> (i) Single line | Each | Rs. 30 lakhs |
|  | (ii) Double line | Each | Rs. 40 lakhs |

### 3.0 Preparation of Detailed Estimates

The detailed estimate is to be prepared based on the detailed drawings. Detailed drawings do not necessarily mean detailed design but they mean that the dimensions of the structures have been decided. For bridges the GAD should be prepared, which shows the span configuration, type and depth of the foundation, the height and cross section of the piers and abutments, the type of girders and other details(Std. Drawings of RDSO are usually used) which enable making the detailed estimate. For building it means the floor plan, elevation and sectional elevation, the column, footing and beam plan. For yard it means the yard plans showing the line, platforms and turnout details. For earthwork it means that the project sheet which shows the ground levels and the formation levels of the center lines. Type plans for the platforms, platform fencing, level crossing facilities etc. are used. All these form the basis, to make the detailed estimate.

Normally the previously prepared detailed estimates for similar works are a good starting point for preparing the detailed estimate and it helps in systematically taking all the broad items. In addition pondering over the drawings and the site condition is essential so as to not to miss the specific conditions prevailing over the project site.

The Unified SOR has been prepared and issued by Railway Board recently and it contains most of the items but still certain items particularly for the project works may not be there. Some of the railways have come up with a list of standard NS items, which contains the most common items forming substantial percentage of the project cost. These would be good and rich source of the item bank to pick the items from.

It was explained in the previous chapters that the detailed estimate is prepared based on the detailed drawings and work break down structure of the work. The various steps in framing a detailed estimate are as under,

## STEP-1

i. Prepare a work break down structure of the Work/Project.
ii. Assemble them in hierarchical pattern in the pyramid shape, breaking them to smallest level of detail.
iii. Assign the suitable technical specifications to each activity.
iv. Prepare the quantities required in the lowest level activities based on detailed drawings and other field data.
v. Assemble them to form next higher level of activity and so on till you reach the level II activity.

## STEP-2

a) Collect historical rates (LAR) of various items from the jurisdiction of the work.
ii) Collect the rate of inflation (Consumer Price Index) of the past 3-4 years from the RBI bulletins.
iii) Collect the market rates of major stores items like Cement, Reinforcement Steel, Permanent way, Quarry products etc. The rates of P.way are issued by Railway Board annually and current rates be only adopted. The prices of steel, cement are fluctuating quite a lot in the recent past and an average of last one year should be worked out based on rates published in 'Builders Friend' or 'Economics Times' or any other reputed publication. Rates of Quarry products are generally site specific and market rates from the neighborhood area only should be obtained.
iv) Obtain the rates of Taxes applicable i.e. Sales tax on works contract, VAT on various major items, rate of royalty on quarry products in last 3 years, any local taxes, levies etc. imposed by municipality or panchayats. These should be obtained not only for the work proposed but also of the works for which the LARs are available.
v) Obtain the site conditions and accessibility of site which are likely to affect the rates.

## STEP-3

i) Prepare a table bringing the various historical rates to present day rates using the compounded rate of escalation.
ii) Compare the present rate of major materials and other inputs used in the work, to the rates in last 3-4 years for which LARs are available. If found varying more than $5 \%$, the LAR should be modified using the material factor, $I_{m}$
iii) Compare the site conditions of the present work to the conditions of works executed in the past and work out a correction index $I_{s}$.
iv) Compare the taxes, local taxes levies etc of the present site and the works done in the past and work out a correction factor $I_{t}$
v) Prepare unit rates from basics for new items of work.
vi) The unit rates should then be prepared for all items using the various corrections ( $I_{m}, I_{s}, I_{t}$ to each element), 1 item on 1 sheet. Lump sum item clubbing up small insignificant items can also be prepared, however back up data should be shown in the sheet.

## STEP-4

i) Tabulate the quantity schedule at Level-III (1less than the lowest level) duly incorporating the level -IV elements.
ii) Fill in the unit rates obtained above and calculate the cost of each and level III, Level-II and finally Level-I to obtain the cost of works.
iii) A provision for unforeseen items is finally added to each part @ $2 \%$ of the cost of schedule.
iv) Direction and general charges as per rates permitted for different type of work is added to the value of work obtained in iii) above.

Listing of items for the major works like earthwork, bridges, buildings and track work are given in the table below. If a similar list is prepared it will not only ensure that items of work are not missed out but it also provides a framework for collection of the rates and preparation of the detailed estimates. These also make the person making the estimate to think systematically.
4.0 Level of Break-Down of Work: The work break down structure and the brief description of items used for a few common types of works are given in following paragraphs for illustration. The level to which any item of work should be broken, depends upon the level at which data is available. If for example, detail estimate of a major bridge with pile foundation, reinforced concrete substructure and PSC superstructure is to be prepared we can break down this work as under,


The next level of breaking down of each of these may or may not be required depending on the availability of information at that level. For example, if pile of specified diameter and specifications is not a commonly executed item of work in any organization, required to break it down to lower levels, as shown below, other wise there is no need to break it down to lower levels.


However, in the other case also the break down to one level lower is considered more convenient to segregate the stores from other material and labor etc. Generally, the detailed estimate is framed under the same items as would be followed for tender schedule, if it is not a Lump Sum contract. For a better appreciation of the concept, following works, generally used in Construction department, have been broken down and would form part items of detailed estimate and also the Tender schedule.
4.1 Bridge Sub-structure with pile foundation:

| S. No. | Item Description | Unit | Components where used |
| :--- | :--- | :--- | :--- |
| 1 | Bored cast-in-situ RCC piles in concrete <br> grade M:35 of diameter 1m/1.2m with all <br> materials labor, tools, equipment, admixtures <br> etc (Cement and Steel shall be paid separately) | RM |  |
| 2 | Supplying, fabricating and erection in position <br> MS liner made from 6 to 8 mm thick plate | MT |  |
| 3 | Supplying and providing TMT/HYSD r <br> einforcement steel in RCC work of all type | MT | Separate item for supplying to enable <br> application of Price variation clause <br> (PVC) |
| 4 | Cutting, bending, binding and placing in <br> position reinforcement steel supplied as <br> per item No 3. | MT |  |
| 5 | Load testing of Pile <br> (a) Initial test as per IS code IS 7911 <br> (b) Routine test as per IS code 7911 | Each <br> Each | The unit can also be test load in <br> tone |
| 6 | Earthwork in excavation in all types of <br> soil except rock requiring blasting (RRB) | cum | For pile cap excavation, foundation of <br> wing wall, return wall, toe wall etc |
| 7 | Chiseling in RRB with mechanical means | cum | - $\quad$ do - |
| 8 | Excavation using controlled blasting | cum | - $\quad$ do - |
| 9 | CC M:10/1:3:6 in leveling course | cum | for all concrete works for leveling <br> course |
| 10 | RCC M:30 in foundation and substructure | cum | For Pile cap, pier and abutment |
| 11 | Supply of cement Grade -53 | Ton |  |
| Note: Since PVC clause for cement and steel is separate it is necessary to have the rates to work out <br> the cost of cement so that PV can be calculated on that amount. This is normally done either by having <br> separate item for supply and utilization for all the RCC/CC works or by specifying a fixed rate in the <br> tender conditions which will be used for calculating the cost of cement/Steel. |  |  |  |


| 12 | Corrosion protection of steel reinforcement using CECRI (Centre for Electro-chemical | MT | Fusion bonded Epoxy Coating (FBPP) can also be used alternatively. Inclusion of this Research Institute), Karaikudi treatment item has to be done after due consideration of site conditions |
| :---: | :---: | :---: | :---: |
| 4.2 Bridge work - PSC Superstructure |  |  |  |
| 1 | Providing and fixing in position HTS strands 12T13 or 19 T 13 for Pre-stressed concrete work with supply and fixing in position of HDPE sheathing, stressing the same and grouting the cable duct | MT | Alternatively some of the Railways keep the work of sheathing, stressing and grouting with the pre-stressed concrete item payable in cum. Bright metal sheathing or CRCA sheathing is also used for |
| 2 | Supplying and fixing the end anchorages for .strands | Each set | Rate is for one set for both the ends of the strand. Separate item for 12T13, 19 T 13 etc. |
| 3 | PSC M:40/45 for girder with 20 mm stone aggregate | cum |  |
| 4 | RCC M:35 in superstructure with 20 mm stone aggregate | cum | For bed block, ballast wall, deck slab, diaphragm, crash barrier, parapet, trolley refuge etc. |
| Note: The item of centering and shuttering is normally included in the respective item of concrete. However in the unified SOR prepared for all zonal Railways shuttering is a separate payable item per sqm. |  |  |  |
| 5 | RCC M: 35 in superstructure with 20 mm stone aggregate | cum | For bed block, ballast wall, deck slab, diaphragm, crash barrier, parapet, trolley refuge, box culverts etc. |
| 6 | Supplying and placing in position Elastomeric Bearing on the pedestal/prepared surface | Cu. cm. | Alternatively POT PTFE bearing can be provided and the unit is normally each bearing of a particular load capacity e.g. 160 ton. This is normally provided for spans greater 30 m |
| 7 | Launching and erection of the PSC girder in position as per the approved scheme | Per span | This item will be operated only when the girder is not cast in the final location. i.e.this item will not be operated in case the girders are cast-in-situ |
| 8 | Epoxy based painting on the exposed surface of the PSC girder | $\begin{aligned} & \hline \text { Per } \\ & \text { span } \end{aligned}$ | This item has to be decided for each work based on environmental condition and location |


| 4.3 Bridge work - Mass CC work - For return, wing wall, face wall of Hume pipe, and other mass CC elements. |  |  |  |
| :---: | :---: | :---: | :---: |
| 1 | CC M:20/M:25 with 40 mm stone aggregate | cum | For foundation and mass concrete substructure - abutment, pier, retaining wall, wing and return wall, face wall of hume pipe etc. |
| 2 | Boulder filling behind abutment/wing wall etc. | cum | Slope of $1: 1$ is to be assumed for |
|  | Backfilling with granular material specified by RDSO | cum | calculation of quantities |
| 5.0 Earthwork in formation in embankment and cutting |  |  |  |
| 1 | Jungle clearance including shrubs | $\begin{array}{\|l\|l} 10 \\ \text { sqm } \end{array}$ | Normally area 1 m beyond the toe is to be taken. In some railways it is included in the earthwork item. |
| 2 | Earthwork with contractor's earth in embankment including mechanical compaction | cum | No deduction in quantities for voids. In some railways item of compaction in cum is paid separately |
| 3 | Earthwork in cutting for formation including side drains in all types of soil except RRB with a free lead of 300 m for cut spoils | cum |  |
| 4 | -do- with controlled blasting (material will not be used for filling in embankment) and stacking within a lead of 300 m | cum | The provision for stacking should be kept depending on the usability of cut spoils and the payment for cutting will be as per cross section measurements |
| 5 | -do- with open blasting (material will not be used for filling in embankment) and stacking within a lead of 300 m | cum | - do - |
| 6 | Extra for mechanical compaction of cut spoils up to free lead of 300 m | cum |  |
| 7 | Extra for leading of cut spoils beyond free lead of 300 m above item No. 6 | Per <br> cum perkm | Lead will be computed for whole km or part thereof |
| 8 | Supplying, spreading and compacting of coarse sand/granular material at specified locations | cum | Used for ground improvement |
| 9 | Blanketing over completed earthwork of specified thickness including mechanical compaction as per RDSO specifications | cum |  |


| 10 | Pitching of slopes with boulders | cum | Normally the thickness is 300 mm and this item is also used in bridges |
| :---: | :---: | :---: | :---: |
| 11 | Turfing of slopes | sqm |  |
| 12 | Providing barricading to protect the adjacent running lines | RM | Inflexible and reasonably strong barrier made of angle iron with wire/Gl sheet horizontally |
| 6.0 Foot over Bridge and Platform Shelter Foot over Bridge and Platform Shelter |  |  |  |
| Item for foundation and concrete including reinforcement can be taken from bridge items. In filled up soils o black cotton soil where under-reamed piles may be required, separate item with RM as unit to be included. |  |  |  |
| 1 | Supplying and fabrication of structural steel as per approved drawing including two coats primer | MT |  |
| 2 | Erection of fabricated steel | MT |  |
| 3 | Painting with ready mixed paint | sqm | Aluminum paint is preferred |
| 4 | AC sheet/aluminium/roofing including fixing with bolts | sqm |  |
| 5 | AC Ridging | RM | For aluminium generally no separate item is required |
| 6 | AC sheet gutter | RM | - do - |
| 7 | HDPE/CI/MS/GI down take pipe including all bents | RM | Item of bell mouth may be extra or MS steel bell mouth may be paid under fabrication |
| 8 | Supplying erection and Grouting of Holding down bolts in foundation | Kg |  |
| 9 | Pre-cast RCC M:25 for steps and precast slabs | cum | For FOB |
| 10 | Tiling using chequered concrete tiles or suitable tiles | sqm |  |
| 11 | Whitewashing of AC sheet | sqm |  |

### 7.0 Track Work:

| 1 | Dismantling and transportations of MG/BG <br> track including turnouts etc. to a specified <br> PWI depot. | RM | This item is mostly required in GC work <br> and yard remodeling works. Separate <br> rate for BG and MG. For dismantling of <br> turnout payment is normally made @ <br> 1.6 times of plain track and that for LC <br> and bridge as 1.3 times. |
| :--- | :--- | :--- | :--- |

$\left.\begin{array}{|l|l|l|l|}\hline 2 & \text { Deep screening of track } & \text { RM } & \\ \hline 3 & \begin{array}{l}\text { Carting of rails of any types including switches } \\ \text { and crossings and placing them on/along the } \\ \text { completed bank }\end{array} & \begin{array}{l}\text { MT } \\ \text { KM }\end{array} & \\ \hline 4 & \begin{array}{l}\text { Carting of sleeper from the Concrete Sleeper } \\ \text { Factory and stacking along the bank }\end{array} & \begin{array}{l}\text { MT } \\ \text { KM }\end{array} & \\ \hline 5 & \begin{array}{l}\text { Dressing and Rolling of formation using } \\ \text { blanketing material to be paid separately }\end{array} & \text { sqm } & \text { Total formation width to be considered } \\ \hline 6 & \text { Spreading and compaction of ballast by rolling } & \text { cum } & \begin{array}{l}\text { Extra lead may have to be considered } \\ \text { in cases of cuttings or other constraints } \\ \text { where ballast cannot be taken along the } \\ \text { track }\end{array} \\ \hline 7 & \begin{array}{l}\text { Linking of track with 60 kg/50 kg rail in main } \\ \text { line and yard on sleeper density 1540/1660 } \\ \text { including LC, ballasted deck bridges }\end{array} & \text { RM } & \begin{array}{l}\text { Separate items for different sleeper } \\ \text { density. The unit is per meter of track }\end{array} \\ \hline 8 & \begin{array}{l}\text { Extra for fabrication and fixing of check rail } \\ \text { on LC/guard rail on ballasted deck }\end{array} & \text { RM } & \\ \hline 9 & \text { Extra for linking of SEJ } & \begin{array}{l}\text { Each } \\ \text { set }\end{array} & \begin{array}{l}\text { RM }\end{array} \\ \hline 10 & \begin{array}{l}\text { Linking of track on girder bridges including } \\ \text { fixing of channel sleepers }\end{array} & \begin{array}{l}\text { In certain railways the rate for fixing of } \\ \text { channel sleepers is per No. and track is } \\ \text { per RM and there is a separate item for } \\ \text { fixing guard rails. }\end{array} \\ \hline 12 & \begin{array}{l}\text { Manual Through Packing of track for making } \\ \text { the track fit for 30 kmph for machine tamping }\end{array} & \text { RM } & \begin{array}{l}\text { Separate sub item is to be made for } \\ \text { each type of turnout. In case of turnout } \\ \text { laid under block normally } 1.5 \text { to 2.0 } \\ \text { times the rate for turnout without block is } \\ \text { specified in the conditions }\end{array} \\ \hline 13 & \begin{array}{l}\text { Machine packing } \begin{array}{l}\text { st round with Railways } \\ \text { packing machine }\end{array} \\ \text { and minor repairs. Practice varies from }\end{array} \\ \hline 11 & \begin{array}{l}\text { Assembling and Linking turnouts } 1 \text { in } 8.5 / 1 \text { in } \\ \text { 12/derailing switch/diamond etc. }\end{array} & \begin{array}{l}\text { This item is for providing assistance for } \\ \text { packing which includes labor for pre }\end{array} \\ \text { and post tamping work, consumables }\end{array}\right\}$

| 14 | Supplying spare parts for tamping machine <br> and UNIMAT as per the list |  | Price list is a part of the estimate |
| :--- | :--- | :--- | :--- |
| 15 | Supplying and providing warning boards, <br> speed indicator boards | Each <br> /MT | Florescent boards if required will have <br> to be so specified |
| 16 | Making dead end buffer of rail/concrete as <br> per approved drawing | Each | Unserviceable rail, if required will be <br> supplied free of cost but has to be taken <br> in the estimate |
| 17 | ATwelding including supply of potions/ Flash <br> butt welding using mobile FBW plant | Per <br> joint | Separate rates have to be there for <br> welding on cess and in track |
| 8.0 Platform walling |  |  |  |
|  |  |  |  |

Note: Item of excavation, concrete in leveling course, concrete in foundation will be same as in bridge works using suitable grade of concrete

| 1 | Brick work cement mortar 1:4 in foundation | cum | Qty for foundation and up to offset near <br> RL to be taken. |
| :--- | :--- | :--- | :--- |
| 2 | Brick work cement mortar 1:4 up to plinth | cum | Qty above offset near RL to be taken. |
| 3 | Pointing in cement mortar 1:2 | sqm | For area above formation level. |
| 4 | Precast RCC M-20 or CC M-20 in coping, <br> including fixing. ( Surface finished with <br> XPM mark) | cum | Coping 750mm wide and 150mm deep <br> to be considered. |
| 5 | Colour washing | sqm |  |
| 6 | Preparing sub-base using oversize ballast or <br> hand-packed boulders of specified thickness <br> ranging from 100-150 mm | sqm |  |
| 7 | Base concrete M:15 over the prepared <br> sub-base | cum | be referred to decide about the type of |
| 8 | Platform surfacing using vacuum dewatered <br> concrete/kota stones/tiles etc. <br> surfacing | sqm | RDSO guidelines for type of flooring to |
| 9 | Platform fencing-Brickwork/Pre-cast concrete <br> /Palisade/Tie bar/random rubble masonry | cum/ <br> sqm |  |

Note: Passenger amenity items like platform benches, water fountain, station name board, platform toilets, non-electric signages and boards etc. as per station classification and traffic are to be included.

Note: Alternatively, the platform brickwork in wall may also be done in pre-cast Z-section or un-coursed/ random rubble masonry depending on the local practices and the materials available

| 9.0 RCC overhead tank |  |  |  |
| :---: | :---: | :---: | :---: |
| 1 | Excavation in foundation, CC M-15 in leveling course, reinforcement. |  | Same items as above can be taken |
| 2 | RCC M-20/M-25 in foundation | cum |  |
| 3 | RCC M-25 in columns and beams | cum |  |
| 4 | RCC M-30 in water retaining structure, such as slab, beams, domes, side walls etc. | cum | This item includes the PVC water stopper |
| 5 | Cl double flange pipe 100/150/200 mm diameter. | m |  |
| 6 | Ductile Iron pipes 80/100/150/200 mm diameter. | m |  |
| 7 | CI specials | Kg |  |
| 8 | Sluice valves 80/100/150/200 mm diameter. | Each |  |
| 9 | Water level indicator | One set |  |
| 10 | Lightening conductor | One set |  |
| 11 | Painting of concrete surface with food grade epoxy paint. | sqm | For inside painting of tank , surface in touch with water. |
| 12 | Painting / Color washing (Snowcem or Apex) | sqm | Qty for outer exposed area. |
| 13 | Steelwork in staircase and platform and railing etc. | MT |  |
| 10.0 Civil works in Level crossing |  |  |  |
| 1 | Excavation in foundation | cum |  |
| 2 | Paver block 150mm thick made of M-40 CC. | sqm |  |
| 3 | Filling moorum or good quality granular soil including compaction. | cum |  |
| 4 | CC in foundation M-20 for gate post and lifting barrier foundation | cum |  |
| 5 | Fabricating and fixing check rails. | m | Qty for RM of check rail i.e. for 1 m track 2 m check rail is required. |
| 6 | Rail post erection. | MT |  |
| 7 | Providing and fixing lifting barrier as per approved drawing of required boom length to be specified | Per set | Lifting barriers at interlocked gates is fixed by S\&T department and those on non-interlocked gate by Engg.department in some railways |


| 8 | Gate leaf supply, fabrication and erection. | MT |  |
| :---: | :---: | :---: | :---: |
| 11.0 Buildings and Quarters |  |  |  |
| 1 | Excavation, Leveling course, reinforcement items can be taken same as above. |  |  |
| 2 | a. CC/ RCC in foundation M-20 | cum |  |
|  | b. Boring and casting RCC M-25 Single under reamed piles of diameter 300/350/400/450mm | RM |  |
|  | c. Boring and casting RCC M-25 double under reamed piles of diameter 300/350/400/450mm | RM |  |
| 3 | Sand filling in foundation and plinth. | cum | This item is required generally in black cotton soil area. |
| 4 | Good quality moorum or granular soil filling and compaction in plinth. | cum | For plinth filing. |
| 5 | Boulder filling / oversize ballast filling hand packed in floors. | cum | Unit can be kept as sqm also for specified depth. |
| 6 | CC M-15 in flooring | cum | Unit can be kept as sqm also for specified depth. |
| 7 | Floor finish IPS/ mosaic tiles / ceramic tiles | Sqm |  |
| 8 | Brick work second class in cement mortar 1:4 up in foundation and plinth | cum | Alternatively concret blocks, random rubble masonry can also be used. Fly ash bricks are to be preferred. |
| 9 | Brick work second class in cement mortar 1:6 up in superstructure | cum | Fly ash bricks are to be preferred. |
| 10 | RCC M-25/ M-20 in columns / beams / slab | cum |  |
| 11 | Door and window frames | Cum <br> RM/ <br> Kg | Units would depend on the type of material |
| 12 | Door shutters | Sqm |  |
| 13 | Window shutters | Sqm | Item rate to include cost of glass also. |
| 14 | Inside painting with oil bound distemper | Sqm | Specification are to be seen for |
| 15 | Outside painting with cement based paint (Snowcem) | Sqm | surface preparation and number of coats |
| 16 | Whitewash | Sqm |  |
| 17 | Painting wood and steel work | Sqm |  |


| 18 | Water proofing of wet area like kitchen sink area, toilet, bathroom, sunken floors etc. | Sqm |  |
| :---: | :---: | :---: | :---: |
| 19 | GI/UPVC pipe providing and fixing 15/20/40/ 50 mm diameter | M | Tees and bends are included |
| 20 | Bib cock 15 mm | Each |  |
| 21 | Stop cock 15 mm | Each |  |
| 22 | Sluice valves/quarter turn valve of various sizes |  |  |
| 23 | WC pan orissa pattern / anglo Indian / European style including flushing cistern | each |  |
| 24 | Kitchen Sink | Each |  |
| 25 | Supplying, hoisting and fixing in position one piece moulded single wall construction, high/low density polyethylene U.V. Stabilized water tanks | Liters |  |
| 26 | Float valve 15/20/25 mm diameter | Each |  |
| 27 | Wash basin | Each |  |
| 28 | Nahani traps / gully traps | Each |  |
| 29 | Pre constructional anti- termite treatment. | Sqm |  |
| 30 | RCC NP-2 pipes 150/200 mm dia | M | For sewerage conduits |
| 31 | Stone ware pipes 100/150 mm diameter | M |  |
| 32 | Cl pipes 75/100 mm dia | M |  |
| 33 | CP shower | Each |  |
| 34 | CP towel rail 400/600/750 mm long. | Each |  |
| 35 | Providing and fixing Cudappah / Marble / Granite slabs of specified thickness in dado and kitchen platform, partitions of shelves. | sqm |  |
| 36 | UPVC / AC/CI Rain water pipes 100/150mm dia | M |  |
| 37 | Fabricating and erection steel work in small sections | MT |  |
| 38 | Providing and fixing mosquito proof SS mesh | Sqm |  |
| 39 | Brass fittings such as hinges, handles etc. | Kg . |  |

Note : This is not an exhaustive list of works but most other works can be broken down in similar way.

## CHAPTER-XIV

## WAY LEAVE FACILITIES

## 1. Introduction

Section 16 \& 17 of Indian Railway act 1989 enjoin upon the railways to make and maintain specified works for accommodation of owners and occupiers of the lands adjoining the railway for the purpose of making good any interruptions caused by the Railway to the use of lands through which the railways is made. These accommodation works as per section 16 of the act may include the following:-
(a) All crossings such as bridges, culverts, Road over bridges, road under bridges
(b) All crossings for carrying water, oil, gas \& drainage pipe lines, electric cables
(c) All crossings for carrying cables for communication, cable TV
(d) Passage or pathway through railway land.

Some of the accommodation works are under ground and others are overhead.

## 2. Incidence of cost \& compulsion on railway for accommodation works

As per section 16 of the Indian Railway act 1989, the cost of the accommodation works will be borne by the railway only during or immediately after the laying out of the formation of the railway over the lands traversed. However the railway administration shall not be liable to execute any further or additional accommodation works for use of owners or occupiers of the lands after expiry of ten years from the date on which the railway passing through the lands was first opened for traffic.
In all other cases, the cost of providing accommodation works which are considered necessary and agreed by the railway administration has to be borne by the owners/users of the adjacent land or the state government or local authorities in case of public facilities. In such cases the cost of maintenance of accommodation works will also have to be borne by them

## 3 Way leave charges

The way leave charges to be levied as per policy circulars issued by the Board till 2009 are given in table on next page.
Notes for table on the next page:-

1. For item $1(\mathrm{a})$ to (e) \& 2(a), the length of land involved should not exceed 50 m .
2. Any proposal for passage/road of width more than 3 m should be dealt under land licensing.
3. For any crossing, minimum width of land to be taken as 1 m for purpose of assessment of way leave charges. For electrical crossings width of land to be decided in consultation with Sr.DEE concerned.
4. For $1(\mathrm{f}) \& 2(\mathrm{a})$ to (d) \& 3 (a) to (b), way leave charges are payable in advance in block of 10 years with annual increase of $7 \%$ per year with discounting of future cash inflow at prevailing interest rates of RBI for Govt securities to be adjusted as per actual market rates at the time of payment of installment for next 10 years. Sample calculation is given in para 4 below.

| No | Case | Way leavecharges |
| :---: | :---: | :---: |
| 1 | (a) Passage or pathway along/across railway land, Cattle crossings (Up to 1 m wide) for pedestrians, cyclists etc.. | One time recovery of Rs.6400/- (way leave facility for 35 years renewable by 35 years |
|  | (b) Water pipeline crossing for individual farmers | One time recovery of Rs.12800/- (way leave facility for 35 years renewable by 35 years |
|  | (c) Electric crossings for individual houses, shops etc- both under ground \& overhead |  |
|  | (d) Water/sewerage pipe lines for individuals upto 300 mm dia |  |
|  | (e) Electricity crossings for state electricity boards and central bodies |  |
|  | (f) ROB/RUB which are under taken on deposit terms and do not involve closure of LC for the portion of ROB/RUB lying over/below railway track as the case may be and also noe LC | Rs.6000/- PA up to two land road crossing two tracks \& Rs.12000/- PA in case wider than 2 lanes or crossing more than 2 tracks |
| 2 | (a) Passage/road wide enough for vehicles (ie. 1 m to 3 m ) by housing societies, private firms, organizations etc | $6 \%$ of market value of land subject to minimum of Rs. 5000/- PA |
|  | (b) Public roads by local bodies/ state Govt \& autonomous bodies, charitable/welfare organizations | 6\% of market value of land subject to minimum of Rs. 10000/- PA |
|  | (c) Under ground water/sewerage/effluent pipe lines |  |
|  | (d) Underground/over head electrical crossing other than those covered under 1 (c) above, OFC \& other than cable TV |  |
| 3. | (a) Open drains \& over ground water/sewerage/oil/gas/effluents pipe lines by private parties including PSU | $10 \%$ of market value of land subject to minimum of Rs.20000/- PA |
|  | (b) Under ground oil/gas pipe lines |  |
| 4. | For cable TVs (Length of track crossing not to exceed 50 m and length along tract not to exceed 500 m . Dia of under ground pipe not to exceed 300 mm \& over ground laying is not permitted) | 3 years charges + 1 year charges as security deposit to be collected in advance |
|  | (a) Charges in Metros:- |  |
|  | (i) Way leave charges | Rs.6000/- per annum |
|  | (ii) Addl supervision charges | Rs.5000/- per annum for single track crossing \& Rs.3000/- per annum for every track |
|  | (b) charges in other than metros |  |
|  | (i) Way leave charges | Rs.3000/- per annum |
|  | (ii) Addl supervision charges | Same as per 4(a)(ii) |
|  | (c) charges for cables laid parallel to railway track in metro as well as non metros | Rs.50/- per RM per annum |
|  | (d) charges for cables within Railway colonies | Free |
|  | (e) License fee for structure up to 15Sqm \& land up to 20 Sam for making base stn | AS per terms of commercial licensing |

### 4.0 Sample calculation for way leave charges for 10 years with discounted cash flow:-

Area of land $=100$ Sqm
Rate of land = Rs.1000/- per sqm
Cost of land = Rs.1,00,000/-
Min charges per annum = Rs.10,000/-

| Yr | Cost of land with 7\% incremental increase PA | Rate of way leave charges | Calculated way leave charges | Annual Way leave charges (subject to min) | Discount factor at 7\%(divide successivel y by 1.07) | Way leave to be paid in advance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | Rs. 1,00,000/- | 6\% | Rs.6000/- | Rs.10,000/- | 1.0000 | Rs.10,000/- |
| 2 | Rs. 1,07,000/- | 6\% | Rs.6420/- | Rs.10,000/- | 0.9346 | Rs.9,346/- |
| 3 | Rs.1,14,490/- | 6\% | Rs.6869/- | Rs.10,000/- | 0.8735 | Rs.8,734/- |
| 4 | Rs. 1,22,504/- | 6\% | Rs.7350/- | Rs.10,000/- | 0.8163 | Rs.8,163/- |
| 5 | Rs.1,31,080/- | 6\% | Rs.7865/- | Rs.10,000/- | 0.7629 | Rs.7,629/- |
| 6 | Rs. 1,40,255/- | 6\% | Rs.8415/- | Rs.10,000/- | 0.7130 | Rs.7,130/- |
| 7 | Rs.1,50,073/- | 6\% | Rs.9004/- | Rs.10,000/- | 0.6664 | Rs.6,663/- |
| 8 | Rs. 1,60,578/- | 6\% | Rs.9635/- | Rs.10,000/- | 0.6228 | Rs.6,227/- |
| 9 | Rs. 1,71,819/- | 6\% | Rs.10309/- | Rs.10309/- | 0.5820 | Rs.6,000/- |
| 10 | Rs. 1,83,846/- | 6\% | Rs.11031/- | Rs.11031/- | 0.5439 | Rs.6,000/- |
| Way leave charges to be paid in advance for 10 years = |  |  |  |  |  | Rs.74,892/- |

### 5.0 Powers for granting way leave facilities

DRMs are delegated powers for grant of way leave facilities. All way leave facilities should be processed through Sr.DEN(Co). Way leave facilities involving more than 100m length of railway land will require GM's approval in consultation with FA\&CAO.

## APPENDIX - I

## UNITS \& CONVERSION FACTORS

## 1. Metric System and Units \& Subunits

The advantage of Metric system over other systems is that the units are multiples of tens or 1/10th and therefore the calculations are very easy. For civil engineering works, metric system has been adopted in Indian Railways, Para E-739 (Engineering code) requires following units be adopted,

| Item | Unit |
| :---: | :---: |
| Length | Meter or Km. |
| Area | Sq M, or Are=100 SqM, Hectare=100 Ares |
| Volume | CuM or Liter |
| Velocity | M/Sec |
| Weight | Kg or Quintal=100Kg or Tonne $=1000 \mathrm{Kg}$ |
| Power | Kg-m/Sec |
| Heat/Energy | Joules (Calorie=4.1868 Joules) |
| Discharge | CuM/Sec |

The units of rates for various items of works should be adopted as per Para E-740 which are given as under,

| Item | Unit |
| :---: | :---: |
| Earth work | Per 100CuM |
| Brick work, Concrete, Pise work, |  |
| Stone masonry, Pitching and Wood work | Per CuM |
| Painting, Plastering, Flooring, Roofing, Turfing | Per SqM |
| Doors and Windows | Per SqM |
| Land | Per Hectare |
| New Road metal ling work | Per 100 SqM |

The sub-units in metric system are named by suitable prefixes like mili (one thousandth), centi (one hundredth), deci (one tenth) etc... The multiple units are named deca (ten times), hecto (hundred times) \& Kilo (thousand times) etc...

The prefixes for formation of multiple and sub-multiple units are given below:-

| No | Prefix | Symbol | Numerical value | In Scientific <br> notation |
| :--- | :--- | :---: | :--- | :---: |
| 1 | Atto | a | 0.000000000000000001 | $10^{-18}$ |
| 2 | Femto | f | 0.000000000000001 | $10^{-15}$ |
| 3 | Pico | p | 0.000000000001 | $10^{-12}$ |
| 4 | Nano | n | 0.000000001 | $10^{-9}$ |
| 5 | Micro | $\mathrm{\mu}$ | 0.000001 | $10^{-6}$ |
| 6 | Milli | m | 0.001 | $10^{-3}$ |
| 7 | Centi | c | 0.01 | $10^{-2}$ |
| 5 | Deci | d | 0.1 | $10^{-1}$ |
| 6 | Deca | da | 10 | 10 |
| 7 | Hecto | h | 100 | 102 |
| 8 | Kilo | k | 1000 | 103 |
| 9 | Mega | M | 1000000 | $10^{6}$ |
| 10 | Giga | G | 1000000000 | 109 |
| 11 | Tera | T | 1000000000000 | 1012 |
| 12 | Peta | P | 1000000000000001 | 1015 |
| 13 | Exa | E | 1000000000000000001 | 1018 |
| 14 | Zetta | Z | 1000000000000000000001 | 1021 |
| 15 | Yotta | Y | 1000000000000000000000001 | 1024 |

Illustrations

| 1 Kilometre $=1 \times 10^{3}$ metres $=1000$ metres | 1 millimetre $=1 \times 10^{-3}$ metres $=0.001$ metre |
| :--- | :--- |
| 1 Kilogram $=1 \times 10^{3}$ grams $=1000$ grams | 1 milligram $=1 \times 10^{-3}$ grams $=0.001$ gram |
| 1 Kilolitre $=1 \times 10^{3}$ litres $=1000$ litres | 1 millilitre $=1 \times 10^{-3}$ litres $=0.001$ litres |

### 1.1 Units of mass \& capacity

In metric system there are simple relationships between the units of length, capacity and mass. The capacity of a cube whose sides measures one decimeter (I tenth of meter ie ten centimeters) is designated as one liter which is the unit for capacity. For practical purposes, the mass of water contained in that cube with sides of one decimeter (I liter) is one Kilogram which is the unit of weight. In true sense, liter is volume occupied by one
kilogram of pure water at temperature of $4^{\circ}$ under normal atmospheric pressure. The prototype of kilogram is a platinum cylinder whose diameter \& height are 39 mm .

### 1.2 Square measure \& cubic measure

In engineering works, square meter and cubic meters are standard unit for area and volume. Square meter is area equivalent to that of a square of sides equal to one meter and cubic meter is volume equivalent to that of a cube of sides equal to one meter. When larger areas are measured, higher units are often used.

## 2. International System Of Unit (SI Units)

This is the latest system of units and similar to MKSA system described above. In addition to the basic units, there is also a derived unit in the SI System.

## (a) Basic units of SI system of units

The SI system includes seven units - Meter (m) for length, Kilogram (kg) for mass, Second (s) for time, Ampere (A) for electric current, Degree Kelvin (K) for thermodynamic temperature, mole for unit of substance (used in chemistry) in terms of atoms of carbon-12 and Candela (Cd) for luminous intensity. These are called the basic units of SI system of units.
(b) Derived units

The expressions for the derived SI units are stated in terms of basic units as per examples shown below:-
(1) Square meter for area
(2) Cubic meters for volume
(3) Meter per second for velocity (length covered in unit time)
(4) Meter per second ${ }^{2}$ for acceleration (increase in velocity in unit time) \& deceleration (decrease in velocity in unit time)
(5) Newton (N) for absolute unit of force. Force is the product of mass and acceleration. When a body of mass of 1 Kg moves with an acceleration of one meter/second ${ }^{2}$, then the force on the body is one Newton. One Newton is equal to one $\mathrm{kg} x$ one meter/ second ${ }^{2}$
(6) Kilogram- force (Kgf) for gravitational unit of force. When a body of mass of 1 Kg moves with acceleration due to gravity ( 9.81 meter/second²), then force exerted is called one Kgf.
(7) Joule ( J ) for energy. Energy is the capacity to do work. Work is defined as the product of force and displacement in the direction of the force. One Newton-meter is one joule i.e. 1 joule is equal to one $\mathrm{Kg} . \mathrm{M}^{2}$ per Second ${ }^{2}$
(8) Watt (W) for power. Power is rate of doing work i.e. work divided by time. One Watt is equal to one joule per second.
(9) Pascal ( Pa ) is unit of pressure. One Pascal is pressure generated by force of one Newton per Sqm area.
(10) Hertz is the unit of frequency. One hertz indicates that one cycle of phenomenon/revolution occurs every second.

## 3. OTHER OLD SYSTEM OF UNITS

While SI system is the international system a slight modification of MKSA system, used on the Indian Railways, some old drawings and records do contain units in older systems, which are as below,

## (a) FPS system

This is a very old British system in which basic units are foot, pound \& second. One foot is equal to 0.3048 m and one pound is equal to 0.4535924 kg .
(b) CGS system

Here the basic units are centimeter, grams \& second. Here also there are derived units as per few examples shown below
a. Unit of force is in Dynes. One gm.cm.per Second ${ }^{2}$ is one dyne
b. Unit of work/energy is ergs i.e. 1 dyne. $\mathrm{cm}=1 \mathrm{gm} . \mathrm{cm}^{2}$.per Second ${ }^{2}$
(c) MKS system

Here the basic units are meter, kilogram, second \& Ampere. This was modified into SI system of units by simply adding units of Degree Kelvin (K) for thermodynamic temperature, mole for quantity of substance in terms of atoms of carbon-12 and Candela (Cd) for luminous intensity.

## 4. CONVERSION OF UNITS:

### 4.1 TEMPERATURE

There are three units of temperatures namely, Centigrade or Celsius (C) , Fahrenheit $(\mathrm{F}) \& \mathrm{Kevin}(\mathrm{K})$. Kevin is an SI unit but most commonly used unit is Centigrade (C).
(a) Centigrade or Celsius

Here the melting point of ice is taken as $0^{\circ} \mathrm{C}$ and temperature of steam point is taken as $100^{\circ} \mathrm{C}$. In between the units are divided into 100 units with each division as $1^{\circ}$.
(b) Fahrenheit

On this scale $32^{\circ} \mathrm{F}$ represents the melting point of ice and $212^{\circ} \mathrm{F}$ represents the steam point. The length between the standard points (melting point of ice \& steam point) is divided into 180 equal parts and each division is $1^{\circ} \mathrm{F}$.

## (c) Kevin

This is an SI unit of temperature which is independent of thermal properties of a substance. Temperature is average kinetic energy of the molecules of a substance and the molecules seize to have kinetic energy when the temperature of the substance should be zero in absolute terms. By careful calculations Lord Kevin concluded that zero Kelvin corresponds to $-273^{\circ} \mathrm{C}$.

### 4.1.1 Relation ship between centigrade and Fahrenheit

In between melting point of ice and steam point we have 100 divisions in Centigrade scale and 180 divisions in Fahrenheit scale. As length between the standard points ie melting point of ice and steam point are same we can say that 100 divisions of Celsius is equal to 180 divisions of Fahrenheit between these standard points. Therefore five graduations on centigrade scale will be equal to 9 graduations of Fahrenheit scale. Therefore $5^{\circ} \mathrm{C}$ (from the diagram below) will be equal to $32+9=41^{\circ} \mathrm{F}$.

|  |  | $0^{\circ} \mathrm{C}$ | 100 graduations | C | $100^{\circ} \mathrm{C}$ |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $0^{0} \mathrm{~F}$ | 32 |  | 180 graduations | F | $212^{\circ} \mathrm{F}$ |

graduations
From above diagram it is clear that $C:(F-32)=100: 180$

$$
\begin{aligned}
(\mathrm{C} / 100) & =(\mathrm{F}-32) / 180 \\
(\mathrm{C} / 5) & =(\mathrm{F}-32) / 9
\end{aligned}
$$

### 4.1.2 Coefficient of linear expansion \& temperature stress

The increase in length per unit of original length per degree centigrade rise in temperature is called co-efficient of linear expansion.

$$
\text { Increase in length }(\delta)
$$

a) Coefficient of linear expansion $(\alpha)=$ per deg. C
Orig. length (L) x change in
Temperature in ${ }^{\circ} \mathrm{C}(\mathrm{t})$
From the above formula, the expansion/contraction of rail of length ' $L$ ' for change in temperature of 't' is given by formula, $\delta=L \alpha t$,
b) Or Thermal strain $=\delta / L=\alpha t$

The modulus of linear expansion of steel $(\alpha)=1.152 \times 10^{-5}$ per degree centigrade.
c) Thermal stress in metals (Due to increase/decrease of temperature)
$=$ Modulus of elasticity of metal x thermal strain $=\mathrm{E} \times(\delta / \mathrm{L})=\mathrm{E} \alpha \mathrm{t}$
d) Thermal Force $=$ Cross-sectional area $\times \mathrm{E} \times \alpha \times \mathrm{t}$

### 4.2 LENGTH:

The conversion factors in same system of unit as well as from one system of unit to the other are given in various tables below:-

| British units | British/UK into metric unit | Metric to British/UK units |
| :--- | :--- | :--- |
| 12 inches $(\mathrm{in})=1$ foot $(\mathrm{ft})$ | 1 inch $=25.4 \mathrm{~mm}$ | $1 \mathrm{~mm}=0.03937$ inches |
| 3 feet $=1$ Yard $(\mathrm{yd})$ | 1 feet $=0.3048 \mathrm{~m}$ | 1 meter $=3.28084$ feet |
| 22 Yards $=1$ chain | 1 mile $=1.609344 \mathrm{Km}$ | $1 \mathrm{Km}=0.62137$ miles |
| 10 chains $=1$ furlong | 1 furlong $=201.168 \mathrm{~m}$ |  |
| 8 furlongs =1 mile | 1 chain $=20.1168 \mathrm{~m}$ |  |
| 1 UK nautical mile $=6080$ feet | 1 rod/pole/perch <br> $=5.0292 \mathrm{~m}$ |  |

### 4.3 Area :

| British units | British/UK into metric unit | Metric to British/UK units |
| :---: | :---: | :---: |
| 144 Sq inches $=1 \mathrm{Sq}$ foot | $1 \mathrm{sq} \mathrm{ft}=0.092937 \mathrm{Sqm}$ | $1 \mathrm{Sqm}=10.76 \mathrm{Sq} \mathrm{ft}$ |
| 9 Sq feet $\quad=1 \mathrm{Sq}$ Yard | $1 \mathrm{Sq} \mathrm{Yd}=0.836127 \mathrm{Sqm}$ | $1 \mathrm{Sqm}=1.19599 \mathrm{Sq} \mathrm{Yd}$ |
| 1210 Sq yard = 1 rood | 1 Sq inch $=0.000645 \mathrm{sqm}$ | 1 Sqm = 1550 Sq inches |
| $\begin{array}{ll}4 \text { roods } & =1 \text { acre } \\ & (4840 \mathrm{Sq} \text { yds })\end{array}$ | $1 \mathrm{acre}=4046.86 \mathrm{Sqm}$ |  |
| 640 acres $=1$ Sq mile | 1 Ares = 100 Sqm |  |
|  | 1 Hectare $=10000$ Sqm |  |

### 4.4 Volume :

| British units | British into MKS | Remark |
| :--- | :--- | :--- |
| 1728 Cu inches = 1 cu foot | 1 UK gallon $=4.54609$ liter |  |
| 27 Cu feet =1 cu yard | 1 US gallon = 3.78541 liter | 1 cum = 1000 liters |

### 4.5 Capacity :

| UK units of capacity | US units of capacity for liquid measure | US units of capacity for dry measure |
| :---: | :---: | :---: |
| 60 minims = 1 fluid drachms | 60 minims $=1$ fluid dram | 2 dry pints = 1 dry quart |
| 8 fluid drachms = 1 fluid ounce | 8 fluid drams = 1 fluid ounce | 8 dry pints $=1$ peck |
| 5 fluid ounce $=1$ gill | 4 fluid ounce $=1$ gill | 4 pecks = 1 bushel |
| 4 gills $=1$ pint | 4 gills $=1$ liquid pint | 7056 cu inches = 1 dry barrel |
| 2 pints $=1$ quart | $\begin{gathered} 2 \text { liquid pints }=1 \text { liquid } \\ \text { quart } \\ \hline \end{gathered}$ |  |
| 4 quarts = 1 UK gallon | 4 liquid quart = 1 US gallon |  |
| 2 UK gallons = 1 peck | 42 US gallons $=1$ barrel (for petroleum) |  |
| 4 pecks $\quad=1$ Bushel |  |  |

4.6 Mass :

| UK - Avoirdupois units | UK - Apothecary units | US units | Indian units |
| :---: | :---: | :---: | :---: |
| $\begin{gathered} 16 \text { Ounces }(o z)=1 \\ \text { pound }(\mathrm{lb}) \end{gathered}$ | 20 grains = 1 scruble | $\begin{aligned} & 2000 \text { pounds = } 1 \\ & \text { short ton } \end{aligned}$ | 180 grains = 1 tola |
| 28 pounds = 1 Quarter | 3 scrubles = 1 drachms | $\begin{aligned} & \hline 2240 \text { pounds }=1 \\ & \text { long ton } \\ & \hline \end{aligned}$ | 80 tolas $=1$ seer |
| 4 quarters=1 hundred wt | 1 drachms=1 ounce | $\begin{aligned} & 1000 \text { pounds }=1 \\ & \text { kip } \end{aligned}$ | 40 seers $=1$ maund |
| 20 hundred weights= 1 ton | 1 ounce $=480$ grains |  |  |
| 14 pounds = 1 stone | $\begin{aligned} & 1 \text { troy ounce } \\ & =1 \text { apothecaries' ounce } \\ & =480 \text { grains } \\ & \hline \end{aligned}$ |  |  |
| 1 pound = 7000 grains | 1 pound $=0.4535924 \mathrm{~kg}$ | $1 \mathrm{~kg}=2.20462$ pound |  |

### 4.7 Miscellaneous

| 1 iron $=1 / 48$ inches | 1 dozen $=12$ |
| :--- | :--- |
| 1 nail $=21 / 4$ inches | 1 score $=20$ |
| 1 hand $=4$ inches | 1 gross $=12$ Doz |
| 1 ell $=45$ inches | 1 quire $=24$ sheets |
| 1 mil $=0.001$ inch | 1 ream $=20$ quires |

## SCHEDULE OF DIMENSIONS FOR B.G.

The SOD for B.G. was last revised in 2004 contains two schedule i.e. schedule I and II. Schedule-I consists of those items which are mandatory and have to be observed on all 1676 mm Gauge Railways in India and schedule II consists of existing infringements of schedule I which may be permitted to continue on existing 1676 mm Gauge Railways.
The dimensions given in schedule-I have been classified under two heads namely for 'Existing works' and for 'New works'. Existing works means the works which were existing before 2004. New works would include all new constructions, additions of new lines/ structure, gauge conversion and doubling. However it will not include the works of alteration such as shifting of points and crossings, extension of siding, building etc.
In this chapter some dimensions of schedule I are given which are useful for preparing yard plan/ drawings of any structure to be constructed near railway track.

| Sr. <br> No. | Description | For Existing <br> work (mm) | For New <br> work / <br> Alteration <br> to existing <br> works (mm) | Remarks |
| :--- | :--- | :--- | :--- | :--- |
| 1. | Minimum Distance centre to <br> centre of track | 4265 mm | 5300 mm | * Extra clearances <br> upto 50 curve has <br> been accounted for. |
| 2. | Minimum Radius of curves | 175 m <br> $(10$ degree) |  | Check rail rails to be <br> provided in curves of <br> $10^{\circ}$ and more |
| 3. | Building and structure |  | 1905 mm | Refer Annexure -I <br> and II for extra <br> clearance required <br> for curves |
| i. Minimum horizontal <br> distance from centre of track <br> to any structure from rail <br> level to 305 mm above RL | 1675 mm |  | For existing works <br> only. For new work <br> refer dimension <br> under item iii to viii |  |
|  | ii. Minimum horizontal <br> distance from centre of track <br> to any structure except a <br> platform From 305 mm above <br> rail level to 4420mm above <br> rail level | 2135 mm |  |  |


|  | iii. From 305 to 1065 mm above RL | - | 1905-2360 | increasing to 2360mm |
| :---: | :---: | :---: | :---: | :---: |
|  | iv. From 1065 to 3355mm | - | 2360mm |  |
|  | v. From 3355 to 4420 mm | - | 2360-2135 | decreasing to 2135 mm |
|  | vi. From 4420 to 5870 mm | - | 3135-915 | decreasing to 915mm |
|  | vii. Below the rail level upto the formation level of the track on straight and curve up to radius 875 m | - | 2575 mm |  |
|  | viii. Below the rail level upto the formation level of the track on straight and curve with radius less than 875 m | - | 2725 mm |  |
| 4. | Minimum horizontal distance of any telegraph post measured from the centre of the track at right angle to nearest track | The height of the post + 2135 mm | The height of the post + 2360 mm |  |
| 5. | i. Minimum height above rail level for a distance of 915 mm on either side of the centre of track for overhead structure | 4875mm |  |  |
|  | ii. Where 25 KV A.C. traction is likely to be used, minimum height above rail level for a distance of 1600 mm on either side of the centre of track shall be: <br> a. Light over head structure such as FOB <br> b.Heavy overhead structure such as ROB or flyover bridges | $6250 \mathrm{~mm}$ $5870 \text { mm }$ |  | a.See Appendix for extra clearances on curve. <br> b.On field, it is preferred to keep minimum height 6250mm even in case of ROB. |
|  |  |  |  |  |


| 6. | Minimum horizontal distance <br> measured at right angle from <br> nearest track to structure <br> carrying electrical conductors <br> crossing a railway | Height of <br> structure in <br> meter above <br> ground level <br> $+6 m$ |  |  |
| :--- | :--- | :--- | :--- | :--- |

Tunnels, through and semi-through girder bridges ( See diagram No. 1A and1-A modified)

| 7. | Minimum distance centre to centre of track | 4495mm | 4725mm |  |
| :---: | :---: | :---: | :---: | :---: |
| 8. | Minimum horizontal distance from centre of track of track to any structure |  |  |  |
|  | i. From RL and upto 305 mm | 1095mm |  |  |
|  | ii. From 305mm to 1065mm | $\begin{array}{\|l\|} \hline 1095- \\ 2360 \mathrm{~mm} \end{array}$ |  | Increasing to 2360mm |
|  | iii. From 1065mm to 3355 mm | 2360mm |  |  |
|  | iv. From 3355 mm to 4420 mm | $\begin{aligned} & 2360- \\ & 2135 \mathrm{~mm} \end{aligned}$ |  | Decreasing to 2135mm |
|  | v. From 4420 mm to 5870 mm | $\begin{aligned} & \text { 2135- } \\ & 915 \mathrm{~mm} \end{aligned}$ |  | Decreasing to 915mm |
| 9. | Maximum distance apart of trolley/safety refuges on Bridges with main spans of less than 100 m | 100 m |  | On Bridges with main span of 100 m or more refuge over each span to be provided |
| Station Yard |  |  |  |  |
| 10. | Minimum distance centre to centre of track | 4265mm | 5300 mm |  |
| 11. | Maximum Gradient in station yard | 1 in 400 | 1 in 1200 |  |
| Platforms |  |  |  |  |
| 12. | Horizontal distance from centre of track to face of passenger /Goods platform coping- | $\begin{aligned} & 1680 / \\ & 1670 \mathrm{~mm} \end{aligned}$ |  | Maximum / <br> Minimum |


| 13 | Horizontal distance from centre of track to face of any platform wall Maximum/ Minimum | $\begin{aligned} & \hline 1905 / \\ & 1675 \mathrm{~mm} \end{aligned}$ |  | New platform wall should be constructed to maximum dimensions |
| :---: | :---: | :---: | :---: | :---: |
| 14 | Height above rail level for high passenger platform Maximum/ Minimum | 840/760 |  | 1. The height in superelevated curved track should be measured from the plane passing through the top of both the rails <br> 2. No passenger platform will be constructed in curve having radius less than 875 M |
| 15 | Maximum height above rail level for medium level passenger platform | 455 mm |  |  |
| 16 | Maximum height above rail level for goods platform (except horse and end loading platforms) | 1065 mmm |  |  |
| Buildings and structures on Platform |  |  |  |  |
| 17. | Minimum horizontal distance of any building on a passenger platform from centre line of track - |  |  |  |
|  | i. From P/F level to 305 mm to 5330 mm | 5180mm | 5180mm |  |
|  | ii. From 305 mm above P/F level to 3430 mm above rail level | 5330 mm | 5330 mm | Increasing uniformly to 5330 mm |
|  | iii. From 3430 mm above rail level to - <br> a. 4115 mm above RL in case of existing work b.For new - 3430 to 4610 above RL | 5330-3810 | 5330-3810 | Decreasing uniformly to 3810mm |
| 18 | Minimum horizontal distance of any building or longitudinal boundary fence from the face of the platform coping of passenger platform which is not on island platform (Minimum) | - | 5485 mm | $\begin{aligned} & \text { Recommended } \\ & 10210 \mathrm{~mm} \end{aligned}$ |


| 19 | Minimum horizontal distance from C/Lof track to a pillar, colomn, lamp post or similar isolated structure on a passenger platform or any building on a goods platform |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | i. From P/F level to 305 mm above platform level | 4570mm | 4570mm | Increasing uniformly to 4720 mm |
|  | ii. From 305 mm above P/F level to 3430 mm above rail level | 4720 mm | 4720mm |  |
|  | From 3430 mm above rail level to 4115 mm above RL | 4720-3810 | 4720-3810 | a.) Decreasing uniformly to 3810 mm . <br> b.) In case of new work 3430-4610mm above RL |
| 20. | Minimum horizontal distance from C/Lof track to a pillar, colomn, lamp post or similar isolated structure on a goods platform |  |  | A structure covering area less than 3716 sq.m should only be considered |
|  | i. From P/F level to 305 mm above platform level | 3960-4110 | 3960-4110 | Increasing uniformly to 4110 mm |
|  | ii. From 305 mm above P/F level to 3980 mm above rail level in case of existing work | 4110 mm | 4110mm | From 305 to 4310 mm above rail level in case of new work |
|  | iii. From 3980mm above rail level to 4115 mm above RL in case of existing works | 4110-3810 | 4110-3810 | a) Decreasing uniformly to 3810 mm <br> b) For new work-4310-4610mm above RL |


| 21. | Minimum height above RL for a width of 1600 mm on either side of the centre of track, of tie rods or any continuous covering in a passenger station | 6250mm |  |  |
| :---: | :---: | :---: | :---: | :---: |
| 22. | Minimum, horizontal distance from centre of track to any structure |  |  |  |
|  | i. From RL to 305 mm above rail level | 1675 mm | 1905mm |  |
|  | ii. From 305 m above rail level to 3355 mm above RL | 2135 mm | 1905-2360 | a. Increasing to 2360mm <br> b. From 305m above rail level to 1065mm above RL in case of new works |
|  | iii. From 1065 mm above rail level to 3355 mm above RL | - | 2360mm | a. For new works only |
|  | iv. From 3355mm above RL to 4420mm above RL | - | 2360-2135 | b. Decreasing uniformly to 2135 mm |
|  | v. From 3355mm above RL to 4115 mm above RL | 2135-1980 | 2135-1980 | From 4420mm above RL to 4610mm above RL for new works |
|  | vi. From 4115 mm above RL to 6250 mm above RL on main line | 1600 mm | 1600mm | From 4610mm above RL to 6250mm above RL for new works. |
|  | vii Below the rail level up to the formation level of the track on straight and curve up to radius of 875 m | - | 2575 mm | These will not be applicable in case of bridges |


|  | viii. Below the rail level up to the formation level of the track on straight and curve up to radius less than 875 m | - | 2725 mm |  |
| :---: | :---: | :---: | :---: | :---: |
| 23 | Points and crossings |  |  |  |
|  | i. Minimum radius of curvature for T/out, cross over, slip points | 218 metre | 8 degree |  |
|  | ii. Minimum angle of crossing (ordinary) | 1 in 16 |  |  |
|  | iii. Diamond crossings not to be flatter than | 1 in 8.5 | CRS | Up to 1 in 10, if recommended by |
| Work shops and Station Machinery |  |  |  |  |
| 24 | Water tanks and cranes |  |  |  |
|  | i. Minimum height above rail level for discharge orifice of water crane | 3660 mm |  |  |
|  | ii. Distance from centre of track to face of tank house less than 60 metre beyond the end of passenger platform Minimum | 7165 mm | 11890mm | Recommended- |
| 25. | Workshops and running sheds |  |  |  |
|  | Minimum distance from centre to centre of tracks in W/shop | 4570mm |  | In running sheds5260 mm |
| 26. | Minimum clear distance from centre of track to any isolated structure such as pillar in work shops | 2285 mm | 2360mm | Running sheds 2515mm |
| 27 | Minimum clear distance, for a height of 1830 mm above rail level, from centre of track to any continuous structure in Work shops | 2745 mm |  | In Running sheds 3275 mm |


| 28 | Minimum height above rail <br> level to overhead tie bars, <br> girders etc. in Work shops <br> and Running sheds | $5030 /$ <br> 6250 mm | 6250 mm where <br> electric traction is <br> likely to be used |  |
| :--- | :--- | :--- | :--- | :--- |
| 29 | Minimum height above rail <br> level of door ways for a width <br> of 1370 mm on either side of <br> centre of track in both <br> Work shops and Running <br> sheds |  |  |  |

## ANNEXURE-A

EXTRA CLEARANCES ON CURVES FOR HIGH SPEED ROUTES (160 KMPH)

| $\begin{array}{c}\text { Degree } \\ \text { of } \\ \text { Curvature }\end{array}$ | $\begin{array}{c}\text { Radius } \\ \text { of } \\ \text { curve }\end{array}$ | $\begin{array}{c}\text { Maximum } \\ \text { permi- } \\ \text { ssible } \\ \text { speed }\end{array}$ | $\begin{array}{c}\text { Super } \\ \text { eleva- } \\ \text { tion }\end{array}$ | $\begin{array}{c}\text { Extra Clearance } \\ \text { between structure } \\ \text { and adjacent track }\end{array}$ |  | $\begin{array}{c}\text { Outside } \\ \text { of } \\ \text { curve } \\ \text { ht. }\end{array}$ | $\begin{array}{c}\text { Extra } \\ \text { Clearance } \\ \text { adjacent } \\ \text { track } \\ \text { when }\end{array}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| there |  |  |  |  |  |  |  |
| is no |  |  |  |  |  |  |  |$]$| structure |
| :---: |
| between |
| track |$|$

## APPENDIX - III

## CLASSIFICATION OF ACCOUNTS OF EXPENDITURE

1.0 GENERAL: The expenditure so also the earnings in Indian Railways is maintained in a scientific manner so as to trace and monitor it to a great degree of accuracy. The officials dealing with expenditure and proposals for expenditure i.e. the Estimates must have knowledge of the system adopted in Railways. The hierarchical tree below shows the various levels of details any expenditure is required to be maintained.

2.0 Demand for Grant: Minister of Railways presents the budget proposal for expenditure of the coming year, before the Parliament divided in 'Demands for grant'. There are 16 demands for grants, sometimes simply referred as demands. The first 15 demands are for revenue expenditure and demand 16 is for other than revenue i.e. for acquisition of assets. The names of various demands are as shown under,

| Demand <br> No. | Name of Demand | Group |
| :--- | :--- | :--- |
| 01. | Railway Board | Policy Formulation and <br> Services Common to all <br> Railways |
| 02. | Miscellaneous Expenditure (General) |  |
| 03. | General Superintendence and Services <br> on Railways. (GM's office, DRM's office, <br> vigilance etc.) | General Superintendence <br> and Services on Railways |


| 04. | Repairs and Maintenance of Permanent <br> Way and Works. | Repairs and Maintenance |
| :--- | :--- | :--- |
| 05. | Repairs and Maintenance of Motive Power |  |
| 06 | Repairs and Maintenance of Carriages <br> and Wagons. |  |
| 07 | Repairs and Maintenance of plant and <br> Equipment |  |
| 08. | Operating Expenses-Rolling Stock and <br> Equipment. | Operation |
| 09. | Operating Expenses-Traffic. |  |
| 10. | Operating Expenses-Fuel. | Staff Welfare, Retirement <br> Benefits and Miscellaneous |
| 11. | Staff Welfare and Amenities. |  |
| 12. | Miscellaneous Working Expenses. | Provident Fund, Pension and other <br> Retirement Benefits. |
| 13. | Appropriation to Funds. | Railway Funds and payment to <br> General Revenues. |
| 14. | Dividend to General Revenues, <br> Repayment of loans taken from General <br> Revenues and Amortization of over <br> Capitalization. |  <br> replacement |
| 15. |  |  |
| 10 |  |  |

The Civil engineers are normally dealing with only 3 demands as under,
4- Repairs and Maintenance of Permanent Way and Works
11- Staff Welfare and amenities
16 - Assets- Acquisition, Construction \& Replacement,
Further details are furnished in following paras.
3.0 Minor Head, Sub-Head, and Detailed Head: Each "Demand for Grant" or simply "Demand" is further sub-divided in Minor Heads, each minor head sub-divided in SubHeads and each sub-head divided into Detailed Head. The Minor Head is also known as Plan Head when we are talking about planned expenditure i.e. under demand 16. The various minor heads, sub heads and detailed heads for the above mentioned demands are given under.

### 3.1 DEMAND NO.4- Repairs and Maintenance Of Permanent Way And Works.

| Minor Head | Sub-Head | Detailed head |
| :---: | :---: | :---: |
| 100. Establishment in offices | 110. Officers \& office establishment | 111.Civil Engineers - other than workshop. |
|  |  | 112 Civil Engineering - Workshop. |
|  |  | 113 Bridge Engineering -other than Workshop. |
|  |  | 114 Bridge Engineering - workshop |
|  |  | 115 Office Establishment - Way and Works other than workshops. |
|  |  | 116 Office Establishment - Way and Works Workshops. |
|  |  | 117 Office Establishment - Bridge - Other than workshop. |
|  |  | 118 Office Establishment-Bridges - Work shop. |
|  | 120 Supervisory staff \& their office staff | 121 Subordinate Supervisory staff-Permanent Way |
|  |  | 122 Subordinate Supervisory staff-works. |
|  |  | 123 Subordinate Supervisory staff-Bridges. |
|  |  | 124 Subordinate Supervisory staff-Workshop |
|  |  | 125 Office staff-Permanent Way. |
|  |  | 126 Office staff-Works. |
|  |  | 127 Office staff-Bridges. |
|  |  | 128 Office staff-Workshop |
|  | 130 Contingent expenses | 130 Same. |
| 200. Maintenance <br> Of Permanent Way. | 210 Group 'A' (B.G.) | 211 Manual Maintenance. |
|  |  | 212 Maintenance by Machines. |
|  |  | 213 Ballasting |
|  | 220 Group 'B' (B.G.) | 221 to 223 As in 211-213. |
|  | 230 Group 'C' (B.G.) | 231 to 233-As in 211-213 |
|  | 240 Group'D' (B.G.) | 241 to 243 -As in 211-213 |
|  | 250 Group E ${ }^{1}$ (B.G.) | 251 to 253-As in 211-213 |
|  | 260 Group'Q'(M.G.) | 261 to 263-As in 211-213 |
|  | 270 Group 'R' (M.G.) | 271 to 273-As in 211-213 |
|  | 280 Group 'S' (M.G.) | 281 to 283-As in 211-213 |
|  | 290 Narrow Gauge | 291 Maintenance. |
|  |  | 293 Ballasting. |

APPENDIX - III

| 300 Maintenance of <br> Bridge work and Tunnels including Road over/ under bridges. | 310 Girder Bridges | 310 Same. |
| :---: | :---: | :---: |
|  | 320 Other Bridges | 320 Same. |
|  | 330 Tunnels | 330 Same. |
|  | 340 Road over/under bridges including Foot-over bridges. | 340 Same. |
| 400 Maintenance of service buildings (other than staff Quarters and Welfare blgs) | 410 Office buildings | 410 Same. |
|  | 420 Stations, Goods Sheds | 420 Same. |
|  | 430 Workshops and Stores | 431 Workshops. |
|  |  | 432 Sheds. |
|  |  | 433 Stores. |
|  | 440 All other structures | 440 Same. |
| 500 Water supply, <br> Sanitation and <br> Roads (other than Colonies, staff Quarters \& Welfare blds). | 510 Water supply | 510 Same. |
|  | 520 Sanitation | 520 Same. |
|  | 530 Service Roads and | 531 Stations, Goods sheds,Office buildings, etc |
|  | Others (Misc.) | 532 Fencing and Level crossing etc. |
| 600 Other repairs \& maintenance. | 610 Shore connections At ferries | 610 Same. |
|  | 620 Station machinery other than water supply arrangements | 620 Same. |
|  | 630 Conservancy of Rivers | 630 Same. |
|  | 640 Trees, plantations, | 641 Hedges and Lawns. |
|  | Nurseries etc. | 642 Nurseries. |
|  |  | 643 Tree plantations. |
|  |  | 644 Others. |
|  | 650 Misc. expenses | 651 Carriage of Revenue Stores. |
|  |  | 652 Loss of cash |
|  |  | 653 Loss of stores- Physical Loss |
|  |  | 654 Loss of stores due to depreciation/ deterioration. |
|  |  | 655 Over/under charges in manufacturing repairs and on cost. |
|  |  | 656 Other adjustments. |
|  |  | 657 Other miscellaneous expenses. |
| 700 Special repairs pertaining to Breaches, Accidents etc. | 710 Breaches | 711 Earthwork, |
|  |  | 712 Bridges. |
|  |  | 713 Permanent Way. |
|  |  | 714 Ballast. |


| including Special Revenue works. |  | 715 Miscellaneous. |
| :---: | :---: | :---: |
|  | 720 Accidents <br> 730 Others | 721 to 725 -As 711 to 715 above 731 Formation Treatment. |
| 900 Credits or recoveries. | 910 Credits for materials released from Revenue works. | 911 Dismantling charges. |
|  |  | 912 Credits for material released from Revenue Works charged to "Ordinary Revenue". |
|  | 920 Share of credits for freight charges on Railway material including coal. | 921 Share of credits for freight charges on Railway coal |
|  |  | 922 Share of credits for freight charges on Diesel oil. |
|  |  | 923 Share of credits for freight charges on Railway stores and material. |
|  | 930 Write back of the cost of Military Sidings initially charged to Capital. | 930 Same. |

### 3.2 DEMAND NO. 11: (Staff Welfare and Amenities)

As for other demands this demand also has minor heads 100 to 900, but civil engineers maintain the residential and welfare building units for which the minor head used is only 500.

| Minor Head | Sub-Head | Detailed head |
| :---: | :---: | :---: |
| 500. Repairs and Maintenance of Residential \& Welfare Buildings | 510 Residential Buildings- All types | 511 Civil Engineering Maintenance Permanent Buildings. |
|  |  | 512 Civil Engineering Maintenance Temporary Buildings. |
|  |  | 513 Electrical Repairs and Maintenance Permanent Buildings. |
|  |  | 514 Electrical Repairs and Maintenance Temporary Buildings |
|  | 550 Welfare Building. | 551 Civil Engineering Maintenance |
|  |  | 552 Electrical Repairs and Maintenance |
|  | 560 Water supply and Sanitation | 561 Civil Engineering Maintenance |
|  |  | 562 Electrical repairs and maintenance |
|  | 570 Improvements in Railway Colonies | 571 Civil Engineering Works. |
|  |  | 572 Electrical Works. |
|  | 580 Supply of Energy for Power and Lighting. | 581 Supply of Energy for Power and Lighting in Rairway Quarters including power for street lighting, pumps etc. |
|  |  | 582 Deduct cost of Energy recovered from Railway staff. |

### 3.3 DEMAND NO. 16: (Asset acquisition Construction and Replacement)

As mentioned earlier the Minor Heads are also called Plan Heads when referring to Demand 16, i.e. Planned Expenditure. These are tabulated below,

| Minor/ Plan Head | Name of Plan Head | Minor/ Plan Head | Name of Plan Head |
| :---: | :---: | :---: | :---: |
| 1100 | New Lines(Construction) | 3600 | Other Electrical Works |
| 1200 | Purchase of New Lines | 4100 | Machinery and Plant |
| 1300 | Restoration of dismantled lines | 4200 | Workshops incl. Production units |
| 1400 | Gauge conversion | 5100 | Staff Quarters |
| 1500 | Doubling | 5200 | Amenities for Staff |
| 1600 | Traffic facility-Yd remodeling etc | 5300 | Passenger and other user Amenities |
| 2100 | Rolling Stock | 6100 | Investments in Govt. <br> Commercial undertakings <br> Road services |
| 2900 | Road safety Works(L. Xing) | 6200 | Investment in Govt.Commercial Undertakings- PSUs |
| 3000 | Road safety works(ROB/RUBs) | 6400 | Other specified Works |
| 3100 | Track renewals | 7100 | Stores suspense |
| 3200 | Bridge Work | 7200 | Manufacturing suspense |
| 3300 | S\&T Works | 7300 | Miscellaneous advances |
| 3400 | Taking over of line wires from P\&T | 8100 | Metropolitan transport Projects |
| 3500 | Electrification Projects |  |  |

4.1 Sub-Heads and Detailed Heads under Demand-16: The sub-heads and detailed heads for all minor heads (Plan Heads) under Demand 16 are same as given for New Lines (Construction) in the table below,.

| Minor- head / <br> Plan Head(LEVEL-I) | Sub-Heads (LEVEL-II) | Detailed Heads (LEVEL-III) |
| :--- | :--- | :--- |
| 1100 New Lines - | 111 Preliminary expenses | 1111 Survey expenses. |
| Construction |  | 1112 Plant. |
|  |  | 1113 Establishment. |
|  |  | 1114 Miscellaneous. |


|  | 1120 Land | 1120 Land |
| :---: | :---: | :---: |
|  | 1130 Structural Engineering Works - Formation. | 1131 Earthwork 1132 Tunnels. |
|  | 1140 Structural Engineering Works-- Permanent Way. | 1141 Rails and fastenings |
|  |  | 1142 Sleepers and fastening |
|  |  | 1143 Points and crossings. |
|  |  | 1144 Ballast |
|  |  | 1145 Fencing. |
|  | 1140 Structural Engineering Works-- Permanent Way. | 1146 Road crossings including foot over/ under bridges at stations and other places |
|  |  | 1147 Miscellaneous. |
|  | 1150 Structural Engineering Works- bridges | 1151 Major bridges-Steel work |
|  |  | 1152 Major bridges-Masonry |
|  |  | 1153 Major bridges Miscellaneous |
|  |  | 1154 Minor bridges-Steel works |
|  |  | 1155 Minor bridges-Masonry |
|  |  | 1156 Minor bridges Miscellaneous |
|  | 1160 Structural Engineering Works- Stations and Buildings | 1161 Offices |
|  |  | 1162 Stations.. |
|  |  | 1163 Workshop and Stores Buildings including Electric Power Stations and sub stations |
|  |  | 1164 Other Service Buildings |
|  |  | 1165 Residential Buildings. |
|  |  | 1166 Buildings and other works in con-nection with staff welfare. |
|  |  | 1167 Station machinery. |
|  |  | 1168 Shore connection for ferry steamers. |
|  | 1170 Equipment, Plant and Machinery | 1171 Overhead Power lines and Trac-tion Equipment. |
|  |  | 1172 Underground cables. |
|  |  | 1173 Electric Telegraphs and |


5.0 Sources of Funds: For a better planning of planned works (Demand-16), separate allocation is made from the receipts of earning into different Railway Funds. These are Capital, depreciation Reserve Fund (DRF), development Fund (DF), Revenue (Open line works revenue) and Safety Fund (SF).Whenever any work is approved under Demand-16, it will have to get fund from either of the funds listed above. The nature of work i.e. new assets, replacement of assets, development of additional facilities for customers, minor expenditure for improvement of assets required for operations or fund requirement for carrying out works for safety of trains and customers determines as to which source of fund, the expenditure be charged to.

For computerization the following alphabets are used to denote these funds, P-Capital, R-Revenue (OLWR), T- safety Fund, Q-Depreciation Reserve Fund and S- Development fund However, where the computers are not being used for accounting, prefixes as below are used,

| Head Of Account | Symbol | What is charge |
| :--- | :--- | :--- |
| Capital(P) | P | New Assets |
| Depreciation Reserve <br> Fund (DRF) (Q) | Q | Works involving replacement of assets |
| Open Line Works <br> Revenue (OLWR) | R | (a) Un-remunerative traffic facility works <br> costing less than Rs.10.00 lakhs <br> (b) Bridge works costing less than <br> Rs.10.00 lakhs |
| Development Fund <br> (I) DF(I) | DF(I) | Passenger amenity works |
| Development Fund <br> (II) DF(II) | DF(II) | Staff amenity works |
| Development Fund <br> (III) DF(III) | DF(III) | Safety works/ traffic facilities |

6.0 Classification Code: Whenever one prepares a proposal for sanction of any work, service or any procurement of store etc, the allocation from which funds will be allotted have to be indicated along with the demand No., Minor head, sub-head and detailed head. The allocation of expenditure/estimates consists of 2 or 4 modules divided by a dash inbetween is as below,
(a) For demand Nos. 1 to 15 i.e. charged to revenue the allocation is of 5 digits, first 2 digits representing the Demand No. and last 3 digits representing the detailed head. Each set of nos. namely representing the Demand no. and detailed head is called a module i.e. 1 st module and $2^{\text {nd }}$ module and they are separated by a dash to avoid any confusion.
Example :- Allocation for manual maintenance of track on Rajdhani Route will be 04-211 (First two digit (04) denoting demand no i.e. Repairs and maintenance of P.Way and last three digit denote detailed head i.e. manual maintenance on Gr'A' route)
(b) For demand No. 16 however there are 7 digit alpha numeric code. In demand 16 , the demand no is not appearing in the code rather this demand is divided in several Plan Heads which appear in the code. Any allocation of 7 alphanumeric code, itself indicates that it is under Demand 16 as for demand No. 1 to 15, the code has only 5-digits.

| Module-1 | Module-2 | Module-3 |
| :--- | :--- | :--- |
| Alpha | Four Digit No. | Two Digit No. |
| P,Q, R, DF(I), | Detailed Head | Primary Unit |
| DF(II),DF(III) \& SF |  |  |

Example: Allocation for expenditure on Steel Girders for major Bridge to be constructed for a new line project will be P-11-51-(PU). The Primary unit (PU) further explains the nature of the Expenditure on Steel girder like cost of store; payment to contractor; cost towards salary of staff etc. the Primary unit is explained in the Para given below.
7.0 PRIMARY UNITS:. While the classification up to the detailed head represents only the activity which is used in allocation of the estimate, however for budgeting purpose the structure of the classification also incorporates a two digit code to represent the primary unit, i.e. the object of the expenditure/indicating on "what" the expenditure is incurred viz., salary, allowances, wages, materials, debits credits, cash, consumable stores etc. There are 32 Primary units as detailed below,

| P.U.No. | Object | PU.NO. | Object |
| :--- | :--- | :--- | :--- |
| 1 | Salary \& wages | 21 | Advertising Expenses |
| 2 | Dearness pay and Dearness <br> Allowances | 22 | Utilities-Water, Electricity, etc. |
| 3 | Productivity Linked Bonus | 23 | Rental for office equipment <br> (other than Data Processing) |
| 4 | House Rent Allowance | 24 | Printing and Stationery <br> including Publications |
| 5 | Compensatory (City) Allowance | 27 | Cost of materials from stock |
| 6 | Interim Relief. | 28 | Cost of materials - Direct <br> purchase |
| 7 | Transport allowance | 31 | Fuel for other than traction |
| 9 | Wages of Casual labour. | 32 | Contractual payments |
| 10 | Kilometer allowance | 33 | Transfer of debits/credits from <br> other units |
| 11 | Overtime allowance | 34 | Adjustment of 'Wages' on POH <br> and other repairs from WMS <br> Account to Revenue Heads. |


| 12 | Night duty allowance | 35 | Adjustment of 'materials' on POH and other repairs from WMS to Revenue Heads. |
| :---: | :---: | :---: | :---: |
| 13 | Other allowances | 36 | Excise duty paid/payable for purchase of materials. |
| 14 | Fees and honoraria | 37 | Customs duty paid/payable for purchase of materials. |
| 15 | Transfer allowance | 38 | Sales Tax paid/payable for purchase of materials |
| 16 | Travelling expenses | 39 | Air Travel (Domestic) |
| 17 | Air Travel Expense sanctioned in lieu of privilege passes | 40 | Air Travel (Foreign) |
| 18 | Office Expenses | 50 | Cost of computer hardware/ system, Software/application software including expenditure on excise /customs and sales tax; IT related consultancy contracts, cost of upgradation i.e. one-time expenditure not being of recurring nature. |
| 19 | Rental for P \& T Telephone and call charges including Trunk Calls. | 51 | Cost of computer consumables (ribbons, cartridges etc.), discs, tapes, floppies, computer stationary etc., rental of computers and AMC i.e. all expenditure of recurring nature. |

Example:- Allocation for Through rail renewal will be will be Q-31-41-28 (First character i.e. Q represents the source of fund(DRF), the second module indicates the Plan head(31) for 'Track Renewals' (The plan head is same as Minor head), next two digit (41) indicate detailed head i.e. 'Rails \& Fastenings' and last two digit (28) denote the primary unit i.e. Purchase of stores, the object of expenditure.

## APPENDIX - IV

## MASS HAUL DIAGRAM

## 1. Earthwork in filling and cutting:-

Earthwork in filling and cutting is an integral part of any highway and railway line work. When only filling involved the issue is simpler as a suitable borrow-area nearest to the embankment is to be selected for ensuring the work is done in the least cost. Things become different when the construction work involves cutting as well as filling. Earth excavated from the cutting is to be utilized in the embankment with the twin objectives of ensuring that:
(i) maximum quantity of earth available from cutting is utilized
(ii) the haulage cost (the haulage distance) of the earth excavated from the cutting is the least i.e. the cost of utilization of earth from cutting plus the haulage cost is less than the cost of earth work in formation using earth from borrow area.

For this purpose, to optimize the cost of cutting and filling, a diagram known as MassHaul (MHD) Diagram is prepared.

## 2. Mass Haul Diagram

It is evident by the name of this diagram that it is essentially a plot of cumulative volume of soil against distance along the route, often called the chainage. Cut volumes are taken to be positive and fill volumes to be negative. As stated above, with the help of M-H diagram transport cost for the haulage of earth excavated from the cutting earth is minimized. Also, the wastage of cutting earth and utilization of borrow material is minimized. The aim is to economize the construction of embankment. MH diagram is a graphical representation of the amount of material taken out from the cutting and used for filling in the adjacent stretches for construction of embankment. It shows the location of mass balance points (CG of the cutting and that of filling), the direction of haul and the amount of earth to be taken to or from any location along the alignment. Thus in a given zone MH diagram is extremely useful in determining the most economical distribution of earthwork from cutting.
3. Volume of Earthwork : - Earthwork in railway embankment is done by compaction in layers to achieve $98 \%$ of maximum dry density (MDD) in most of the cases. Therefore, generally the earth excavated from cutting is compacted to a lower volume e.g. 1 cum of excavated earth from cutting will reduce to around 0.9 cum after compaction in the bank. The ratio between the volume after compaction and that before excavation is known as shrinkage factor.

Shrinkage factor = Volume after compaction/Volume before excavation
The typical values of shrinkage factor for different soils are tabulated below

| Material | Bulk Density ( g/m3) | Shrinkage Factor |
| :--- | :---: | :---: |
| Clay (Low PI) | 1.65 | - |
| Clay (High PI) | 2.10 | 0.90 |
| Clay and Gravel | 1.80 | - |
| Sand | 2.00 | 0.89 |
| Sand \& Gravel | 1.95 | - |
| Gravel | 2.10 | 0.97 |
| Chalk | 1.85 | 0.97 |
| Shale | 2.35 | 1.33 |
| Limestone | 2.60 | 1.36 |
| Sandstone (Porous) | 2.50 | - |
| Sandstone (cemented) | 2.65 | 1.34 |
| Basalt | 2.95 | 1.36 |
| Granite | 2.41 | 1.33 |

As can be seen from the soils for formation of embankment have shrinkage factor of about 0.9. Though the shrinkage factor for rocks like shale, limestone, sandstone, granite etc. is 1.33 but these are normally not used for construction of embankment.

## 4. Terms related to MH diagrams:

a) Excavation (E) - refers to any excavated material.
b) Free haul (F) - when material is excavated it will be moved over a certain distance free of charge. This distance is the 'free haul' and is normally specified by the department in the contract conditions. This is also known as free lead.
c) Overhaul $(\mathbf{H})$ - is defined as distance over which the excavated material must be hauled minus the free haul distance. This is also known as 'Extra lead' and is separately payable to contractor. The rate for overhaul is normally specified by the contractor. This rate is normally given in Rs./m3/unit distance (Say, every 100m or part thereof).
d) Borrow Earth (B) - refers to the fill material that must be brought to the proposed railway/highway site over and above that available from the cut spoils from the alignment. The cost of borrow is normally given in Rs./m3, and this rate normally includes cost of excavating borrow and all leads and lifts.
e) Economic Overhaul Limit (LEOH) - a distance beyond which it is uneconomic to overhaul after deducting free haul i.e. when cost of;
[ Excavation(E)+ Overhaul(H)] < Cost of Borrow-earth.
f) Waste - is the excavated material that cannot be used for fill on the project site either due to the quantity of cut spoils being more than the requirement of bank or it being available beyond the Economic Overhaul limit. Normally, an engineer will try to roughly balance the amount of cut and fill required on a project at the design stage so that the amount of fill that must be hauled in or the amount of waste that must be hauled away are not excessive. Waste can also include excavated materials that are unsuitable for use as a fill because they have unacceptable engineering properties (such as peat, clays, etc.).
g) Balance Line: It is a horizontal line drawn on the longitudinal section so that the quantities of cut and fill material is balanced within this region/ Chainage.

The terms will be clearer by looking at the figure below. Sometimes it is more economical to waste the cutting material and use borrow material. This occurs where it is necessary to haul excavated material for long distances to use as fill.


Figure - Typical Mass Haul Diagram

### 5.0Steps to draw Mass Haul Diagram:

## Step-1: Calculation of Cross Sectional Area

The first stage in the production of the Mass Haul Diagram is the calculation of the cross sectional areas of cut or fill at different chainages along the alignment. The method is explained with the help of example in Para-5.
Step-2: Calculation of Volumes
Once the cross sectional areas are known at various chainages along the alignment, it is possible to calculate the cumulative volume along the cut by interpolating between the different chainages. If the shrinkage factor is used then changes in volume (mostly reduction) due to compaction is accounted for automatically.

## Step-3: Drawing MH diagram

MH diagram is plot of the cumulative volumes of cut and fill along an alignment. Typically, the mass diagram is plotted below a profile of the route; with the ordinate at any station representing the sum of the volumes of cut and fill up to that chainage. A mass diagram is shown below, with its associated profile. The most economical way to handle the distribution of earthwork volumes can be determined from the diagram.

The rising curve on the mass diagram indicates excavation and a descending curve indicates embankment. If a horizontal line is drawn to intersect the diagram at two points, excavation and filling (adjusted for shrinkage) will be equal between the two stations represented by the points of intersection. Such a horizontal line is called a balance line, because the earthwork in excavation balances the earthwork in embankment between the two points at the ends of the balance line.

Since the ordinates represent the cumulative volume of excavation and embankment, the total volumes of excavation and embankment will be equal where the final ordinate equals the initial ordinate. If the final ordinate is greater than the initial ordinate, there is an excess of excavation (as shown in this mass diagram); if it is less than the initial ordinate, the volume of embankment is the greater and additional material must be obtained to complete the embankment. Engineers strive to balance the amount of cut and fill during a new project to avoid costly hauling of materials.
The following are the properties of a typical MH diagram.

- A rising curve indicates an increasing volume (cut).
- A maximum point on the curve represents the end of a cut i.e.

Transition Point.

- A falling curve represents a decreasing volume (fill).
- A minimum point represents the end of a fill i.e. Transition Point.
- Areas at the end of the diagram represent a waste or a deficit.


Figure - Mass Haul Diagram

The top portion of the figure shows the ground profile of the project section. The bottom portion of figure shows mass diagram. This diagram is a running sum of the total quantity of material that is surplus or deficient along the project profile. In the mass-haul diagram horizontal distance (on the $X$ axis) shows the haul distances between stations. The vertical dimension in the diagram shows the cumulative volume of material (on the Y axis).

An excavation operation produces an ascending mass diagram curve. In the given diagram excavation is occurring between stations $A$ and $B$, and then station $C$ and $D$ so the curve is ascending in this portion. The quantity can be obtained on the Y axis of the diagram. The total volume of excavation between stations $A$ and $B$ is obtained by projecting vertical line and the difference between two volumes. Filling is occurring between stations $B$ and $C$, partly from the cutting material ( $B \& P$ and $Q \& C$ ) and partly from the borrow area ( $P$ and $Q$ ); the curve is descending. The distance of haul can be obtained on the X -axis between the CG of respective cutting and filling masses.

The maximum and minimum points on the mass diagram, where the curve transitions from rising to falling or from falling to rising, indicate a change from an excavation to fill situation or vice-versa. These points are referred as Transition Points (TP).
6. Different Cases Requiring MHD: Normally, one comes across following cases,

1. The formation line and level is fixed and cut spoils are to be used in forming embankment. All leads will be paid for. This is the case, most contractors come across.
2. The formation line and level is fixed and cut spoils are to be used in forming embankment. However, within a specific lead the cut spoils are to be used in embankment, within the rates for cutting. Payment for earth quantity lead beyond the specified free lead is only paid extra. Most of the departments/ clients keep such conditions.
3. The formation levels are to be fixed so that minimum cost is involved by optimizing leads and quantities.
4. This is same case as No. 3 but there is another option of importing earth from outside even when cut spoils are available, if it is more economical.

These different cases are explained by the following example.
6.1 Example: The Cross sectional area quantities of cut and fill required at different chainages are given in the table below (The quantities between chainages are shown in the row of ending chainage). MH diagram is to be drawn after calculating the quantity of earth work required and the lead required to be paid to the contractor (where payable).

CASE 1 - No free lead is provided in the contract (all leads are to be paid)

| Chainage(m) | Depth(m) | X-Sec (Sq.m) | Chainage(m) | Depth(m) | X-Sec (Sq.m) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1000 | +2.9 | +120.0 | 2000 | -1.8 | -67.5 |
| 1100 | +4.0 | +180.0 | 2100 | -2.3 | -94.5 |
| 1200 | +4.0 | +157.0 | 2200 | -2.0 | 0 |
| 1300 | -2.7 | +42.0 | 2300 | +1.0 | +162.0 |
| 1400 | 0 | -52.5 | 2400 | +5.7 | +315.0 |
| 1500 | -3.0 | -150.0 | 2500 | +5.9 | +109.0 |
| 1600 | -6.1 | -300.0 | 2600 | +1.10 | -15.0 |
| 1700 | -6.0 | -135.0 | 2700 | -2.10 | -94.0 |
| 1800 | -2.0 | -7.5 | 2800 | -2.9 |  |
| 1900 | -0.9 | -22.5 |  |  |  |

Step-1: Calculate cumulative quantities of earth work up to the chainages.

| Chg(m) | X-Sec (m $\left.{ }^{2}\right)$ | Cum. Qty <br> $\left(\mathrm{m}^{3}\right)$ (Area <br> X100) |  | Chg(m) | X-Sec <br> $\left(\mathrm{m}^{2}\right)$ | Cum. Qty <br> $\left(\mathrm{m}^{3}\right)$ <br> (AreaX <br> $100)$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1000 | +120.0 | 0 | 2000 | -67.5 | -16500 |  |
| 1100 | +180.0 | +12000 | 2100 | -94.5 | -23250 |  |
| 1200 | +157.0 | +30000 | 2200 | 0 | -32700 |  |
| 1300 | +42.0 | +45750 | 2300 | +162.0 | -16500 |  |
| 1400 | -52.5 | +50250 | 2400 | +315.0 | +15000 |  |
| 1500 | -150.0 | +45000 | 2500 | +109.0 | +25900 |  |
| 1600 | -300.0 | +30000 | 2600 | -15.0 | +24400 |  |
| 1700 | -135.0 | 0 | 2700 | -94.0 | +15000 |  |
| 1800 | -7.5 | -13500 | 2800 |  |  |  |
| 1900 | -22.5 | -14250 |  |  |  |  |

From the quantity in the last chainage it is seen that $15000 \mathrm{~m}^{3}$ of earth is not usable and is to be wasted.

Step-2: Draw the longitudinal section and cumulative quantity diagram, as below


Step-3: Find the balancing chainage where cut is equal to fill and also find the centroid distance between quantities of fill and cut.
a) It is noted that cumulative quantity at Ch. 1700 is NIL i.e. the quantity of cut and fill in Ch 1000-1700 is reached and the maximum quantity to be moved is 50250 Cum at Ch 1400. Draw a vertical ordinate from the maxima point i.e. from apex point, of the Mass Haul diagram, where maximum Qty of 50250 Cum is reached and is to be moved. This is met at Ch 1400. Divide the ordinate in 2-parts and draw a horizontal line through it. The horizontal line cuts the MHD curve at Ch. 1170 and Ch. 1620. These are the centroid points of the cut and fill earth works respectively.
b) Similarly find balancing Chainages for other portion of the length one for each maxima or minima point. It may be noted that there are 2 more such maxima and minima points at Ch 2270 and Ch 2650.
Note: Here, the balancing lines in three portions are such that they have different heights from the base line and as such may not offer an optimum solution. However, when all leads have are payable, it may not make significant difference in the expenditure and cost.

Step-4: Find the Qty and the lead (Haul) required.
The quantities and lead for the 3-portions are as under,

| Chainage (m) | Quantity <br> $($ Cum $)$ | Centroids <br> $(\mathrm{m})$ | Lead <br> $(\mathrm{m})$ | Qty X Lead <br> $($ Cum. m) |
| :--- | :--- | :--- | :--- | :--- |
| $1000-1700$ | 50250 | $1170 ; 1620$ | 450 | 22612500 |
| $1700-2440$ | 34000 | $2010 ; 2400$ | 390 | 13260000 |
| $2440-2500$ | 15000 | - | - | - |
| $2500-2800$ | 11500 | $2540 ; 2750$ | 210 | 2415000 |

CASE 2: When free lead is provided in contract (Say 300m)

$-40000!$

Mark the apex points on the $X$ axis and mark the free haul ( 300 m in this example) on either side of this and draw a horizontal balance line $A B$. Measure the ordinate of this balance line and draw another balance line CD by dividing it in two halves. The lines $C$ and $D$ are the centroids of the cutting and filling beyond the free haul. Repeat the same for all the apices (plural of apex).

The quantities and lead along with cost is as under,

| For CH. 1000-2400 |  |  |
| :---: | :---: | :---: |
| Free haul Quantity | 50,250 cum |  |
| Rate of Earthwork including free haul of 300 m | Rs. 100 per cum |  |
| Cost of free haul quantity of EW | $50250 \times 100$ | Rs.50,25,000 |
| Overhaul quantity (for which lead is payable) | 38,500 cum |  |
| Extra lead | $510-300=210 \mathrm{~m}$ |  |
| Rate of extra lead (say) | Rs. 15 per cum |  |
| Cost of Extra lead (Overhaul) | 38,500 $\times 210 \times 15 /(100)$ | 12,12,750 |
| For CH. 1700-2400 |  |  |
| Free haul Quantity | 34,000 cum |  |
| Cost of free haul quantity of EW | $34,000 \times 100$ | Rs.34,00,000 |
| Overhaul quantity | 21,500 cum |  |
| Extra lead | $680-300=380 \mathrm{~m}$ |  |
| Cost of Extra lead (Overhaul) | $38,500 \times 380 \times 15 /(100)$ | 12,25,500 |
| For CH. 2400-2500 |  |  |
| Free haul Quantity (wasted) | 15,000 cum |  |
| Cost of free haul quantity of EW | 15,000 $\times 100$ | Rs.15,00,000 |
| For CH. 2400-2500 <br> Free haul Quantity | $\begin{aligned} & 11,500 \text { cum }(26,500- \\ & 15,000) \\ & \hline \end{aligned}$ |  |
| Cost of free haul quantity of EW | $11,500 \times 100$ | Rs.11,50,000 |
| Overhaul quantity | Nil |  |

TOTAL COST
Rs. 1,35,13,250

## CASE 3: Optimization of the total cost

This is actually not a separate case but it talks about the process of fixing of balance line so as minimize the total cost of the earthwork in embankment and cutting taken together. It is possible to optimize the lead and quantities by moving the balance line upward or downward. In this case the balance line is moved upward by the qty. wasted i.e. by 15000Cum. The position after moving the balance line upward and accounting for free lead is shown in the MH diagram below.

If we see the diagram though the wastage quantity is same the haulage distances in the first segment have reduced but in the second segment have increased. Trial and error can give us the optimum location of the balance line. Alternatively a computer program can be developed.


CASE 4: Possible Variations
In the above example all lead are considered as economical and earth has been led for any distance, the maximum lead being 680 m . Many times the economic lead is specified and whenever the lead exceeds that distance the cut spoils are not used in the bank rather earth is imported from outside which may be cheaper at times. This will depend on the cost of the borrow earth or the private earth or the contractor's own earth as we call it. This variation can also be incorporated in the Mass haul Diagram

## APPENDIX - V

## NO OBJECTION CERTIFICATE FOR CONSTUCTION OF ANY STRUCTURE NEAR THE RAILWAY LAND

In order to cover safety aspect the following guidelines have been issued for consideration of issue of 'No Objection Certificate' to the owners for erection of their buildings/ structures in the vicinity of Railway land within 30 m from the existing Railway boundary.
i) It should be certified by the Division that the land is not required for Railway's own development in the foreseeable future.
ii) The party concerned would be required to submit a plan showing the location of the proposed construction in respect of the existing Railway boundary, location of the nearest kilometer post or electric overhead structure or any prominent landmark belonging to Railway.
i) The drawing should also indicate the structural details such as foundation, height of the building in reference to the nearest rail level, type of structures and drainage arrangements. The division will satisfy about the factual position at site.
ii) The height of the building should be restricted so that a clear space equal to half the height of the building is available between the nearest edge of the building and the railway boundary.
iii) The foundation of the building is considered strong enough to avoid foundation settlement and failure of the building. For multi-storied buildings pile foundation may be preferred. The owner should provide stability certificate form RCC designer/ consultant.
iv) In case the ground level on which the building to be constructed is higher than the railway formation level, the same shall be examined by the railway with regard to safety and if necessary the clear distance from the railway boundary to the face of the building may be suitably increased.
v) Provided such structures do not obstruct the visibility of the train drivers on curve.

The details of site with reference to railway should be collected and a separate drawing is to be prepared.

The building location with reference to railway boundary should be shown in the drawing. The distance between railway boundary and nearest edge of proposed structure should be mentioned. The cantilever balcony or open terrace is also considered as the edge of the building. The nearest edge of proposed building should have distance of half of the total height of the building from railway boundary. This drawing should have also mentioned kilometers and north point. A sample drawing is enclosed.


## APPENDIX - VI

## UPGRADATION OF LEVEL CROSSING

The drawing for up gradation of level crossing should show following things :
i) Fencing should be shown in drawing parallel to track on both the side of each gate. It should be 15 m in length.
ii) Width of the gates at right angles to the centre line of the road should be mentioned on the drawing.
iii) Location of Gate lodge with reference to railway track and road. The gate lodges shall be so sited that a clear and unobstructed view is obtained of all approaching trains and road vehicles. Where level crossing is on curve, the gate lodge should be built on the outside of the curve.

The minimum distance of gate lodge from
a) from Centre line of nearest track - 6 m
b) from Edge of road metalling $-6 m$
iv) If the L.C. gate is within station limit it should be interlocked.
v) The distance of lifting barriers from centre line of the track should be mentioned in drawing. The gate post should have minimum distance of 3 m from the centre line of track.
vi) The fixed ends of the lifting barriers should be marked clearly.
vii) If OHE post falling near the L.C. gate, the location of OHE post should be marked. It should not obstruct visibility of gateman. It should not obstruct the way of wires for operation of barriers.
viii) Length of the guard rail should be mentioned. It should be minimum 2 metres more than the width of gate.
ix) Gradients between the gates and outside the gates, kilometers, class of gate, category of road should be mentioned on the drawing. Provision of rumble strips on approaches of the level crossing should be shown.
x) Position of indicators should be mentioned.
xi) If the section is electrified, height gauge should be shown on both the side.
xii) Centre line of the track should be mentioned. On both the ends the name of next station and main station should be mentioned.
xiii) Cross section of the road between the barriers should be shown with formation of road.
xiv) Volume of traffic in terms of TVUS should be mentioned.
xv) Railway land boundary should be shown. The distance of boundary from the track centre should be mentioned.
xvi) If the road crossing the track in angle, the angle of crossing between the centre line of the road and railway should be mentioned, which should not be less than 45 .
xvii) If the track is curved or road approach is curved the radius of centre line of track or road should be mentioned.
xviii) The drawing should be complied the Annexure -9/1 Para No. 904 of IRPWM.

A sample drawing is enclosed on nex page.

## UPGRADATION OF LEVEL CROSSING




VISIBILITY CONDITION AT 10 m .

## APPENDIX - VII

## LAND PLAN

1.0 Land Plans : There are two distinct purposes for which Land plans are required,
a) Land plan showing the proposed land acquisition.
b) Certified Land plans duly signed jointly by revenue department and Railway Officer as a record of owner ship of the land by Railway.
2.0 Land Acquisition: For land acquisition, land plans are to be prepared based on the cadastral map/ village map obtained from Revenue Department. TILR office (Taluka Inspector of land record).in villages and In bigger cities however, a separate office of Land records is custodian of these cadastral maps. These maps show the details of all the boundaries of the properties and land holdings with survey nos. assigned to each plot, the revenue jurisdiction of each village, municipality, Government land etc. These plans are normally to a scale of 1 cm to 10 m and also 1 cm to 5 m . For heavy built up areas, smaller scale is adopted and for rural area bigger scale i.e. $1 \mathrm{~cm}=10 \mathrm{~m}$ is adopted.
2.1 Width of Land Required: For preparation of land plan first land width required is to be calculated based on bank height / depth of cutting. Minimum width required shall be calculated as per Annexure- III, of Engineering code. For banks minimum land required on either side from center line of track is $(6.85+3 h)$ meters, where ' $h$ ' is height of bank and for cutting $(7.345+2 d)$ meters, where ' $d$ ' is depth of cutting. These minimum required land widths shall be further increased for space required for requirements such as for ballast stacking, working space etc as the case may be, and depending upon site conditions. For station yards, any other use like workshop, colony offices requirement is to be assessed separately. Cultivated land, costly land and land in habited area shall be acquired for minimum possible width.
2.2 Preparing Drawing: After calculating width of land strip required on either side of center line of alignment, it is plotted chainage wise on the tracing paper, on which cadastral map has been traced. Area of each survey no. falling within the strip of land required by Railway is to be calculated with the help of graph sheet, planimetre etc, if it is an irregular shape. Land schedule is to be prepared for the area of land which is to be acquired from a particular village in specified cadastral map as per pro-forma given in D1. Land plan so prepared for proposed land acquisition shall be signed by field officers and Chief Engineer of the Railway. Minimum two copies of land plans are to be made, one for Railway's use and another for revenue department. These land plans are prepared each cadastral map wise and each village wise i.e. if one village is on more than 1 sheet equal no of drawings will be prepared and if there are more than one village on one map, the plans prepared will be more than for same village.

The land plan should show the outer boundary line to all land for whatever purpose it may be required for permanent occupation. This land should be distinguished on the land
plans by being colored pink and temporary land in yellow only in the copies of plans made for revenue authority for use in the acquisition of land.
2.3 Authority for acquisition or relinquishment of land in the Railways is Railway Board. The sanction of Construction Estimate and Techno-economic Report, where details of the land requirement are provided is considered sufficient towards meeting this requirement. The Terms of reference issued by Railway Board also contain specific mention, if land is to be acquired for future double line or not, is to be kept in mind. If land to be acquired for double line and construction of only single line is to be done then on which side of alignment, future double line is to be kept shall be decided before hand.
3.0 Certified Land Plan: On finally handing over of the land to the Railway, Final land plan is prepared based on Joint measurement sheet issued by revenue department duly incorporating all details of site as finalized during enquiry of section IX (3) \& (4) under Land Acquisition Act. The plan is prepared on a bigger scale of 1 cm to 50 m on a tracing cloth, in ink by Railway department and signature of revenue surveyor, TILR and district collector beside signature of Railway officer of rank not lower than Divisional Engineer, who has witnessed the joint measurements. This is called "Certified Land Plan" and copies are kept with State Revenue office as well as Railway as a proof of transfer of land to railway.

As per Para - 837 to 850 of Engineering code, following stipulations are laid down for making Certified Land Plans:-

1 For preparation of land plans data should be obtained during the progress of the survey for location of line.

1. Final land plan or CERTIFIED Land Plan should be made showing boundaries of land acquired for permanent occupation i.e. permanent land.
2. The position of boundaries of land should be determined by dimension written on plan. These dimensions should be complete to enable such boundaries being readily ascertained or verified. Normally all distances are measured from center line of Railway main line and the chainages with reference to center line of Station Building, which in turn is demarcated with reference to known survey pillar.
3. The name of villages to which land belongs be written on the plan alongside of line indicating the village boundary. If the village boundary crossing the railway line, the village name should be written on both side of railway line and chainages of crossing point to be mentioned.
4. The land plans shall be made up in sets for continuous portion of land, each set being complete for a revenue district.
5. Land plans shall be kept up to date either by adding to the existing plans or substituting new sheets as may be necessary.
6. A complete series of land plans for the whole line should be kept in the office of Chief Engineer of the railway.
A sample drawing for proposal for acquisition of land is given on next page.


## ACCIDENT SITE SKETCH

At the time of an accident/derailment, dimensional sketch has to be prepared by drafts man / PWI giving following details. This sketch will be signed by representatives of the concerned department at site. The guide lines of accident manual are as under-

1. The sketch giving train number, date, kilometerage of the site of accident should be properly labeled.
2. The north point should be indicated.
3. It should indicate prominently the direction of movement and also the names of stations in rear and advance of the site of accident.
4. It should cover a length of about 300 meters behind the point of mount and almost an equal distance in front.
5. The position of level crossing, Telegraph post/OHE Masts, Bridges, Tunnels, and Gradient post with gradient symbols
a. Curves with demarcation of beginning and end of curve.
6. It should also indicate -
a. The position of the derailed vehicles and the marks left by them either on sleepers or rails or ballast.
b. Point of mount (POM) with position of joints on either side or distance from any fixed point like SRJ of nearest point or Km post or level crossing etc.
c. Point of drop (POD) and distance from point of mount.
d. The pair of the wheels of first derailed vehicle.
e. The position of every displaced rail/wagon and detachable component found.
f. In all cases dimension from nearest kilometer post and centre line of the track should be given.
7. In case of accident within station limit, sufficient details about the station layout should be shown in order to fully explain the movement of the affected train in relation to topography of the place. The signal aspect at the time of accident should also be indicated.
8. The distance of the site of accident from a permanent structure to fix the site of accident precisely should be indicated.
9. The distances should be indicated to show the extent of disturbance caused in the P.Way or train composition on account of the accident.
10. If necessary, more than one sketch should be enclosed, one clarifying the yard layout and the system of working it and other giving accident details.
11. In case serious accident/ Sabotage cases, Photograph of site should also be taken.
12. Any other details considered necessary.

A sample sketch for the guidance is enclosed.
ACCIDENT SITE PLAN


## List of RDSO Drg. Pier and Abutment.

MBG Loading-1987 (M20)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass Concrete Pier Grade M-20 Spans <br> 6.10m \& 9.15m MBG | B-1695 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $12.2 m$ MBG | B-1696 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $18.3 m$ MBG | B-1697 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $24.4 m ~ \& ~ 30.5 m ~ M B G ~$ | B-1698 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $30.5 m ~(U S) ~ \& ~(O W) ~ M B G ~$ | B-1733 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $45.7 ~ \& ~ 61.0 m ~(O W) ~ M B G ~$ | B-1734 |  |
| Mass Concrete Pier Grade M-20 Spans <br> $76.2 m ~ M B G ~$ B-1735 |  |  |

MBG Loading-1987 (M 25)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass Concrete (M-25) Pier for PSC Girder <br> 12.2 m span (Seismic Zone I to III) | BA-10331 |  |
| Mass Concrete (M-25) Pier for Pre-cast PSC <br> Slab 6.1m span (Seismic zone I to III) | BA-10333 |  |
| Mass Concrete (M-25) Pier for Composite <br> girder 12.2m (Seismic Zone I to III | BA-10335 |  |

HM Loading-1995 (M 20)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass concrete (M-20) pier for PSC deck <br> slab 6.1m span (Seismic Zone I to III) | BA-10321 |  |
| Mass concrete (M-20) pier for open web <br> girder 45.7m span HM loading 1995 <br> (Seismic Zone I to III) | BA-10323 |  |
| Mass concrete (M-20) pier for open web <br> girder 30.5m span HM loading 1995 <br> (Seismic Zone I to III) | B-10325 |  |
| Mass concrete (M-20) pier for PSC <br> girder 18.3m spanHM loading 1995 <br> (Seismic Zone I to III) | B-10327 |  |
| Mass concrete (M-20) pier for PSC <br> girder 12.2m spanHM loading 1995 <br> (Seismic Zone I to III) | B-10329 |  |

## (2) ABUTMENTS

MBG Loading - 1987 Grade (M-20)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass Concrete Abutment with M-20 Grade <br> Span 6.10m MBG | B-1689 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 9.15m MBG | B-1690 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 12.2m MBG | B-1691 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 18.3m MBG | B-1692 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 24.4m MBG | B-1693 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 30.5m MBG | B-1694 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 30.5m (OW \& US), 45.7m (OW) MBG | B-1736 |  |
| Mass Concrete Abutment with M-20 Grade <br> Span 61.0 (OW), 76.2m (OW) | B-1737 |  |

MBG Loading - 1987 Grade (M-25)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass Concrete (M-25) abutment for PSC <br> Girder 12.2m span MBG loading -1987 <br> (Seismic Zone I to III) | BA-10332 |  |
| Mass Concrete (M-25) abutment for precast <br> PSC slab 6.10m span MBG loading-1987 <br> (seismic Zone I to III) | BA-10334 |  |
| Mass concrete (M-25) abutment for composite <br> girder 12.2m span (seismic Zone I to III) | BA-10336 |  |

HM Loading - 1995 Grade (M-20)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Mass concrete (M-20) abutment for PSC <br> deck slab 6.1m span HM loading 1995 <br> (Seismic zone I to III) | BA-10322 |  |
| Mass concrete (M-20) abutment for open <br> web girder 45.7m span HM loading 1995 <br> (Seismic zone I to III) | BA-10324 |  |
| Mass concrete (M-20)abutment for open <br> web girder 30.5m span HM loading 1995 <br> (Seismic zone I to III) | B-10326 |  |
| Mass concrete (M-20) abutment for PSC <br> girder 18.3m span HM loading 1995 <br> (Seismic zone I to III) | B-10328 |  |
| Mass concrete (M-20) abutment for PSC <br> girder 12.2m span HM loading 1995 <br> (Seismic zone I to III) | B-10330 |  |

## LIST OF RDSO DRG. FOR RAILWAY STEEL GIRDERS

(1) PLATE GIRDERS (B.G.)
(a) MBG loading-1987 Plate girder welded type ( $10 \times 10$ ' cycles) with bracings \& intermediate stiffeners riveted.

| Span | Description | Drawing No. | Alteration/ <br> Date |
| :--- | :--- | :--- | :--- |
|  | General arrangement | B-16012 |  |
|  | Details of cross frame, bearing \& part list | B-16012/1 |  |
|  | Assembly drawing \& dispatch list | B-16012/2 |  |
|  | Welding sequence | B-16012/3 |  |
| 18.3 m span | General arrangement | B-16013 |  |
|  | Details of splice, bearings \& part list | B-16013/1 |  |
|  | Assembly drawing \& dispatch list | B-16013/2 |  |
|  | Details of x-frame \& welded connections | B-16013/3 |  |
|  | Welding sequence | B-16013/4 |  |
| $24.4 ~ m ~ s p a n ~$ <br> $(10 x 10$ <br> cycles) | General arrangement | B-16005 |  |
|  | Details of splice and Cross Frame | B-16005/1 |  |
|  | Assembly drawing | B-16005/2 |  |
|  | Details of Bearings, Part List \& Dispatch List | B-16005/3 |  |
|  | Welding sequence | B-16005/4 |  |

(b) 25t loading - 2008 plate girder welded type ( $10 \times 10^{\prime}$ cycles) (Bracings \& Int. stiffeners riveted)

| Span <br> date | Description | Drawing No. Alteration/ |
| :--- | :--- | :--- |
|  | General arrangement | B-16014 1/20-02-2009 |
|  | Details of X- frame, bearings \& part list | $\mathrm{B}-16014 / 1$ |
|  | Assembly drawing \& dispatch list | $\mathrm{B}-16014 / 2$ |
|  | Welding sequence | $\mathrm{B}-16014 / 3$ |
| 18.3 m span <br> $(10 \times 10$ <br> cycles $)$ | General arrangement | $\mathrm{B}-16015 \quad 1 / 20-02-2009$ |
|  | Details of splice, bearings \& part list | $\mathrm{B}-16015 / 1$ |
|  | Assembly drawing \& dispatch list | $\mathrm{B}-16015 / 2$ |
|  | Details of X-frame and welded connections | $\mathrm{B}-16015 / 3$ |
|  | Welding sequence | $\mathrm{B}-16015 / 4$ |

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| 24.4 m span | General arrangement | B-16016 |
| :--- | :--- | :--- |
| (10x10' <br> cycles $)$ | Details of splice, cross frame \& part list | B-16016/1 |
|  | Assembly drawing \& dispatch list | B-16016/2 |
|  | Details of bearing | B-16016/3 |
|  | Welding sequence | B-16016/4 |

(c) Elastomeric bearing for MBG 1987 different clear span welded type for 4 million cycles

| 12.2 m Clear span for 4 million cycles | B-1584 R1 |  |
| :--- | :--- | :--- |
| 18.3 m Clear span for 4 million cycles | B-1585 R1 |  |
| 24.4 m Clear span for 4 million cycles | B-1586 R1 |  |

d) DFC loading (32.5t axle load) plate girder. Welded type ( $10 \times 10$ ' cycles) Bracings \& Int. stiffeners riveted.

| Span | Description | Drawing No. | Alteration date |
| :---: | :---: | :---: | :---: |
| $\begin{aligned} & 12.2 \mathrm{~m} \text { span } \\ & \left(10 \times 10^{\prime}\right. \\ & \text { cycles }) \end{aligned}$ | General arrangement | B-16017 |  |
|  | Details of cross frame, bearings \& part list | B-16017/1 |  |
|  | Assembly drawings \& dispatch list | B-16017/2 |  |
|  | Welding sequence | B-16017/3 |  |
| $\begin{aligned} & \hline 18.3 \mathrm{~m} \text { span } \\ & \left(10 \times 10^{\prime}\right. \\ & \text { cycles }) \end{aligned}$ | General arrangement | B-16018 |  |
|  | Details of splice \&, bearings | B-16018/1 |  |
|  | Assembly drawings \& dispatch list | B-16018/2 |  |
|  | Details of x-frame \& part list | B-16018/3 |  |
|  | Welding sequence | B-16018/4 |  |
| $\begin{aligned} & \hline 24.4 \mathrm{~m} \text { span } \\ & \left(10 \times 10^{\prime}\right. \\ & \text { cycles }) \end{aligned}$ | General arrangement | B-16019 |  |
|  | General arrangement | B-16019/A |  |
|  | Details of splice, x-frame, part \& dispatch list | B-16019/1 |  |
|  | Assembly drawings | B-16019/2 |  |
|  | Bearing | B-16019/3 |  |
|  | Welding sequence | B-16019/4 |  |

(2) 25T Loading - 2008 Open Wed Girder (welded Through Type)

| Span | Description | Drawing No. | Alteration date |
| :---: | :---: | :---: | :---: |
| 30.5m Span | General arrangement | B-11678 |  |
|  | Stress sheet | B-11679 |  |
|  | Camber diagram | B-11680 |  |
|  | Bearings | B-11681 |  |
|  | Bottom Chords | B-11682 |  |
|  | Top Chords | B-11683 |  |
|  | End Raker and Portal | B-11684 |  |
|  | Verticals | B-11685 |  |
|  | Diagonals | B-11686 |  |
|  | Bottom Chord Joints | B-11687 |  |
|  | Top Chord Joints | B-11688 |  |
|  | Cross girders | B-11689 |  |
|  | Welded through type Stringers | B-11690 |  |
|  | Sway bracings | B-11691 |  |
|  | Bottom lateral bracings | B-11692 |  |
|  | Top Lateral bracings | B-11693 |  |
|  | Erection Drawings | B-11694 |  |
|  | Shipping List | B-11695 |  |
| 45.7m Span | General arrangement | B-17001 |  |
|  | Stress sheet | B-17002 |  |
|  | Camber diagram | B-17003 |  |
|  | Bearings | B-17004 |  |
|  | Bottom Chords | B-17005 |  |
|  | Top Chords | B-17006 |  |
|  | End Raker and Portal bracings | B-17007 |  |
|  | Verticals | B-17008 |  |
|  | Diagonals | B-17009 |  |
|  | Bottom Chord Joints | B-17010 |  |
|  | Bottom Chord Joints | B-17010/1 |  |
|  | Top Chord Joints | B-17011 |  |
|  | Top Chord Joints | B-17011/1 |  |
|  | Cross girders | B-17012 |  |
|  | Stringers | B-17013 |  |
|  | Sway bracings | B-11614 |  |
|  | Bottom lateral bracings | B-11615 |  |
|  | Top Lateral bracings | B-11616 |  |
|  | Erection Drawings | B-11617 |  |
|  | Shipping List | B-11618 |  |


| 61.0 Span | General arrangement | B-17021 |  |
| :---: | :---: | :---: | :---: |
|  | Stress sheet | B-17022 |  |
|  | Camber diagram | B-17023 |  |
|  | Bottom Chords | B-17025 |  |
|  | Top Chords | B-17026 |  |
|  | End Raker and Portal bracings | B-17027 |  |
|  | Verticals | B-17028 |  |
|  | Diagonals | B-17029 |  |
|  | Bottom Chord Joints | B-17030 |  |
|  | Bottom Chord Joints | B-17030/1 |  |
|  | Bottom Chord Joints | B-17030/2 |  |
|  | Top Chord Joints | B-17031 |  |
|  | Top Chord Joints | B-17031/1 |  |
|  | Cross girders | B-17032 |  |
|  | Stringers | B-17033 |  |
|  | Stringers at expansion joints | B-17033/1 |  |
|  | Sway bracings | B-17034 |  |
|  | Bottom lateral bracings | B-17035 |  |
|  | Top Lateral bracings | B-17036 |  |
|  | Erection Drawings | B-17037 |  |
|  | Shipping List | B-17038 |  |
| 76.2 Span | General arrangement | B-17041 |  |
|  | Stress sheet | B-17042 |  |
|  | Camber diagram | B-17043 |  |
|  | Bottom Chords | B-17045 |  |
|  | Top Chords | B-17046 |  |
|  | End Raker and Portal bracings | B-17047 |  |
|  | Verticals | B-17048 |  |
|  | Diagonals | B-17049 |  |
|  | Bottom Chord Joints | B-17050 |  |
|  | Bottom Chord Joints | B-17050/1 |  |
|  | Bottom Chord Joints | B-17050/2 |  |
|  | Top Chord Joints | B-17051 |  |
|  | Top Chord Joints | B-17051/1 |  |
|  | Top Chord Joints | B-17051/2 |  |
|  | Cross girders | B-17052 |  |
|  | Stringers | B-17053 |  |
|  | Stringers at expansion joints | B-17053/1 |  |
|  | Sway bracings | B-17054 |  |
|  | Bottom lateral bracings | B-17055 |  |
|  | Bottom lateral bracings | B-17055/1 |  |
|  | Top Lateral bracings | B-17056 |  |
|  | Erection Drawings | B-17057 |  |
|  | Shipping List | B-17058 |  |

(3) RDSO Drawing for Open Web Welded Girders (MBG Loading)

| Span | Description | Drawing No. | Alteration date |
| :---: | :---: | :---: | :---: |
| 30.5m Span | General arrangement | BA-11461 | 1/31.10.03 |
|  | Stress sheet | BA-11462 |  |
|  | Camber diagram | BA-11464/R |  |
|  | Bearings | BA-11465 | 1/10.8.04 |
|  | Bottom Chords | BA-11466 | 1/31.10.03 |
|  | Top Chords | BA-11467 | -do- |
|  | End Raker and Portal bracings | BA-11468 | -do- |
|  | Verticals | BA-11469 | -do- |
|  | Diagonals | BA-11470 | -do- |
|  | Bottom Chord Joints | BA-11471 | -do- |
|  | Top Chord Joints | BA-11472 | -do- |
|  | Cross girders | BA-11473 |  |
|  | Stringers | BA-11474 |  |
|  | Sway bracings | BA-11475 |  |
|  | Bottom lateral bracings | BA-11476 |  |
|  | Top Lateral bracings | BA-11477 |  |
|  | Erection Drawings | BA-11478 |  |
|  | Shipping List | BA-11479 |  |
|  | PTFE POT bearing | BA-11571 |  |
| 45.7 m span | General arrangement | BA-11481 | 2/13.2.07 |
|  | Stress sheet | BA-11482 | 1/13.2.07 |
|  | Camber diagram | BA-11484/R |  |
|  | Bearings | BA-11485 |  |
|  | Bottom Chords | BA-11486 | 2/13.2.07 |
|  | Top Chords | BA-11487 | 1/18.11.03 |
|  | End Raker and Portal bracings | BA-11488 | 2/13.2.07 |
|  | Verticals | BA-11489 | 2/23.5.03 |
|  | Diagonals | BA-11490/R |  |
|  | Bottom Chord Joints | BA-11491 | 3/13.2.07 |
|  | Bottom Chord Joints | BA-11491/1 | 2/13.2.07 |
|  | Top Chord Joints | BA-11492/R |  |
|  | Cross girders | BA-11493 | 2/13.2.07 |
|  | Stringers | BA-11494 |  |
|  | Sway bracings | BA-11495 | $1 / 2.12 .02$ |
|  | Bottom lateral bracings | BA-11496 | 1/13.2.07 |
|  | Top Lateral bracings | BA-11497 | 1/2.12.02 |
|  | Erection Drawing | BA-11498 |  |
|  | Shipping List | BA-11499 | 1/2.12.02 |
|  | PTFE POT bearing | BA-11573 |  |

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| 45.7 m <br> span <br> Under <br> Slung <br> Type | General arrangement | B-11641 |  |
| :---: | :---: | :---: | :---: |
|  | Stress sheet | B-11642 |  |
|  | Camber diagram | B-11643 |  |
|  | Bearings | B-11644 |  |
|  | Bottom Chords | B-11645 |  |
|  | Top Chords | B-11646 |  |
|  | End Raker and Intermediate cross frame | BA-11648 |  |
|  | Verticals | B-11647 |  |
|  | Diagonals | B-11649 |  |
|  | Diagonals | B-11649/1 |  |
|  | Bottom Chord Joints | B-11650 |  |
|  | Bottom Chord Joints | B-11650/1 |  |
|  | Top Chord Joints | B-11651 |  |
|  | Top Chord Joints | B-11651/1 |  |
|  | Top Chord Joints | B-11651/2 |  |
|  | Bottom lateral bracings | B-11652 |  |
|  | Top Lateral bracings | B-11653 |  |
|  | Erection Drawing | B-11654 |  |
|  | Shipping List | B-11655 |  |
| 61.0 m span | General arrangement | BA-11581 | 1/20.4.04 |
|  | Stress sheet | BA-11582 | 1/13.2.07 |
|  | Camber diagram | BA-11583/R |  |
|  | Bearings | BA-11584 |  |
|  | Bottom Chords | BA-11585 | 1/20.4.04 |
|  | Top Chords | BA-11586/R |  |
|  | End Raker and Portal bracings | BA-11587 | 1/20.4.04 |
|  | Verticals | BA-11588 | 1/20.4.04 |
|  | Diagonals | BA-11589/R |  |
|  | Bottom Chord Joints | BA-11590/R |  |
|  | Bottom Chord Joints | BA-11590/1/R |  |
|  | Bottom Chord Joints | BA-11590/2/R | 1/26.12.06 |
|  | Top Chord Joints | BA-11591/R | 1/26.12.06 |
|  | Top Chord Joints | BA-11591/1/R |  |
|  | Cross girders | BA-11592/R |  |
|  | Stringers | BA-11593/R | 1/26.12.06 |
|  | Stringers at expansion joint | BA-11593/1 | 1/26.12.06 |
|  | Sway bracings | BA-11594 | 1/20.4.04 |
|  | Bottom lateral bracings | BA-11595 | 2/ 26.12.06 |
|  | Top Lateral bracings | BA-11596 | 1/20.4.04 |
|  | Erection Drawing | BA-11597 | 2/ 26.12.06 |
|  | Shipping List | BA-11598 | 2/ 26.12.06 |
|  | PTFE POT bearing | BA-11575 |  |


| 61.0 m span1987 (provisional) (Under Slung Type) | General arrangement | BA-11661 |  |
| :---: | :---: | :---: | :---: |
|  | Stress sheet | BA-11662 |  |
|  | Camber diagram | BA-11663 |  |
|  | Bearings | BA-11664 |  |
|  | Bottom Chords | BA-11665 |  |
|  | Top Chords | BA-11666 |  |
|  | Verticals | BA-11667 |  |
|  | End Raker and Intermediate cross frame | BA-11668 |  |
|  | Diagonals | BA-11669 |  |
|  | Bottom Chord Joints | BA-11670 |  |
|  | Bottom Chord Joints | B-11670/1 |  |
|  | Bottom Chord Joints | B-11670/2 |  |
|  | Top Chord Joints | B-11671 |  |
|  | Top Chord Joints | B-11671/1 |  |
|  | Top Chord Joints | B-11671/2 |  |
|  | Cross Girders | B-11672 |  |
|  | Stringer | B-11673 |  |
|  | Bottom lateral bracings | BA-11674 |  |
|  | Top Lateral bracings | BA-11675 |  |
|  | Erection Drawing | BA-11676 |  |
|  | Part List | BA-11677 |  |
|  | PTFE POT bearing | B-11579 |  |
| 76.2m Span | General arrangement | BA-11601/R |  |
|  | Stress sheet | BA-11602/R |  |
|  | Camber diagram | BA-11604/R |  |
|  | Bearings | BA-11605 |  |
|  | Bottom Chords | BA-11606/R |  |
|  | Top Chords | BA-11607/R |  |
|  | End Raker and Intermediate cross frame | BA-11608/R |  |
|  | Verticals | BA-11609/R |  |
|  | Diagonals | BA-11610/R |  |
|  | Bottom Chord Joints | BA-11611/R |  |
|  | Bottom Chord Joints | B-11611/1/R |  |
|  | Bottom Chord Joints | B-11611/2/R |  |
|  | Top Chord Joints | B-11612/R |  |
|  | Top Chord Joints | B-11612/1/R |  |
|  | Top Chord Joints | B-11612/2/R |  |
|  | Cross Girder | BA-11613/R |  |
|  | Stringer | BA-11614/R |  |
|  | Stringer | BA-11614/1 |  |
|  | Sway bearings | BA-11615/R |  |
|  | Bottom lateral bracings | BA-11616 |  |

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|  | Bottom lateral bracings | BA-11616/1 |  |
| :--- | :--- | :--- | :--- |
|  | Bottom lateral bracings | BA-11616/2 |  |
|  | Top Lateral bracings | $\mathrm{BA}-11617 / \mathrm{R}$ |  |
|  | Erection Drawing | $\mathrm{BA}-11618 / \mathrm{R}$ |  |
|  | Shipping List | $\mathrm{BA}-11619 / \mathrm{R}$ |  |
|  | PTFE POT bearing | $\mathrm{BA}-11577 / \mathrm{R}$ |  |

(4) COMPOSITE GIRDERS (BG)

1. MBG Loading - 1987

| Span date | Description | Drawing No. | Alteration/ |
| :---: | :---: | :---: | :---: |
| 9.15 <br> Clear spans <br> (Straight <br> track) | Details of main girder | B-1623 | 1/1.8.1996 |
|  | Bearing details \& Part List | B-1623/1 | 2/29.1.2001 |
|  | Cross Frame Details \& Lifting Arrangement | B-1623/2 | 1/1.8.1996 |
|  | Assembly drawing \& Shipping List | B-1623/3 | 1/1.8.1996 |
|  | Details of Deck Slab | B-1623/4 | 1/1.8.1996 |
|  | Stud Shear Connector | B-1701 |  |
| 12.2 Clear span (Up to $4^{\circ}$ curve) | Details of main girder | B-1569/R | 1/1.8.1996 |
|  | Bearing and Cross Frame Details | B-1569/1/R | 1/1.8.1996 |
|  | Assembly drawing | B-1569/2/R | 1/1.8.1996 |
|  | Part List and Shipping List | B-1569/3/R | 1/1.8.1996 |
|  | Details of Deck Slab | B-1569/4/R | 1/1.8.1996 |
|  | Stud Shear Connector | B-1731 | 1/1.8.1996 |
| 18.3 Clear span | Details of main girder | B-1534/R | 1/5.5.93 |
|  | Details of Deck Slab | B-1534/1 | 1/30.3.05 |
|  | Details of Splice Joint \& Shear Connector | B-1534/2/R |  |
|  | Details of Bearing | B-1534/3/R | 1/14.9.95 |
|  | Part List and Shipping List | B-1534/4/R |  |
|  | Erection Drawing | B-1534/5/R | 1/5.5.93 |
|  | Stud Shear Connector | B-1738 |  |
| 18.3 Clear span With depth of web plate $=1350 \mathrm{~mm}$ | Details of main girder | B-1534/R | 1/5.5.93 |
|  | Details of Deck Slab | B-1534/1 | 1/30.3.05 |
|  | Details of Splice Joint \& Shear Connector | B-1534/2/R |  |
|  | Details of Bearing | B-1534/3/R | 1/14.9.95 |
|  | Part List and Shipping List | B-1534/4/R |  |
|  | Erection Drawing | B-1534/5/R | 1/5.5.93 |
|  | Stud Shear Connector | B-1738 |  |


| 18.3m Clear <br> Span with <br> restricted <br> depth | Details of Main Girder | $\mathrm{B}-1759$ |  |
| :--- | :--- | :--- | :--- |
|  | Detail of Deck Slab | $\mathrm{B}-1759 / 1$ |  |
|  | Splice Joint \& Shear Connector | $\mathrm{B}-1759 / 2$ |  |
|  | Bearing | $\mathrm{B}-1759 / 3$ |  |
|  | Part List and Shipping List | $\mathrm{B}-1759 / 4$ |  |
|  | Erection Drawing | $\mathrm{B}-1759 / 5$ |  |
| 20.0mClear <br> Span for <br> straight track | Details of Main Girder | Details of Cross Frame | $\mathrm{B}-1581 / \mathrm{R}$ |
|  | Details of Deck Slab | $1 / 1.8 .96$ |  |
|  | Details of Bearings | $\mathrm{B}-1581 / 1 / \mathrm{R}$ | $1 / 1.8 .96$ |
|  | Assembly Drawing, Part List \& Shipping List | $\mathrm{B}-1581 / 4 / \mathrm{R}$ | $1 / 1.8 .96$ |
| 24.4mClear | Details of Main Girder | $\mathrm{B}-1730$ | $2 / 30-04-2004$ |
|  | Details of Deck Slab | $\mathrm{B}-1730 / 1$ |  |
|  | Details of Cross Frame \& Lifting Beam | $\mathrm{B}-1730 / 2$ | $2 / 30-04-2004$ |
|  | Details of Splice Joint | $\mathrm{B}-1730 / 3$ |  |
|  | Details of Bearing | $\mathrm{B}-1730 / 4$ |  |
|  | Erection Drawing | $\mathrm{B}-1730 / 5$ |  |
|  | Part List \& Shipping List | $\mathrm{B}-1730 / 6$ |  |

## APPENDIX - XI

## LIST OF RDSO DRG. FOR RCC/PSC BRIDGE SLBAS

## 1. MBG Loading - 1987

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 6.1 m <br> (Pretensioned) | Precast Prestressed Concrete Slab 6.1m | BA-10221/R | $1 / 17-4-01$ |
| 3.05 m -do- | Precast Prestressed Concrete Slab span <br> 3.05 m | BA-10235 | $8-9-01$ |
| 3.66 m -do- | Precast Prestressed Concrete Slab span <br> 3.66 m | BA-10236 |  |
| 4.57 m -do- | Precast Prestressed Concrete Slab span <br> 4.57 m | BA-10237 |  |
| 6.1 m -do- | PSC slab with 3 units span 6.1m | BA-10239 |  |
| 9.15 m -do- | PSC slab with 3 units span 9.15m | BA-10240 | $1 / 26-06-08$ |
| 9.15 m (Post <br> tensioned) | PSC Slab Span 9.15m | BA-10241 |  |
| 12.2 m (Post <br> tensioned) <br> 4 pieces | General arrangement \& cable profile | RDSO/B- <br> $10248 / R$ |  |

2. 25 T Loading - 2008

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 6.1 m <br> (Pretensioned) | Concrete slab (2 unit) span 6.1m | RDSO/B-10257 |  |
| 3.05 -do- | Concrete slab (2 unit) span 3.05m | RDSO/B-10259 |  |
| 3.66 m -do- | Concrete slab (2 unit) span 3.66m | RDSO/B-10260 |  |
| 4.57 m -do- | Concrete slab (2 unit) span 4.57m | RDSO/B-10261 |  |
| 9.15 m -do- | Concrete slab (3 unit) span 9.15m | RDSO/B-10263 |  |

3. HM Loading - 1995

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 3.05 m <br> (Pretensioned) | Precast prestressed (pretensioned) <br> concrete slab span 3.05m | BA-10249/R |  |
| 3.66 m <br> (Pretensioned) | Precast prestressed (pretensioned) <br> concrete slab span 3.66m | BA-10250/R |  |
| 4.57 m <br> (Pretensioned) | Precast prestressed (pretensioned) <br> concrete slab span 4.57m | BA-10251/R |  |
| 6.1 m <br> (Pretensioned) | Pretensioned PSC Slab with 3 units <br> span 6.1m | BA-10238 |  |
| 9.15 m <br> (pretensiond) | Concrete slab (3 unit) span 9.15m | RDSO/B-10263 |  |
| 12.2 m <br> (Post-tensioned | General arrangement \& cable profile | RDSO/B-10255 |  |
|  | Details of reinforcement | RDSO/B-10255/1 |  |
|  | Seismic restrainer of solid slab for <br> single track | RDSO/B-10255/2 |  |

4. DFC Loading ( 32.5 T )

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 6.1 m <br> (Pretensioned) $)$ | Concrete slab span (3 unit) <br> span 6.10 m | RDSO/B-10264 |  |

(B) REINFORCED CONCRETE SLABS (Ballasted)

## 1. Precast R.C. Bridge Slab (MBG)

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| Span 0.61 m <br> to 2.44 m | Span 0.61m, 0.915m, 1.22m, 1.83m <br> $\& 2.44 \mathrm{~m}$ (Concrete Grade M-25) | BA-to 10051 | $1 / 23-4-00$ <br> A0 |
| Span 0.61 m <br> to 2.44 m |  <br> $2.44 \mathrm{~m}($ Concrete Grade M-30) | BA-10052 | $1 / 23-4-00$ <br> A0 |
|  | General arrangement and details of R.C. <br> approach slab MBG laoding-1987 | BA-10059 |  |

2. 25 T Loading - 2008

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 0.61 m to 2.44 m <br> (M25 Concrete) | Precast R.C. bridge Slab standard span <br> $0.61,0.915,1.22,1.83 ~ \& ~ 2.44 \mathrm{~m}$ | RDSO/B-10063 | $1 / 31-03-$ <br> 2009 |

3. HM Loading-1995

| Span | Description | Drawing No. | Alteration/ <br> date |
| :--- | :--- | :--- | :--- |
| 0.61 m to 2.44 m <br> (M30 Concrete) | 0.61 to 2.44 m <br> (M30 Concrete) | Precast R.C. bridge Slab Standard <br> span 0.61, 0.915, 1.22, 1.83 \& 2.44 m | BA-10060 |

4. DFC Loading

| Span | Description | Drawing No. | Alteration/date |
| :--- | :--- | :--- | :--- |
| Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m |
| Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m | Span 0.61 m to 2.44 m |

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## LIST OF RDSO DRG. FOR RCC BOX CULVERTS

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| Standard drawing of single box culvert <br> (GeneralArrangement) | M-00004 |  |
| Standard drawings of double box culvert <br> (GeneralArrangement | M-00005 |  |
| Standard drawing of limited subway <br> General Arrangement | M-00008 |  |

APPENDIX - XIII

## LIST OF RDSO DRG. FOR PSC GIRDERS

1. MBG Loading (2008)

| Span | Description | Drawing No. | Alteration date |
| :---: | :---: | :---: | :---: |
| 12.2 m I -Girder of Restricted Depth, Suitable for all curves | General Arrangement | RDSO/B- 10256 |  |
|  | Details of cable profile | RDSO/B-10256/1 |  |
|  | Diaphragm cable layout | RDSO/B-10256/2 |  |
|  | Details of reinforcement | RDSO/B-10256/3 |  |
| 12.2m, I-Girder suitable for curve of up to 2.50 track(C/C of Pier-13.4m) | General Arrangement | RDSO/B-10265 |  |
|  | Cable Profile stress chart \& deflection | RDSO/B-10265/1 |  |
|  | Detail of Reinforcement | RDSO/B-10265/2 |  |
|  | Details of anchorage \& expansion joint | RDSO/B-10265/3 |  |
| 12.2m, I-Girder suitable for straight track(C/C of Pier-13.4m) | General Arrangement | RDSO/B-10258 |  |
|  | Cable Profile stress chart \& deflection | RDSO/B-10258/1 |  |
|  | Detail of Reinforcement | RDSO/B-10258/2 |  |
|  | Details of anchorage \& expansion joint | RDSO/B-10258/3 |  |
| $\begin{aligned} & \text { 18.3m, I-Girder (C/C } \\ & \text { of Pier 19.8m) } \end{aligned}$ | General Arrangement | RDSO/B-10262 |  |
|  | Cable Profile stress chart \& deflection | RDSO/B-10262/1 |  |
|  | Detail of Reinforcement | RDSO/B-10262/2 |  |
|  | Details of anchorage \& expansion joint | RDSO/B-10262/3 |  |

## 2. MBG Loading - 1987

| Span | Description | Drawing No. | Alteration date |
| :---: | :---: | :---: | :---: |
| 12.2m (Post Tensioned I Type) MBG Loading-1987 for Old Codal Provision Gap between Girder = 750 mm c/c of Pier $=$ 14.11m (suitable for PQRS loading) | General Arrangement | BA-10223 | 1/11-4-01 |
|  | Cable Profile Stress Chart and Deflection | BA-10223/1 | 1/11-4-01 |
|  | Detail of Reinforcement | BA-10223/2 | 1/27-3-01 |
|  | Detail of Anchorage and Expansion Joint | BA-10223/3 | 1/27-3-01 |
| 12.2m (Post Tensioned I Type) MBG Loading-1987 for New Codal Provision Gap between Girder = $750 \mathrm{~mm} \mathrm{c} / \mathrm{c}$ of Pier $=14.11 \mathrm{~m}$ (suitable for PQRS loading) | General Arrangement | RDSO/B-10246 |  |
|  | Cable Profile Stress Chart and Deflection | RDSO/B-10246/1 |  |
|  | Detail of Reinforcement | RDSO/B-10246/2 |  |
|  | Detail of Anchorage and Expansion Joint | RDSO/B-10246/3 |  |
| 12.2m, 4 I-Girder of span (Post tensioned type) (restricted height) | General Arrangement \& Bearing | RDSO/B-10244/R |  |
|  | Details of cable profile | RDSO/B-10244/1/R |  |
|  | Details of cable layout | RDSO/B-10244/2/R |  |
|  | Details of reinforcement | RDSO/B-10244/3/R |  |
| 12.2 m c/c pier 13.4 m <br> (Post tensioned type) to MBG loading- 1987 (suitable for PQRS loading) Gap between Girder $=1200 \mathrm{~mm}$ | General Arrangement | RDSO/B-10254 |  |
|  | Stress Chart \& Deflection | RDSO/B-10254/1 |  |
|  | Details of reinforcement | RDSO/B-10254/2 |  |
|  | Expansion Joints | RDSO/B-10254/3 |  |
| 12.2 m c/c pier 14.11 m <br> (Post tensioned type) (suitable for PQRS loading) Gap between Girder $=1200 \mathrm{~mm}$ | General Arrangement | RDSO/B-10254(A) |  |
|  | Cable Profile Stress Chart \& Deflection | RDSO/B-10254(A)/1 |  |
|  | Details of reinforcement | RDSO/B-10254(A)/2 |  |
|  | Details of Anchorage Expansion Joint | RDSO/B-10254(A)/3 |  |
| Span 12.2m, 3 T-Girders | General Arrangement | RDSO/B-1752 |  |
|  | Reinforcement and Bar Bending Schedule | RDSO/B-1752/1 |  |
|  | Strands, Stress Table and Deflection | RDSO/B-1752/2 |  |


| 18.3m Span (Post Tensioned I Type ) Old Codal Provisions (c/c of pier $=20150 \mathrm{~mm}$, gap between girder 750mm) | General Arrangement | BA-10227 |  |
| :---: | :---: | :---: | :---: |
|  | Cable Profile Stress Chart and Deflection | BA-10227/1 |  |
|  | Detail of Reinforcement | BA-10227/2 |  |
|  | Detail of Anchorage and Expansion Joint | BA-10227/3 |  |
| 18.3m (Post tensioned Type) 4-I Girders (restricted height) |  <br> Bearing | RDSO/B-10245/R |  |
|  | Details of cable profile | RDSO/B-10245/1/R |  |
|  | Diaphragm Cable Layout | RDSO/B-10245/2/R |  |
|  | Details of Reinforcement | RDSO/B-10245/3/R |  |
| 18.3m (Post tensioned type ) (New Codal Provisions) c/c of pier 19800mm, Gap between girder 1200mm | Concrete Dimensions | BA-10247 |  |
|  | Details of cable profile stress chart \& deflection | BA-10247/1 |  |
|  | Details of reinforcement | BA-10247/2 |  |
|  | Details of anchorage \& expansion joint | BA-10247/3 |  |
| 24.4m (Post tensioned type ) Box Girder | Concrete Dimensions | BA-10243 |  |
|  | Details of cable profile | BA-10243/1 |  |
|  | Details of reinforcement (sheet 1 of 2) | BA-10243/2 |  |
|  | Details of reinforcement (sheet 2 of 2) | BA-10243/3 |  |
|  | Bar bending schedule and miscellaneous details | BA-10243/4 |  |
| PSC Box Girder with Segmental Construction Span 30.5m | General Arrangement and Elastomeric Bearing | BA-10222 | 1/20-4-01 |
|  | Cable Profile | BA-10222/1 | 01-8-96 |
|  | Stress Sheet, Cable Profile and Deflection. | BA-10222/2 | 01-8-96 |
|  | Reinforcement of PSC Box Girder | BA-10222/3 | 01-8-96 |
|  | Reinforcement of Diaphragm and Tangn Anchorage Tendon | BA-10222/4 | 01-8-96 |
|  | Bar Bending \& Quantity Schedule | BA-10222/5 | 01-8-96 |
|  | Shear Key and Expansion Joint | BA-10222/6 | 01-8-96 |

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| 30.5m (Post tensioned <br> type ) PSC Box Girder | Concrete Dimensions | RDSO/B-10242 |  |
| :--- | :--- | :--- | :--- |
|  | Details of cable profile | RDSO/B-10242/1 |  |
|  | Details of reinforcement <br> (sheet 1 of 2) | RDSO/B-10242/2 |  |
|  | Details of reinforcement <br> (sheet 2 of 2) | RDSO/B-10242/3 |  |
|  | Bar bending schedule and <br> miscellaneous details | RDSO/B-10242/4 |  |
| Precast PSC (Post <br> Tensioned) Box Girder <br> Span 45.1m | General Arrangement | BA-10232 | $1 / 20-4-01$ |
|  | Cable Profile | BA-10232/1 |  |
|  | Reinforcement | BA-10232/2 |  |
|  | Bar Bending and Quality <br> Schedule | BA-10232/3 |  |
|  | Reinforcement of Diaphragm <br> and Tendon Anchorage | BA-10232/4 |  |
|  | Stress Sheet, Vertical Profile <br> of Cable and Deflection <br> Sequence | BA-10232/5 |  |
|  | Pin Bearing | BA-10232/6 | $1 / 11-05-07$ |

3. Pot-PTFE fixed bearing for PSC box girder $\mathbf{3 0 . 5} \mathbf{~ m}$ span MBG loading - 1987

| Description | Drawing No. | Alteration/date |
| :--- | :--- | :--- |
| Pot-PTFE Fixed Bearing | RDSO/B-10253 |  |
| Pot-PTFE Transverse Bearing | RDSO/B-10253/1 |  |
| Pot-PTFE Longitudinal Bearing | RDSO/B-10253/2 |  |
| Pot-PTFE Free Bearing | RDSO/B-10253/3 |  |

4. Expansion Joint for Railway Concrete Bridge Deck

| Description | Drawing No. | Alteration/date |
| :--- | :--- | :--- |
| Expansion Joint for Railway Concrete Bridge Deck | RDSO/B-1757R |  |

## APPENDIX - XIV

## LIST OF RDSO DRG FOR PASSENGER PLATFORM SHELTER

| Width(m) | Description | Drawing No. | Alterations |
| :---: | :---: | :---: | :---: |
| $\begin{aligned} & \text { General } \\ & 7.00 \end{aligned}$ | BG PF roofs standard Type Sections | RA-10501 | No.3/29.3.84 |
|  | General Arrangement Drawing | RA-10531 | No 4/23.11.93 |
|  | Cantilever Truss | RA-10532 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10533 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10534 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 2/23.11.93 |
| 8.23 | General Arrangement Drawing | RA-10517 | No 4/23.11.93 |
|  | Cantilever Truss | RA-10518 | No 3/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10519 | No 5/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10520 | No 3/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Angle Iron Runner for roof and side |  |  |
|  | sheeting | RA-10513 | No 4/23.11.93 |
|  | Welded Purlins | RA-10521 | No 2/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 7/23.11.93 |
| 9.14 | General Arrangement Drawing | RA-10523 | No 4/23.11.93 |
|  | Cantilever Truss | RA-10511 | No 3/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10524 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10525 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10513 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 9.45 | General Arrangement Drawing | RA-10526 | No 4/23.11.93 |
|  | Cantilever Truss | RA-10511 | No 3/23.11.93 |

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|  | Angle Iron Runner for roof and side | RA-10512 | No 3/23.11.93 |
| :---: | :---: | :---: | :---: |
|  | sheeting |  |  |
|  | Gable end covering | RA-10516 | No 3/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10513 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 10.36 | General Arrangement Drawing | RA-10528 | No 4/23.11.93 |
|  | Cantilever Truss | RA-10511 | No 3/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10529 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10530 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 2/23.11.93 |
| 10.67 | General Arrangement Drawing | RA-10502 | No 5/23.11.93 |
|  | Cantilever Truss | RA-10539 | No 1/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10506 | No 5/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10508 | No 3/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 2/23.11.93 |
|  | Double Butterfly Type (BG) |  |  |
| 12.19 | General Arrangement Drawing | RA-10535 | No 5/23.11.93 |
|  | End Cantilever Truss | RA-10532 | No 1/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10536 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10533 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10534 | No 2/23.11.93 |
|  | Intermediate gable End covering | RA-10538 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 2/23.11.93 |

APPENDIX - XIV

| 14.33 | General Arrangement Drawing | RA-10540 | No 2/23.11.93 |
| :---: | :---: | :---: | :---: |
|  | End Cantilever Truss | RA-10518 | No 3/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10541 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10519 | No 5/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10520 | No 3/23.11.93 |
|  | Intermediate gable End covering | RA-10542 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 15.24 | General Arrangement Drawing | RA-10543 | No 4/23.11.93 |
|  | End Cantilever Truss | RA-10511 | No 3/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10541 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10513 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10525 | No 2/23.11.93 |
|  | Intermediate gable End covering | RA-10542 | No 2/23.11.93 |
|  | Angle Iron runner for side walling | RA-10513 | No 4/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 16.15 | General Arrangement Drawing | RA-10527 | No 4/23.11.93 |
|  | End Cantilever Truss | RA-10510 | No 3/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10511 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10513 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10525 | No 2/23.11.93 |
|  | Intermediate gable End covering | RA-10515 | No 2/23.11.93 |
|  | Angle Iron runner for side walling | RA-10524 | No 4/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 16.46 | General Arrangement Drawing | RA-10509 | No 4/23.11.93 |
|  | End Cantilever Truss | RA-10510 | No 3/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10511 | No 2/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10513 | No 4/23.11.93 |


|  | sheeting |  |  |
| :---: | :---: | :---: | :---: |
|  | Gable end covering | RA-10525 | No 2/23.11.93 |
|  | Intermediate gable End covering | RA-10515 | No 2/23.11.93 |
|  | Angle Iron rafter and runner | RA-10512 | No 2/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10514 | No 2/23.11.93 |
| 18.29 | General Arrangement Drawing | RA-10544 | No 4/23.11.93 |
|  | End Cantilever Truss | RA-10539 | No 1/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10543 | No 1/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10529 | No 4/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10530 | No 2/23.11.93 |
|  | Intermediate gable End covering | RA-10547 | No 2/23.11.93 |
|  | Angle Iron rafter and runner | RA-10546 | No 3/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 5/23.11.93 |
| 18.60 | General Arrangement Drawing | RA-10548 | No 4/23.11.93 |
|  | End Cantilever Truss | RA-10539 | No 1/23.11.93 |
|  | Intermediate Cantilever Truss | RA-10545 | No 1/23.11.93 |
|  | Angle Iron Runner for roof and side | RA-10506 | No 5/23.11.93 |
|  | sheeting |  |  |
|  | Gable end covering | RA-10508 | No 3/23.11.93 |
|  | Intermediate gable End covering | RA-10547 | No 2/23.11.93 |
|  | Angle Iron rafter and runner | RA-10546 | No 3/23.11.93 |
|  | Roof Stanchions | RA-10503 | No 7/23.11.93 |
|  | Welded Purlins | RA-10521 | No 5/23.11.93 |
|  | Cl pipe valley gutter | RA-10522 | No 5/23.11.93 |

## LIST OF RDSO DRG. FOR RCC INTZ. TANK

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| General Arrangement, capacity $\mathbf{4 5 0} \mathbf{~ k I}$ | $\mathrm{B}-1235$ |  |
| Details of tank (M-20) | $\mathrm{B}-1236$ |  |
| Staging (M-15) | $\mathrm{B}-1237$ |  |
| Landing platform (M-15) | $\mathrm{B}-1238$ |  |
| General Arrangement, capacity 225 kI | $\mathrm{B}-1239$ |  |
| Details of tank (M-20) | $\mathrm{B}-1240$ |  |
| Staging \& Landing platform (M-15) | $\mathrm{B}-1241$ |  |

(2) RCC Intz tank on cylindrical shaft ( Zones I to IV)

| Description | Drawing No. | Alteration/date |
| :--- | :---: | :---: |
| General Arrangement <br> Capacity 250 Kiloliter with cylindrical <br> shaft 20m high for seismic zones I to IV. | B-1378 |  |
| Details of Tank | B-1379 |  |
| Staging and landing platform | B-1380 |  |
| General Arrangement <br> Capacity $\mathbf{1 0 0}$ Kiloliter with cylindrical shaft <br> 20m high for seismic zones I to IV. | B-1381 |  |
| Details of Tank | B-1382 |  |
| Staging and landing platform | B-1383 |  |
| General Arrangement <br> Capacity 50 Kiloliter with cylindrical shaft <br> 15m high for seismic zones I to IV. | B-1388 |  |
| Details of Tank | B-1389 |  |
| Staging and landing platform <br> Typical drawing of raft foundation for different <br> bearing capacities of soil and seismic | B-1390 |  |
| zone I to IV |  |  |


[^0]:    other items the concept of tailoring diagram has been used

