RETS

PRACTICAL GUIDE BOOK SERIES

MASONRY and CONCRETE

RAILWAY ENGINEERING TECHNICAL SOCIETY
PUNE - INDIA

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MASONRY AND CONCRETE

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PREFACE

The learning of 'Masonry and Concrete' is imparted in Civil Engineering Degree, diploma and to trade apprentice courses, in various Colleges and Institutes. However, it has been my observation while working in Railways in various capacities, that large no. of Engineers, supervisors and artisans have to learn methods of proper working from their seniors, peers and few skilled artisans in the field. Several Hand books, and literature available in the market on the subject, generally have information but it is cloaked behind high level theory, tables, formulas and codal provisions and it is a difficult task for any person of average intelligence and patience, especially for field Engineer/Supervisor, to sift through the required information from these normally thick volumes. The B.S./I.S. Codes and so also the Specifications framed by several Government departments like CPWD and Railways demand the quality of a finished work but not guide about the method to achieve it, besides being worded in techno-legal language for reasons of having an upper hand while dealing with contractor. I understand that, in some organisations and in advanced countries a 'Method Statement' is prepared by a Technical Consultant for all works, even of basic nature, which is approved by the Technical Department owning the work and is followed at the field by all the Engineers, Supervisors and the Artisans. In Government departments in India, like Railways and CPWD, this is mainly left to the decision and the method adopted by the artisans and field supervisors. The work is then as good as the artisans and Supervisors employed on the work. The B.S./I.S. codes give detailed specifications of the materials and the tender specifications make a mention of the same, but one finds that there are different set of specifications being followed in the field, mainly due to ignorance about the B.S./I.S. specifications, so much so that field supervisors have also become used to the "Chalta Hai" attitude, which gets strengthened, day by day, with their experience. An attempt has been made to provide the controlling specifications and field tests of the materials used in works and it has been deliberately avoided to reproduce the codes. While working as Principal Chief Engineer on Western Railway, I started work of preparing "Method statements' for commonly used items of work in the Railways, with the assistance of Shri G.C.Jain, DyCE/Planning, W.Rly. and several SE(Work) of W.Rly., with the idea to make it a part of all contracts, in Western Railway. Shri Jain, retired from service and the process got delayed. The work has been now completed by Shri A.V.Dasare Sec. Engineer/ IRICEN and Shri N.R.Kale, Assistant Executive Engineer/IRICEN but the format has been changed from that of a statement to that of a guide book. This Practical Guide book is expected to serve the field Supervisors as a substitute for 'Method Statement' and guide the artisans about the steps for proper execution of work. I do not claim it to be a comprehensive treatise on

the Science and art of 'Masonry and Concrete', as it has been the intention to make a very short and crisp presentation on the few factors that any field Engineer/ Supervisor would like to know for achieving proper quality of work. This is a collection of procedures and good practices and I am sure that the readers can enrich it further by their contribution and suggestions, which are welcome.

1-9-2008

A. K. GOEL

President, Railway Engineering Technical Society, and
Director, Indian Railway Institute of Civil Engineering
Pune-411001

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CHAPTER 1

MASON'S TOOLS

1.0 The various tools used by mason for his work can be grouped as follows.

a) Common tools: In this category all types of tools commonly used for setting the masonry work such as

Trowlels: Brick trowel, Nyla, Margin trowel, Gauging trowel, Angle trowel.

Floats: Wooden floats, Metal floats,

Plumb bob

Mason's square

Line dori

Screed board/ Aluminium Box section.

Measuring Tape

b) Mortar Making tools: Generally these tools are used in making mortars for masonry.

Pharma

Mixing tray

Sand screen

Pan (Ghamela)

Spade(Phawra)

Bucket

Drum

Punja

c) Levelling tools: These tools are used for setting the levels at the time of work.

Spirit level

Level tube

d) Finishing tools: These tools are used for finishing work such as Sponge

M .S. Corners

Cove corner

Jointer/slicker

Convex or concave jointer

Vee Jointer

Grapevine Jointer

Brushes

d) Cutting tools: These are tools used for minor cutting or chpping work

Chisels

Hammers

Taccha

Tile cutter

Portable Circular Saw

2.0 Common Tools

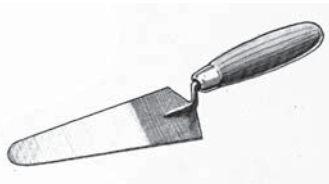
2.1 Trowels: Trowels are the basic and traditional tools which have developed into many various shapes and sizes as per their functions. Some common types of trowels are as follows:

a) Brick trowel (Thapi):- Brick trowel is usually about 18 cm long with a steel blade and wooden handle. Brick trowels are used to pick up mortar and spread it in the level for the next course of brick. It is traditional tool which has developed into many various shapes and sizes. The blade being flat on one side for lifting the mortar from the pan. The curved edge is hardened for cutting bricks. The handle is set at an angle to balance the tool while keeping the mason's hand clear of the mortar.

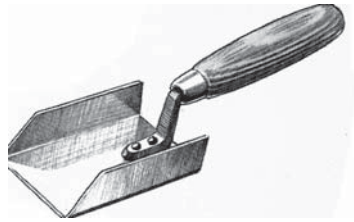
b) Nyla (Small size brick trowel) :-It is also a trowel but smaller size having length about 12.5cm and used to mainly fill the joints between the bricks.

c) Margin trowel: The margin trowel is like a pointing trowel but has a flat rectangular blade. It is used by plasterers to apply and smooth material in areas where a larger trowel would be inconvenient.

d) Gauging trowel: - The gauging trowel having blade length 15cm to 20cm is used by plasterers in the same way as a margin trowel. It is preferred by some masons for general application, such as mixing small quantities of quick setting plaster.



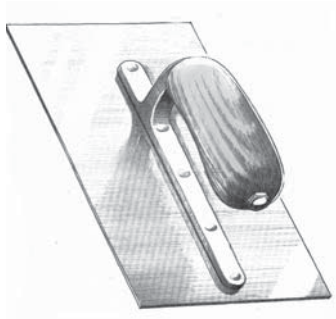
e) **Angle trowel: -** The angle trowel has a flat blade with the edges turned up at right angles of size length 100mm x 62mm wide and 25mm height. It is used by plasterers to smooth the surface of the material when working in to a corner.



2.2 Floats

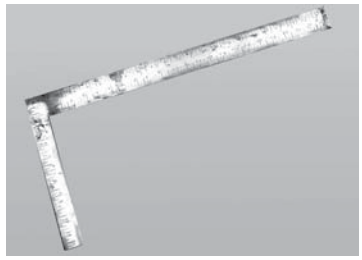
a) **Wooden float (Randha):-** Wooden strip of 50 cm length and 10 cm width with handle used for laying mortar in line on brick work, some times at the time of plaster also. It is also available in smaller sizes such as 25cm x 10 cm.The main purpose of using floats is to fill voids, level ridges and smooth the surfaces in the preparation of troweling.

b) **Metal float:** The metal float is a flat rectangular sheet of steel normally 25cm x 10cm with a handle fitted centrally down the back face. Its general purpose is for both applying and finishing the material, applying sanla or neat cement finish to plaster.

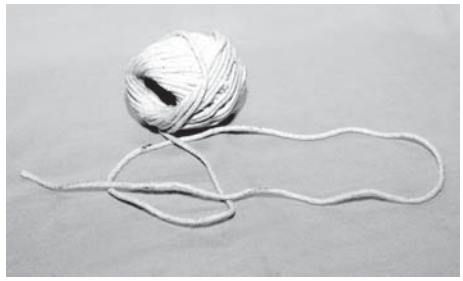


c) **Plumb Bob (Olamba):** Plumb bob is a basic tool for mason to construct any masonry work in vertical plane. It is available in normally mild steel with coating having weight about 30-40 gms.The plumb bob is pointed weight attached to a length of line which is contained in the bob itself and fastened in a slot in the cap

d) **Mason's square(Gunnya):** This is used to set out a right angled corner. It is M.S. square having 30cm x 60cm long arms with inch or Cms marking. It is used for laying corner of bricks in rectangle also measurement of width of wall.

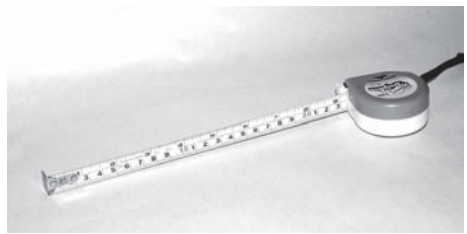


e) Line dori: This also required by any mason as a basic tool for doing the work in line. Normally a jute dori of 3mm dia. with wax coating is used. Nowadays nylon line dori are quite in use it may be of 1mm to 2mm dia.



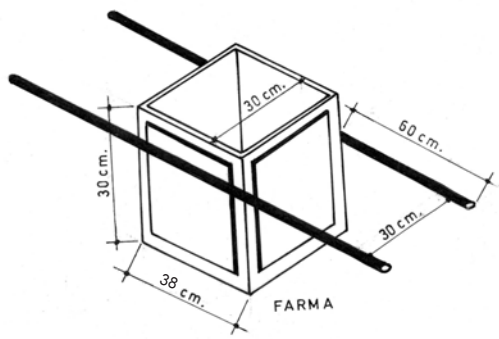
f) Screed board/ Aluminium Hallow box section: Screed board is used for leveling the surface at the time of plastering and flooring work. It may of wooden batten of size 50mm x 65mm of length 1.2m to 1.5m. A aluminium hallow box section of size 65mm x 30mm and 1.5m length is also used. This can be named as straight edge.

g) Measuring Tape:- A steel tape having marking in Metres and foot and subdivided in Cms and inches is normally used by mason for measuring the length and width of masonry. It is available in 2m, 3m, 5m, 15m and 30m in length.

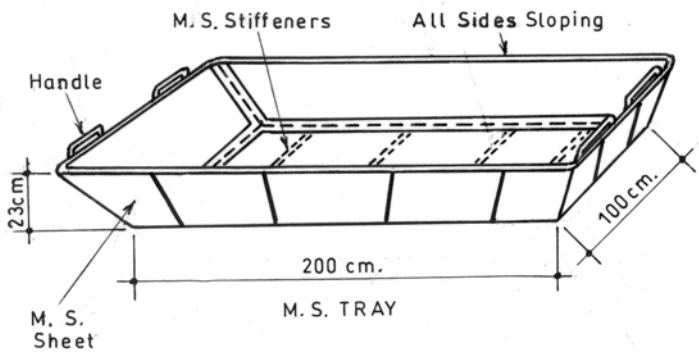


3.0 Mortar Making tools:

a) Pharma: It may be wooden or steel box of measurement 30cm x30cmx 30cm having volume equal to volume of one bag of cement. While dumping raw material for mortar (say 1:4), for one bag of cement 4 pharma sand will be mixed.

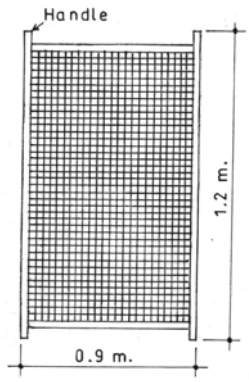


b) Mixing Tray: For mixing mortar the tray made up of mild steel is used generally. It is 2.0m in length and 1.0 m wide with handles as shown.



c) Sand screen: Generally a wire mesh of overall size 0.9m x 1.2m fixed on wooden frame or angle frame used as screen for sand. The screen is made up of 0.6mm dia.wires and 10 x10 wires per inch square for masonry work.

For plastering work a screen having 0.3mm dia of wire with 24 x24 wires per inch square.



SCREEN

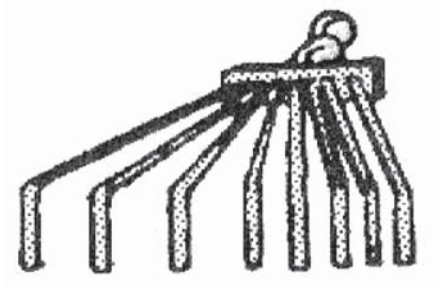
d) Pan (Ghamela) : For transportation of mortar a iron pan of 40cm dia is used. It can be used for proportiong the mix also. If there is 1:4 mortar mix then 1 pan of cement can be mixed with 4 pans of sand

e) Spade (Phawra): It is most common tool for mixing the mortar and for filling the pans.

f) Bucket: Generally an iron bucket of up to 10 lit. capacity is used for mixing the water in the mortar.

g) Drum: A 200 lit capacity M.S. drum is used to store the water. Now-a-days PVC containers are also available.

h) Panja: A group of 8 to 10 wires of 6mm M.S bars of length 500mm and these wires are bent at 90 degree at edges (as shown in fig.) is very useful tool for spreading the concrete in particular area with required thickness.



4.0 Leveling Tools

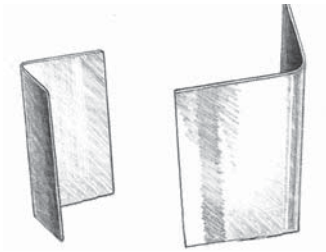
a) Spirit level: This is the most important tool with help of which level between any two surfaces can be judged by movement of bubble. Normally this instrument is used for tiling work for checking level of tiles.

It is normally 30 cm long. The important part of any level is the vial. This is curved or barreled glass or plastic tube containing a clear liquid which may be alcohol, oil or chloroform. There is a bubble of air in liquid which floats to the highest point of the curve, where two lines are marked on the vial. When the level is "true" the bubble will come to rest between the two marked lines.

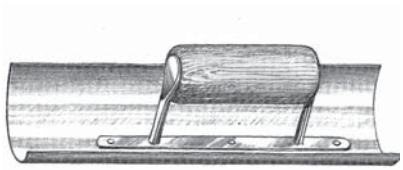
b) Level Tube: A thin 6mm dia PVC transparent tube of about 8-10m. in length and is used to check the levels when filled with water. Basic principle is that water will occupy same level, is used for making the work in level.

5.0 Finishing Tools

a) **Sponge:** A square of sponge of size 12.5 cm x 10 cm is used to finish plaster surfaces as sand faced plaster. By applying two to three rounds of this sponge fine texture of sand will appear on surface.

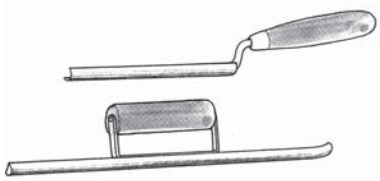


b) **M.S. Corners:** Small pieces of MS sheet of about 12.5 cm in length and used for perfectly finishing of corners of wall and edges of door and window plaster.

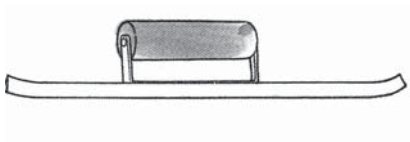


c) **Cove Corner:** The cove corner is like a metal float, but the rectangular blade is bent in to a curve across its width. It is used to smooth the internal curve of the decorative plaster moldings sometimes found between ceilings and walls.

d) **Jointer/Slicker**:- It is having a blade length of 12.5 to 30cm with hard wood handle and used to finish the mortar joints between bricks. The mortar joints between bricks must be formed in order to make them weatherproof and to improve the appearance of the brick work.



e) **Convex/concave Jointers:** It is also a blade length 12.5cm to 30cm. This is used for finishing the joint in concave joint.



f) **Vee-Jointer:** It is also a blade length 12.5cm to 30cm and looks like concave jointer but has a deep, sharply angled blade for finishing V shaped joints.

g) **Grapevine Jointer:** Same as per convex jointer but having shape as in drawing having central rib for a decorative flat joint with a deeply impressed shadow line in the centre.

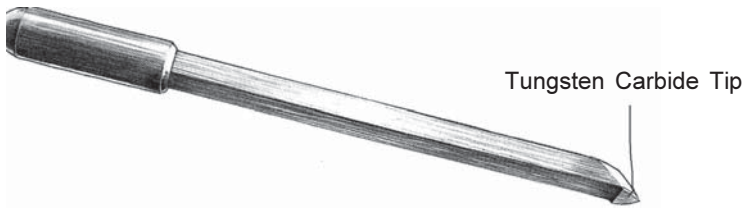
h) Brushes: At least two types of brushes 25mm wide and 75mm wide brush should be with mason for cleaning the surfaces and finishing work.

6.0 Cutting Tools

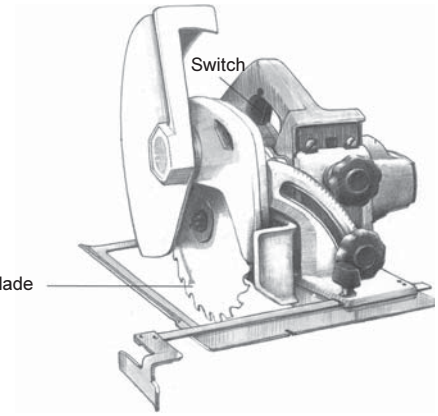
a) Chisel and Hammer: Various types of chisel and hammer are available in market but mason should have at least two types of hammers which weigh 1 pounds and 4 pounds for dismantling work and chisels of size 10cm for small work and 20 cm for major work of dismantling.

b) Taccha: It is just like a hammer but having both ends pointed edges and used for hacking the concrete surfaces of beams and columns or slabs before plastering, for better bonding. Some taccha have one point as pointed sharp for deep hacking.

c) Tile cutter: The simplest tile cutter is a square sectioned steel shaft of 20cm length with a pointed tungsten carbide tip. It is used to score a line on the glazed surface of a ceramic tile prior to snapping it off.



d) Portable Circular saw: The portable circular saw is an invaluable power tool. It is primarily a woodworking tool, but with special tile cutting blades it can be used to cut the ceramic as well as other types of tiles.



CHAPTER 2

MATERIALS

1.0 Cement:

Cement is the most important constituent of all works to be carried out by a mason. It is manufactured by burning naturally occurring raw materials such as lime, silica, alumina and iron oxide. The burning produces clinker and it is ground in mill with small quantity of gypsum to produce cement.

The cement when in contact with water reacts chemically to form cement gel, a hydration product which gives the strength and binding property to cement. During this reaction heat also is generated, called heat of hydration. Theoretically, water equal to 26% of weight of cement is only required to fully react (hydrate) the cement. However, for full hydration of cement to take place, long time is required, as the gel has a complex structure and part of the water always stays around the cement gel, preventing water to react further immediately, creating porosity in the cement paste. More the water added to cement more will be porosity and thereby lesser strength of cement paste. The further hydration of cement gel takes place slowly and continues even after hardening of concrete.

1.1 Types of cements:-

a) **Ordinary Portland cement (OPC):**- Grade-33 this is commonest cement available in market. It is used in most masonry works in India. However, of late many large plants in India are not producing this cement and preferring higher grade cements.

b) **High strength Cement:-** Grade-43 and Grade-53 cements are primarily the same as OPC but are ground finer and thus develop higher strength initially i.e. at 7 days and 28 days but long term strength is expected to be same as OPC.

c) **Ground Granulated blast furnace Slag Cement:**- Blast furnace slag from steel plants has properties similar to cement. The cement clinker is mixed with about 25-65 % of slag and grounded. The cement thus produced has almost identical properties as that of OPC however; the early gain of strength is slower compared to OPC. Thus opening the form work in case of Reinforced cement concrete or Plain Cement concrete, made with Slag cement will be delayed. Because of slow chemical reaction, the heat of hydration is also less compared to OPC, and therefore shrinkage cracks are also less.

d) **Pozzolana Portland cement:**- It is made by blending about 10-25%

of pozzolanous material like fly ash, burnt clay etc. This behaves also like Slag cement with initial gain of strength being delayed. Since the heat of hydration generated on coming in contact with water is less, initially, this cement if used in plaster etc., will produce less cracking.

There are many other special purpose cements such as Rapid hardening Portland cement, low heat Portland Cement, sulphate resisting cement, etc., but are used under special requirements only.

These days many big Cement Plants are producing Granulated blast furnace slag cement (GBF) and pozollana Portland cement in good quantity and OPC production is proportionately cut down. These cements can be used in lieu of OPC for general building works and plain and reinforcement concrete. However due to delayed development of initial strengths, the curing should be done for a prolonged period and removal of form work be extended by about 30% over the periods specified for OPC.

1.2 Testing of Cement

a) Laboratory test: - All the cements are tested in the cement plant before dispatch. Each bag of cement has the marking of the I.S. specifications to which it is manufactured, the grade of cement, the week, month, year of manufacture and the name of the company manufactured the cement.

If the cement is purchased directly from the cement plant, it will accompany with the test certificate. It is recommended that independent testing of cement from a reputed test house should be got done for bulk purchase of cement. 1 bag of cement intact in its original packing be picked at random and sent to test house for testing. The laboratory is required to test the parameters as given in Annexure -1.

b) Field test: - Field tests should be done by the Junior Engineer at site, for every truck load of cement received at site as under.

i) The stitching of the bag should be intact and original.

ii) Check the grade of cement and I.S. specifications of cement.

iii) Check date (w- is marked for week, m- for month and y- for year) of manufacture- It should be fresh and not older than 3 months. Older than six months is not to be used. No lumps should be present.

iv) Put hand in one bag and the feel of the cement and on rubbing between the fingers should be silky, and it should feel cool.

v) When a pinch is dropped in water it should float first before sinking.

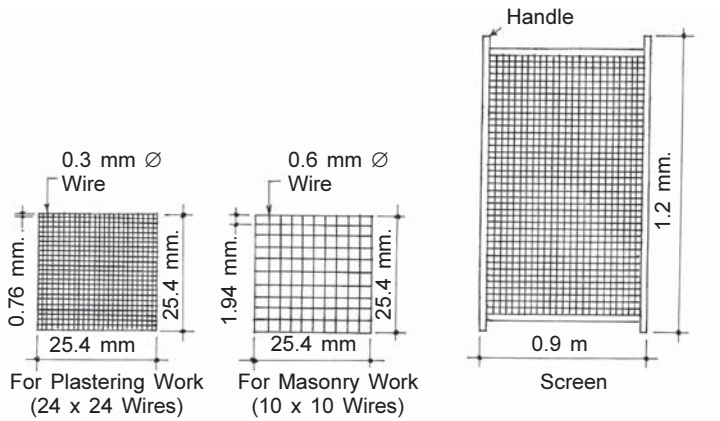
vi) Immerse a small cube made of cement paste in water and after 24 hours it should gain some strength and its edges should be intact.

vii) Weigh 5 bags and the average weight should be 50Kg.

2.0 Fine aggregate (Sand):-

2.1 Fine aggregate could be naturally occurring sand or crushed stone sand. The aggregate retained on 75 micron sieve and passing through 4.75 mm sieve is called sand. The coarser sand having 4.75 mm and 2.36 mm particles are generally not preferred for masonry and plaster work, but are useful for concrete work. As per the I.S. code, the sand for masonry and plaster should be as per the following gradation.

Masonry Mortar (I.S.2116-1980)		Plaster Mortar (I.S.1542-1977)	
Sieve size	% passing by wt.	Sieve Size	% passing by Wt.
4.75mm	100	4.75mm	95-100
2.36mm	90-100	2.36mm	95-100
1.18 mm	70-100	1.18 mm	90-100
600micron	40-100	600micron	80-100
300micron	5-70	300micron	20-65
150micron	0-15	150micron	0-50



DETAILS OF SCREENS FOR SAND

It would therefore be proper for site control that a screen of hole openings of 1.94 mm provided by a steel wire mesh of 10x10 wires per inch (diameter of wire is 0.6 mm) of for masonry work and a screen of hole opening of 0.76 mm provided by a wire mesh of 24x24 wires per inch (diameter of wire is 0.3 mm) for plaster work, is used to screen the sand before use. Normally, therefore screen with 4 wires per cm. of screen is used for masonry and 9 wires per cm for plaster work.

2.2 Impurities in Sand: - It should not contain any appreciable quantity of clay lumps, mica, shale, and salts etc. which are visible by naked eye. There could be also organic impurities like decayed vegetable matter, sea shells etc which should not be allowed. In some areas such as coastal areas fine aggregate is dredged from the creek bed and all these impurities are bound to be present in variable quantities. Since importing sand from far away places could be very expensive, marine sand may have to be used. Such sand should be washed in potable water in sand washing machine and should not be used as such.

The maximum quantity of silt (finer particles smaller than 75 micron) can be allowed in sand up to 8% by weight or 7% by volume. If the % of fines below 75 micron is more than permissible, the sand has to be washed to bring it less than the permitted. However, if the silt is very much in excess, it is preferable to change the source of supply.

2.3 Bulking of Sand: - The fine aggregate i.e. sand has a property of swelling in volume when wet. The sand when surface dry or when fully saturated has the least volume. The approximate adjustment required to the volume of sand to be used at different water content of sand is as under:-

Moisture Content (% by weight)	Bulking (% by Volume)
2	15
3	20
4	25
5	30

In case the sand is moist at the time of preparing the mix, necessary adjustment i.e. additional volume of sand be added and also quantity of water reduced.

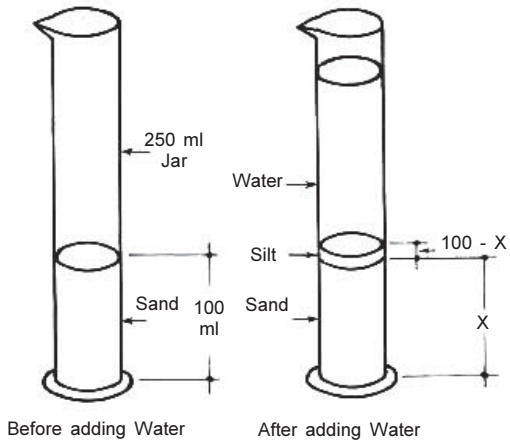
2.4 Testing of Sand:-

a) Laboratory: - All chemical and physical properties should be tested while selecting or approving a source for sand. The tests shall be for,

i) Grading
ii) Organic impurities
iii) Inorganic impurities
iv) Chloride content
v) Sulphate content as SO_3
vi) Silt content

b) Field Tests:

i) Determination of silt content: Sand is filled in a measuring cylinder of 250 ml. capacity, up to 100ml mark. Clean potable water is added up to the 150ml mark. A pinch of common salt is added and the jar shaken vigorously. The cylinder is kept on the table undisturbed and contents allowed to settle for 2 hours. Sand will settle below and fine deposits of silt and clay impurities will come to the top. Measure the the level of sand, say it is X.

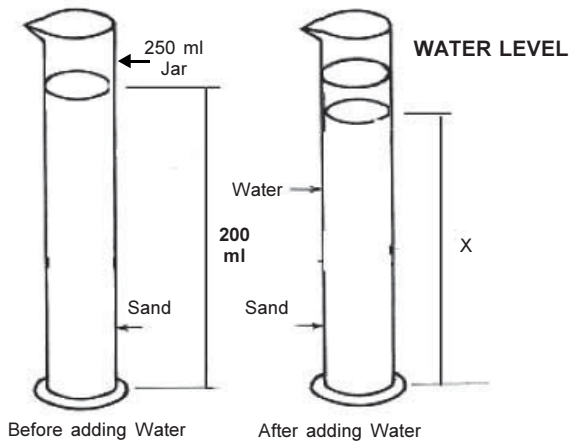


DETAILS OF SILT CONTENT IN SAND

Silt content = (100-X) %.

ii) Visual inspection for Impurities:- coloured particles other than sand such as shells, gravels, lime, clay lumps etc can be seen while unloading the sand from truck. Such impurities should not exceed 1% of the sand received. Much of these impurities can be removed by simple screening.

iii) Bulking of sand: - Take sand in a measuring cylinder of 250ml capacity, up to 200ml mark. Pour water in the cylinder so that the sand is fully submerged. Stir the cylinder well. Allow about 15 minutes for sand to settle down. Measure the mark to which the sand stands in the cylinder, say X ml.



MEASUREMENT OF BULKAGE OF SAND

% bulkage of sand = { (200-X)/X}100

iv) Grading: - It is a good practice to check the grading of sand when received at site, to avoid wastage at the time of using it. It is to be ensured that all sand is screened before use. The sand used for plastering is finer and should pass through a screen with 9 holes per

cm length of screen; sand for masonry work should pass through a screen with 4 wires per cm length of screen. For concrete, not less than 20% of sand should be fine passing through a sieve of 600 micron.

3.0 Stone Aggregate:

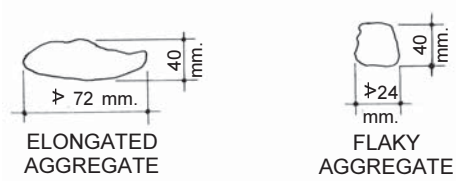
a) Properties:-

i) Crushing strength: The crushing strength of the stone, as a rule should be more than the grade of concrete in which it is to be used. It is therefore of great importance for high strength concretes. While deciding to obtain stone aggregate from a particular quarry, this has to be ascertained and subsequently checked that material is being supplied from the same quarry.

ii) Abrasion Resistance: - The stone particles on rubbing with each other or some outside environment should not degrade and is measured by Abrasion resistance of aggregate. It should not be more than 30% for wearing surfaces and 50% for other structures.

iii) Shape of particles: - Crushed stone aggregate should be angular, cubic shape and not flaky or elongated. A cubic shape has all the 3 dimensions length, width and height same, and crushed stone should be as close to this as possible. A particle having ratio of one of the dimensions less than 0.6 times or more than 1.8 times of the nominal size of aggregate is termed as flaky or elongated and such particles give comparatively less strength and less durability, keeping other things same. The shape of particles not only depends on the crusher jaws but also on the quality of rock.

In some areas such as North-east India river boulders are crushed to form coarse aggregate, this can be per-mitted, if only one surface of the crushed stone only has rounded face.



iv) Water absorption: - The water absorption, when stone aggregate is kept soaked in water for 24 hours should not exceed 2% by weight.

v) Soundness of aggregate: - A stone aggregate is said to be unsound when it undergoes excessive changes in volume with increase or decrease of temperature. This is mostly of importance in areas where freezing and thawing can produce such changes.

vi) Alkalie Aggregate reaction: - In some of the aggregate the alkalie present in the cement reacts with the stone constituents. Such reactions will cause harmful expansion of aggregate and result in expansion of concrete causing crack. This is therefore not considered proper to use such aggregate. Dolomitic limestones, and a few other

known stones and can be avoided in the concrete. In India however this type of aggregates are found in very few locations and should not be used.

All the above properties have to be ascertained at the time of selecting a particular source or quarry. At the time of execution of work the site Engineer is to merely ensure that the source is not changed and carry out some field tests. The properties of Fine and Coarse aggregate are given in Appendix-2.

b) Field Tests:

i) The particles should be angular cubic shaped. Flaky and elongated particles should be minimum.

ii) Absorption of water on being soaked for 24 hours should not be more than 2% by weight.

iii) Size/grading should be as required.

4.0 Bricks

4.1 Brick is produced in almost all parts of India and there is considerable difference in type of soil, process of manufacture and hence the finished product is also different. Brick is a block of baked/burnt clay of size 230mmx110mmx70mm. The modular brick is 190x90x90 mm. The bricks have a frog 100mm length, 40mm width and10-20 mm depth on one of the faces of the brick. Each brick has manufacturers identification marked in the frog.

4.2 Bricks are subjected to following tests for acceptance:-

a) Visual properties

b) Dimensional tolerances

c) Water absorption

d) Compressive strength

e) Efflorescence

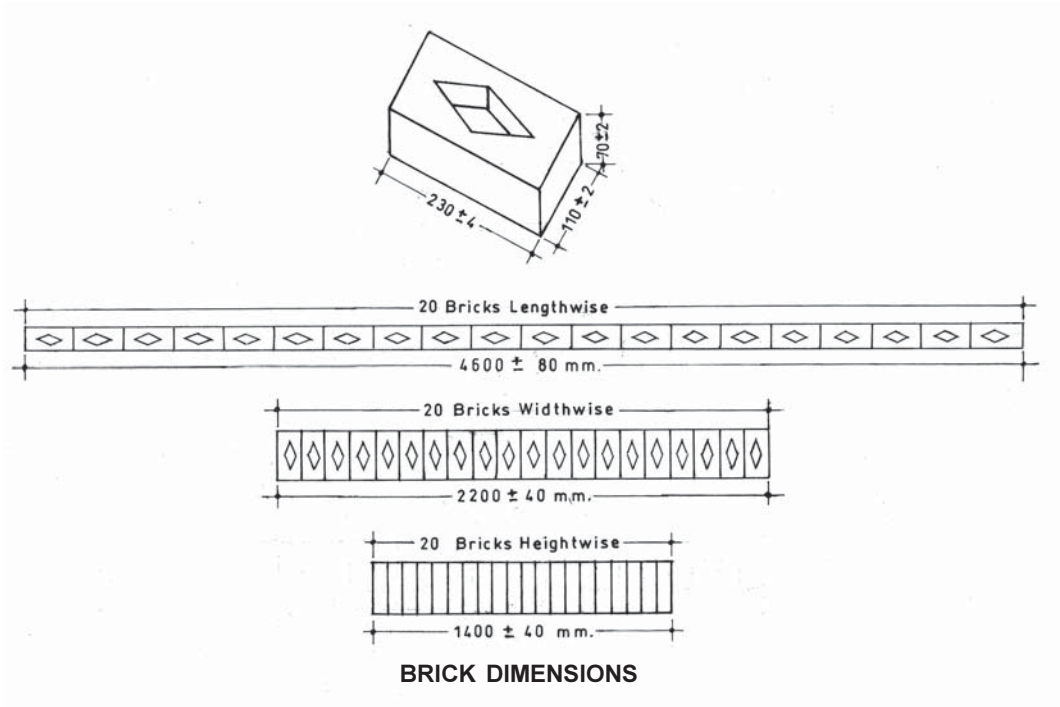
4.3 Visual properties

1. Reddish and uniform in colour.
2. It should have sharp edges and corners and should be free from cracks, chips, warpage.
3. Should give clear metallic ringing sound when two bricks are struck together.
4. Should not be over burned and under burned.
5. % ge of broken bricks should not be more than 5% in a load of truck.

4.4 Dimensional Properties

Arrange twenty bricks length wise in one row and measure the length

of this row and it should be 4600 ± 80 mm. Arrange twenty bricks in width-wise in one row and measure the length of this row and it should be 2200 ± 40mm. Similarly arrange twenty bricks in one row as shown and measure the length of this row and it should be 1400 ± 40mm.



BRICK DIMENSIONS

4.5 Water Absorption:

The water absorption of a brick when kept soaked in normal water for 24 hours should not be more than 20% by weight of brick. In lower quality of bricks having less compressive strength the water absorption will also be more. However no relaxation is permitted.

4.6 Compressive strength:

Bricks are classified in different class designation based on the compressive strength of the brick, as under,

Class Designation	Minim. Comp. strength (Kg/cm^2)
100	100
75	75
50	50
35	35

It is recommended to use class 75 bricks in permanent buildings. However in large parts of country, such bricks may not be available. The choice of selection of bricks remains very limited due to local availability

constraints. In many big projects also bricks of lower class are being used. It is therefore considered that depending on the quality of bricks locally available, a conscious techno-economic decision should be taken at higher level.

4.7 Efflorescence:

It is the property of brick, when moist and on drying shows traces of salts leach out on the surface. If this is more than moderate, i.e. "when there is heavy deposit and covering up to 50% of the area of brick but unaccompanied by powdering or flaking of the surface" when tested in laboratory as per I.S.3495 (Pt.3)-1992 the brick is not suitable for use.

4.8 Field Tests:

All the properties of visual properties, dimensions, water absorption, compressive strength need to be carried out for all the lots received at site. In regard to strength of the brick a simple test is done by dropping a brick flat on its face on firm ground, from a height of 60 cm. and the brick should not break.

4.5 The prescribed samples to be tested and permissible defectives is as under:

Lot Size	Visual Properties		Dimensional property		Water absorption, Strength, Efflorescence	
	Sample size	Defective permitted	Sample size	Defective permitted	Sample size	Defective permitted
2001-10000	20	1	2x20	0	5	0
10001-35000	32	2	3x20	0	10	0
35001-50000	50	3	4x20	0	15	1

5.0 Steel Reinforcement Bars:

The commonly available reinforcement bars are,

a) Mild steel rounds

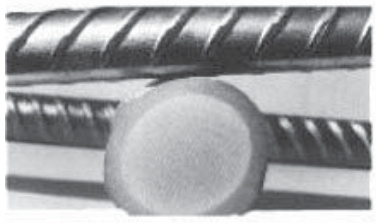
b) High yield strength deformed bars or Cold twisted deformed bars

a) Mild steel Bars:- These bars conform to I.S. 432-part 1 -1982. These are rounded bars and were most commonly used in the past. However, now a days only 6mm diameter rods are used to this specification. These are mostly rolled by re-rollers, though primary

producers like SAIL, Tata Steel, RINL also do roll this diameter. These are mostly supplied in coils but long lengths of 11-12 meter are also available. The rolling tolerances of this round is ± 0.2 mm in diameter.

b) **High yield strength deformed bars (HySD)**:- All other size of bars from 8mm -50mm diameter are produced in this steel as per I.S.1786-1985. These bars are about 10% costlier than mild steel bars but consumption of these bars would be approximately 30% less due to higher strength and better bond properties, and it is this reason that these bars are mostly used in construction of RCC works. These are also called TOR bars. These bars are deformed while in hot state. TOR is marked on these bars at every meter of the bars. The yield strength of these bars is 415 N/mm^2.

A variation of HySD bars is TMT bars (Thermo Mechanically Treated bars). These are manufactured under identification names as Fe415, Fe500 and Fe 550. The HySD bar is given a special heat tempering procedure, which increases the strength of the bar. The figure following the Fe indicates the yield strength of the bar i.e. Fe415 indicates a TMT bar with Yield stress of 415 N/mm^2. These bars are manufactured in diameters ranging between 4mm to 50mm. These bars are now a days being used in heavy structures like major bridges etc. These TMT bars were first produced by Tata Steel followed by SAIL. These are now being manufactured by some other smaller firms also. One has to be more circumspect about the quality control measures put in place by the smaller producers.



HySD bars
TMT bar

CTD bars

c) **Cold Twisted deformed bars** : Sometimes CTD bars are considered synonymous to HySD bars as these are also to follow IS-1786-1985 and have same minimum requirement of mechanical properties of strength, ductility, bond etc. The mild steel bar is twisted under cold condition, hardens the steel and gives higher yield stress, by work hardening. The re- rollers are producing CTD bars only. The main steel plants namely, SAIL and Tata Steel however have switched to HySD or TMT bars. In several countries of Europe and America use of CTD bars has been prohibited in RCC or PSC work, specially in

seismic areas of zone III, IV and V. However in India there is no such restriction.

d) **Corrosion Resistant Steel bars**: TOR steel bars are also manufactured with addition of small quantity of Copper and Chromium and are identified as CRS (Corrosion Resistant Steel) bars and also HCR (High Corrosion Resistance) bars. The manufacturers of these steels claim that these bars resist corrosion; however, the claims are disputed by several users and laboratories. They cost about 2-3% higher than the TOR steel bars.

5.1 The unit weight, area, and rolling tolerances for various bars are given in table below,

Dia. of bar (MM)	Weight (kg/meter)	Area (cm^2)	Rolling tolerances
6	0.22	0.28	±7% by wt.
8	0.39	0.50	—do—
10	0.62	0.79	——do—
12	0.89	1.13	±5% by wt.
16	1.58	2.01	-do-
20	2.47	3.14	±3% by wt.
22	2.98	3.80	-do-
25	3.85	4.91	-do-
28	4.83	6.16	-do-
32	6.31	8.04	-do-
36	7.99	10.18	-do-
40	9.86	12.57	-do-
45	12.49	15.90	-do-
50	15.41	19.64	-do-

6.0 Concrete blocks:

In areas where good quality bricks are not available economically, concrete blocks are used in place of bricks. The blocks can be solid, hollow, or with cavities depending upon requirement. The blocks can be manufactured to any dimensions required, either at site or obtained from a factory. Portable hand operated and power operated machines are available for casting the blocks. The blocks are to be made as per I.S.2185 (Pt.1 &2)-1979. The solid blocks are normally of size 300x150x200 or 300x100x200 mm. Half size blocks of 150x150x200 and 150x100x200 mm are also manufactured as required for building a bond.

The minimum requirements of concrete blocks are as under,

S.No.	Property	Min. Requirement
1.	Compressive strength of concrete (Min.)	4.0 N/mm2 Achieved by 1:5:10 conc.
2.	Density of concrete (Max.)	1800 Kg/m3
3.	Water absorption(Max.)	10%

The concrete blocks suffer from one shortcoming that they shrink on drying and cause cracks in masonry. It is therefore essential that after curing the blocks for 28 days, they should be dried in open air for at least 28 days before use to allow for initial shrinkage. Further maximum possible time be allowed before plastering the surface made with concrete blocks. Precautions are required in stacking for the blocks to allow maximum exposure for drying as below,

i) Stacking area should be preferably in shade.

ii) The blocks should be stacked in rows and heaps with gap of 50 mm between each, allowing for proper ventilation.

iii) There should be a gap of about 1 m after every 25 rows.

iv) More than 6 blocks should not be stacked, one above other specially when they are green.

6.1 Quality tests

All the tests as prescribed for bricks are applicable for the blocks also. Similarly, the sampling size is also same as for bricks. Following field tests should be exercised,

i) Check the dimensions as explained for bricks.

ii) The edges should be sharp, straight and at right angles.

iii) Should be free from cracks.

iv) It should not break when dropped down from 1.0 m height on hard ground.

v) Percentage of broken blocks should not be more than 5% in one truck load.

vi) Check the average weight of block and density should not be less than 1800 Kg/m3

vii) Water absorption when kept in water for 24 hours should not be more than 10% by weight of block.

7.0 FLOOR AND WALL TILES

The pre-cast, polished tiles are a very practical and aesthetically pleasing choice for cladding the floors and also walls as fixing the tiles is very quick compared to laying in-situ flooring. The conventional tiles used are,

a) Plain cement and plain coloured tiles

b) Terrazzo tiles /Marble mosaic tiles

c) Chequered cement tiles
d) Glazed Wall/floor tiles
e) Vitrified Ceramic tiles
f) Marble stone tiles or slabs
g) Granite stone tiles or slabs
h) Paver blocks

7.1 Plain cement and plain coloured tiles:

These tiles are available in 200x200x20mm, 250x250x22 mm and 300x300x25 mm. The wearing top layer of 5-6 mm containing quartz sand and cement could be plain or added with pigment for desired colour. These are manufactured as per I.S.:1237-1980 and tiles so manufactured have an I.S. identification mark on each tile. These tiles are manufactured for

a) General purpose
b) Heavy duty.

The requirements are as under,

Item	General purpose	Heavy Duty
1	2	3
Process of Manufacture	Under pressure of 140 Kg/cm^2	Under pressure of 140 Kg/cm^2
Size tolerances	L &W +_1mm, Th +5mm	L &W +_1mm, Th +5mm
Water absorption	Maxim. 10%	Maxim. 10%
Thickness of wearing layer	5mm	6mm
Weight (Kg/Sq m2)	40-50	40-50
Resistance to wear	Maxim. Av. Wear 3.5mm	Maxim. Av. Wear 2.0mm
Finish and surface	Initial grinding and grouting the wearing layer. No surface defects like projections, depression, holes, cavities, cracks or blemishes.	Initial grinding and grouting the wearing layer. No surface defects like projections, depression, holes, cavities, cracks or blemishes.

The Public usage areas and other areas where the wear and tear is expected to be more should be provided with heavy duty tiles. However, it is observed that at the heavily used areas like PF surfaces at Railway stations etc., these tiles wear out very fast, probably because of poor quality control and tiles not manufactured to strict I.S. specifications.

7.2 Terrazzo Tiles/Marble Mosaic tiles:

These tiles are also available in sizes 200x200x20 mm, 250x250x22 mm and 300x300x25 mm. These are also manufactured as per I.S.1237. The specifications are identical to plain tiles, except that the wearing layer

contains marble chips, 0 No. to 5 No., marble powder and cement (grey or white depending on colour) in case of Terrazzo tiles and marble chips varying from 0 to 20mm. in mosaic tiles. The chips greater than No.5 should have a flat surface and these are pressed into the tiles with broader surface exposed. These tiles are for general purpose only and for heavy duty areas 'Heavy Duty' tiles are also manufactured and should be used.

These tiles are prepolished; however require finishing polish with fine grained carborundum blocks of 320No. and 400 No.

7.3 Chequered tiles:

Chequered tiles provide non-slippery surface under all conditions of rain etc. and therefore are used for external floors only. These are also used for demarcating the edge of platform etc. for blind persons. Chequered tiles are available either in plain or terrazzo finish. These are manufactured as per I.S. 13801-1993. These tiles are also available in sizes 200x200x22 mm, 250x250x22 mm, and 300x300x25mm. and are manufactured practically the same way as plain or terrazzo tiles except that there are grooves of not less than 3 mm depth, the center to center spacing ranging between 25 to 50mm, on the wearing surface. There are several patterns available in the top wearing surface. The specifications for these tiles are similar to Plain/ coloured or terrazzo tiles, in regard to water absorption, dimensions, and defects etc. The resistance to wear when measured as per I.S.1237 shall not be more than 2mm.

It is pointed out that chequered tiles are being manufactured to various thicknesses 30mm or even 40mm, mainly depending on the plan dimensions, but it may not in any way guarantee the extra durability or performance of thicker tiles. The property which is of importance is "resistance to wear" and that is provided in the wearing surface at the top. The tiles shall have a I.S. identification mark on the back face.

Chequered tiles for stairs treads are available with different designs. These tiles have a higher thickness which is required for higher strength at the nosing area. The minimum thickness of such tiles is 30mm, the front part of tile for a minimum length of 75mm, including the nosing has grooves parallel to nosing, at centre to center of 25mm and balance portion of tile has normal checkers. It should be ensured while fixing the tread tile that it goes right up to the riser and or shall be embedded in the riser or plaster on the riser up to 12mm.

7.4 Glazed wall/floor tiles :

These tiles are manufactured in various sizes 300x300 mm, 200x200 mm, 300x200 mm, 250x200 mm, 150x150 mm,200x100 mm,200x150 mm. The top surface is glazed. Floor tiles are normally used of matt finish

whereas the wall tiles are glossy finish. The properties of glazed tiles are as under,

Item	I.S.777-1988
Tolerance in size (mm)	Diagonals perfect, ±0.1mm in sides
Thickness (mm)	5-6 (±0.4 mm)
Weight in Kg/sqm	9-10.5
Water absorption (%)	10-18
Scratch Hardness(MOHs)	4 (Minim)
Mod. Of Rupture (Kg/cm2)	200
Crack, cavity, holes, corner	Top surface –no defect

These tiles are for general purpose only and not for public areas.

7.5 Vitrified Ceramic tiles:

The vitrified tiles are available in very wide range of colours and designs. These are manufactured to I.S.13712-1993. The main difference in glazed tiles and vitrified tiles is in respect of hardness, scratch resistance and water absorption. The properties of vitrified ceramic tiles are as under,

Item	I.S.13712-1993
Common sizes (Cm)	60x60 ,60x40 ,60x30 ,45x45 ,30x30 ,20x20
Thickness (mm)	8-10
Weight (Kg/Sqm)	16-22
Water absorption (%)	0.5
Scratch hardness of surface (MOHs)	6(Minim)
Mod. of rupture	400 Kg/cm^2

These tiles have a very high level of polish and have to be handled carefully besides offer a slippery surface, even when they are not wet. These are therefore used in very selected locations of in- doors, where movement of people is minimum and very high level of gloss is required. These tiles since have a very less water absorption should normally be fixed using special adhesives, grouts and joint fillers. However, these are also being fixed quite satisfactorily using cement slurry etc.

7.6 Marble stone tiles/slabs:

Marble is a natural occurring rock of crystallized limestone and is available in several different colours, shades, and quality. Marble slabs and blocks are used in India for ages. Marble Tiles which are of lesser thickness are also available, these days. Different marbles are known by their colour and the area from where it has been mined. The rates are also different in the same wide range depending on purity and texture. Marble has pleasing appearance and takes good polish but has poor abrasion property, due to

which should not be used for heavy duty areas.

Pure white marble is considered to be the best, and is from Makrana in India. The next best quality is considered to be Makarana white with some lighter shade and spots. Then there are white marbles with blue and grey shades. Among the white variety, Rajnagar marble, which has coarser grains, is the cheapest.

Coloured marbles include black marble, black zebra marble, green marble, pink marble, grey marble, brown marble etc.

Very superior marble in variety of colours is also imported from Italy, which is even costlier than granite tiles/slabs.

The properties of Indian marble are as under,

ITEM	PROPERTY
Sp. Gravity	2.5
Hardness (Minim)	3 MOHs
Crushing Strength(Kg/cm2)	720
Water absorption (%)	0.4%
Thickness available	Tiles-18mm-24mm (±1.5mm) Slabs- 50mm-150 mm(±2mm)

The tiles are machine cut in standard sizes varying between 600x600 mm and 100x100 mm in different combinations of length and width. The finer grain marbles get better polish. The top surface should be free from any defects like cavities, holes, cracks etc and corners should be perfect without any breakages. It is very important that the slabs/tiles used in one area should be of uniform colour and texture, if the marble is streaked it should be in one direction only i.e. either length or width wise if they are not square.

7.7 Kotah Stone Tiles/Slabs:

Sandstone primarily found in Kota area of Rajasthan is greenish grey colour very hard and scratch resistant stone. Tiles and slabs of Kota stone are used on floors in heavy duty areas such as Railway platforms, concourses etc. Common thickness of Kotah stone tiles is 22mm to 40mm. The tolerance in thickness allowed is maxim. ±2mm for machine cut slabs/ tiles. Hand cut slabs/tiles are generally not used, unless the thickness is above 50mm. These are pre-polished and when struck with any stone or iron piece give clear ringing sound. Some properties of Kotah stone are as under,

Compressive Strength	2175 kg/sq. cm
Abrasion Resistance	18.12 (Abrasion value)
Water Absorption	0.31 %
Moh Hardness No.	will scratch -3 Calcite will not Scratch- 2.1/2 Galena
Density	2.5 to 2.65 Kg/m^3

7.8 Tandoor and Shahbad stone Tiles:

There are some other stone tiles/slabs such as polished Tandoor and polished Shahbad stone tiles/slabs which are far softer stones and cheaper, look somewhat like Kota stone to an untrained eye and need to be cautious in identifying the stone. The comparison is given below,

Kotah stone	Tandoor stone	Shahbad stone
Greenish Grey	Bluish	Yellowish
Texture is superior	Texture not superior when compared to Kotah	Poor texture compared both to Tandoor &kotah
Has rigid structure, practically no layers	More layered formation	It is weak at edges.
Abrasion resistance-High	Abrasion resistance-less than Kotah.	Abrasion resistance poor
Able to get mirror polish shine	Gets glossy polish but not much shiny	No shine

The proper judgement comes with experience. It is a better idea to keep 3 polished sample tiles, one each of Kotah, Tandoor and Shahbad stones for comparison with the received material at site, even if the doubt persists opinion of the reputed test house be taken. All the angles, and edges of the Tiles/Slabs shall be true, square and free of chippings and the surface shall be fully plane.

7.9 Granite Tiles/Slabs:

Granite is the hardest natural stone available and its slabs/tiles take a very shiny polish. Among the floor slabs/tiles this is the costliest item. These are used in concourse hall floors/walls of big hotels for decorative finish. They have a very high abrasion resistance and scratch hardness of 6, MOHs.

Granite stone slabs are being used traditionally for table tops, kitchen working boards and sometimes in places of worship, for their ability to be cleaned with plane water with or without detergents to a very high degree. These can however, also be used for very heavy duty indoor areas. However the draw back is of very low “slip resistance” of polished granite floors. This co-efficient is very much reduced if the surface gets wet, either due to spillage or rain water reaching the floor. Flame cutting the polished granite slab increases the roughness of tile/slab, but it also takes away the smooth and shiny surface for which this type of flooring is chosen in the first place.

Granite stones slabs come under different colours and textures. There are fine textured stones and broad texture stones. The colour could be pink, rust, green, mix of green and pink, yellowish, black, black with spots of white, brown , gray with black spots or white with spots of gray etc. The rate also is different for different colours, textures, and gloss etc. The slabs/tiles are machine cut and polished when received at site. Normally, it is preferred to

receive the supply of natural stone tiles/slabs as per the sample.

The normal field tests as applicable to any floor tile have to be done for granite stone tiles/ slabs. Special focus has to be on the gloss and finish and uniformity of colour. All angles and edges should be true, square and free of chippings and the surface shall be fully plane.

8.0 Interlocked Paver Blocks

Interlocking paver blocks floors can be made in any design or shape desired. These are increasingly used not only in walkways and jogging tracks but also in circulating areas of building compounds, storage yards, petrol pumps, swimming pool decks, parking lots etc. They are water resistant in nature; the life of the blocks is much more than the ordinary PCC or cement tiles. The shape of the blocks is so designed that, on laying they interlock with each other and do not get disturbed by any longitudinal or transverse loads coming on the floor. The pavers are either with glossy finish as in case of light duty pavers and matt finish used for heavy duty vehicular road surfaces.

8.1 Raw Material:

The blocks are made in either single or double layers for normal or heavy duty usage.

a) Top layer consists of white cement, marble powder, marble granules, and required pigments for colour.

b) The bottom layer consists of cement, sand and coarse aggregate of required mix to provide strength to the base.

However, the pavers for vehicular roads are made in single layer only and are made from appropriate grade of concrete.

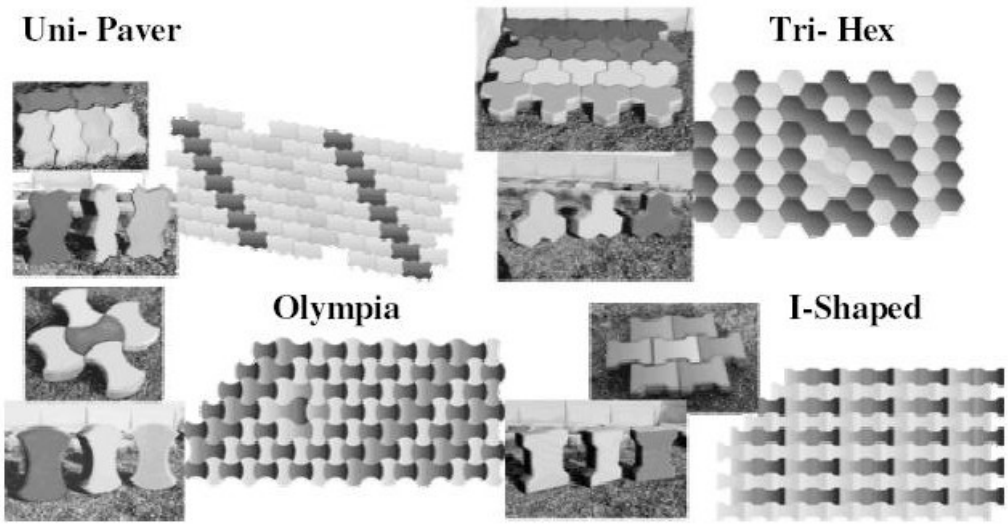
8.2 Concrete Block Making Machines:

The machine should be capable of producing high quality Paver Blocks by obtaining high level of compaction by application of hydraulic compaction pressure of 800 psi and also by high intensity vibration to the rubber lined moulds of 3000 R.P.M. The block making machine should ensure high degree of dimensional accuracy (+ 3mm), precast block with spacer nibs (2mm to ensure uniform joints) & high compaction energy.

8.3 Manufacturing process:

The raw materials are mixed separately in required proportion in mixers and ball mills and filled into hoppers of the paving block machine. The block is cast automatically with compaction of 800 psi as per the design of the rubber lined moulds, simultaneously is vibrated at 3000 R.P.M. The blocks are then put into curing chambers and ready for dispatch after 24 hours of steam curing. Generally 80mm and above blocks which are used for roads or in traffic areas are manufactured in single layer in natural cement

colour only. However for light use such as footpaths and walk way plazas or even parking spaces glossy finish coloured blocks are used. For some of very light use areas 40 mm thick paver blocks are also being used, though not recommended by I.S. 15658-2006. The blocks are made in various shapes to provide good interlocking; some of the common shapes are shown below.



8.4 Specifications of Paver Blocks:

The technical specifications of paver blocks are given in table below. The sample size – Minimum 2 blocks per 10000 blocks for external and 3 samples per 5000 for internal. Average of minimum 8 blocks per site.

S.No.	Test	Specification
1	Thickness	50,or 60 or 80 or 100 mm or 120 mm
2	Shape	Uni-paver, Tri-hex, Olympia or I-shape or any other specified
3	Chamfer	3, 4 or 5 $\pm$ 1mm along top edges, for 60, 80 & 100mm
4	Dimension Tolerance	$\pm$2 mm for length and width, $\pm$3 mm for thickness
5	Compressive strength	35 N/mm^2 for 60mm, 40 N/mm^2 for 80mm and 50N/mm^2 for 100 mm
6	Abrasion Resistance	Minimum 1.5
7	Water absorption	Maximum 5.8
8	Skid resistance	Top surface required
9	No. of layers	Single or double

8.5 Choice of Paver Blocks

The thickness of the paver affects its ability to carry and spread loads to neighboring units when set. The greater the paver thickness, the greater the interlock with neighboring pavers and the greater the load carrying capacity. Normally following guidelines are followed for choosing the paver blocks,

a) To withstand regular, repeat vehicle traffic, where trucks also ply but, the speed is restricted to about 30 kmph, the paver must be at least 80 mm thick.

b) For pedestrian traffic and residential driveways, parking area for cars etc., 60 mm -thick pavers are adequate.

c) For high speed main roads having mixed traffic of trucks buses etc. the thickness of blocks should be 100 mm.

As per IS 15658-2006, following are the recommended grades of paver blocks for different traffic categories

8.5 Recommended Grades of Paver Blocks for Different Traffic Categories

S. No.	Grade Designation of Paver Blocks	Specified Compressive Strength of Paver Blocks at 28 days in N/mm^2	Traffic category	Recommended Minimum Paver Block Thickness In mm	Traffic Examples of Application
1	2	3	4	5	6
1.	M-30	30	Non - traffic	50	Building premises, monument premises, landscapes, Public gardens/Parks.domestic drives, paths, and patios, embankment slopes, sand stabilization etc.
2.	M-35	35	Light - traffic	60	Pedestrian plazas, shopping complexes ramps, carparks, office driveways, housing colonies, office complexes, rural roads with low volume traffic, farm houses, beach sites, tourist resorts, local authority footways, residential roads etc.

1	2	3	4	5	6
3.	M-40	40	Medium-traffic	80	City streets, small and medium market roads, low volume roads, utility cuts on arterial roads, etc.
4.	M-50	50	Heavy-traffic	100	Bus terminals, industrial complexes, mandi houses, roadson expansive soils, factory floor, service stations, industrial pavements, etc.
5	M-55	55	Very heavy traffic	120	Container terminals, ports, docks yards, mine access roads, bulk coargo handling areas, airport pavements, etc.

Notes:

a. Non –traffic areas are defined as areas where no vehicular traffic occurs.

b. Light-traffic is defined as a daily traffic up to 150 commercial vehicles exceeding 30 KN laden weight or an equivalent up to 0.5 million standard axles (MSA) for a design life of 20 years (A standard axle is defined as a single axle load of 81.6 KN).

c. Medium traffic is defined as a daily traffic of 150-450commercial vehicles exceeding 30kN laden weight, or an equivalent of 0.5 to 2.0 MSA for a design life of 20 years.

d. Heavy traffic is defined as a daily traffic of 450-1500 commercial vehicles exceeding 30kN laden weight, or an equivalent of 2.0 to 5.0 MSA for a design life of 50 years.

e. Very heavy traffic is defined as a daily traffic of more than 1500 commercial vehicles exceeding 30 kN laden weight or an equivalent of more than 5.0 MSA for a design life of 20 years.

APPENDIX-1

Testing Requirement of cements in Laboratory

Property	OPC(33 Gd) I.S.269-1976	OPC(53Gd.) I.S.8112-1976	Pozz. Portland I.S.1484-1976	Port. Slag I.S.455-1976
Fineness(cm^2/gm)	2.25	3.5	3.0	3.25
Initial setting time Minm.(Min.)	30	30	30	30
Final setting time Maxm.(Hours)	10	10	10	10
Comp. Strength (kg/cm^2)				
3 days	160	230	-	160
7 days	220	330	220	220
28 days	-	430	310	-
Soundness, Max. expansion (mm)	10	10	10	10
Max. Heat of hydration(cal/gm) at 7 days	85	-	-	-
Max. drying shrinkage			0.15	
Max. % of magnesia	6.0	6.0	6.0	6.0
Max. Sulphur as SO_3	2.75	2.75	2.75	2.75
Insoluble residue	2.0	2.0	-	2.0
Loss on ignition	5.0	5.0	5.0	5.0
Permitted additives	1.0	1.0	1.0	1.0
Lime saturation factor	0.66-1.02	0.66-1.02	-	-
Ratio of alumina to Iron oxide	>0.66	>0.66	-	-

APPENDIX-2

Testing requirements of fine and coarse aggregate.

1. Deleterious Material:

The aggregates should be free of deleterious material such as pyrites, coal, lignites, shale, mica, clay lumps, alkalies, soft fragments, sea shells, organic impurities etc. The maximum %ge that can be permitted are as under,

S.No.	Deleterious Substance	Sand Natural	Crushed Coarse aggregate
1	Coal & lignite	1.0%	1.0%
2	Clay lumps	1.0%	1.0%
3	Particles finer than 75 mic.	3.0%	3.0%
4	Shale	1.0	-
	Total maxm. of all	5.0%	5.0%

Notes:

1. The presence of Mica in fine aggregate is known to reduce the strength of concrete. Though no permissible limits for Mica are laid down, but suitable reduction in strength of concrete based on trials should be effected.

2. The aggregates should be free of organic impurities and no permissible limits are laid down. It should be confirmed by tests that the strength of concrete is not less than 95% of design strength due to presence of organic impurities.

2. Mechanical Properties :

S.No.	Property	Coarse Aggregate	sand
1	Crushing value	45% maxm. 30% maxm. for wearing surfaces of structure	-
2	Impact value	-Do-	-
3	Abrasion value	50% maxm. 30% maxm. for wearing surfaces of structure	-
4	Soundness	12% maxm. with Na_2SO_4 18% maxm. with $MgSO_4$	10% maxm. with Na_2SO_4 15% maxm. with $MgSO_4$

3.Grading

a) Coarse aggregates (Graded)

I.S.Sieve\ Nom. size	Percentage passing		
	40 mm	20 mm	12.5 mm
40 mm	95-100 %	100%	-
20 mm	30-70 %	95-100 %	100 %
12.5 mm	-	-	90-100 %
10 mm	10-35 %	25-55 %	40-85 %
4.75 mm	0-5 %	0-10 %	0-10 %

b) Sand

IS Sieve Size	Percentage Passing			
	Zone I	Zone II	Zone III	Zone IV
4.75 mm	90-100 %	90-100 %	90-100 %	95-100 %
2.36 mm	60-95 %	75-100 %	85- 100%	95-100 %
1.18 mm	30-70 %	55-90 %	75-100 %	90-100 %
600 micron	15-34 %	35-59%	60-79%	80-100 %
300 micron	15-20 %	8- 30 %	12-40 %	15-50 %
150 micron	0-10%	1 -10 %	0-10 %	0 -10 %

Notes:

1. The sand will be acceptable in a particular zone, even if , the percentage passing from any sieve, other than 600 micron, is out of the range by 5%.

2. This limit of 5% will also not apply on the coarse particles in zone I and fine particles in Zone IV.

CHAPTER 3

EXCAVATION OF FOUNDATION

1.0 Line out of building:

Line out and building setting is the most important and basic requirement for any execution of building works.

1.1 Preliminary works:- Before starting the actual layout of a building a layout drawing should be prepared. It can be named as centre line plan or foundation plan of the building and plot boundaries should be finalized.

1.2 Finalization of levels:- With respect to the approaching road level, plinth level of the building is to be decided. Generally it is 450mm above the road finished level. Original ground levels should be recorded.

1.3 Instruments and tools:- Line string, plumb, hammer, pegs, nails, measuring tapes30M, at least 2 nos., tube level, spade, pick axe, right angle, etc.

1.4 Procedure of line out :- The line out of a Yard office as per drawing on next page is described, step by step, as under.

1.41 Preparation of centre line plan:-

i) First prepare a centre line plan of building by adding wall thickness in the inner measurements of room as shown in Drg. below and then draw a line at a distance generally more than 1.5 M so that after plotting on ground it should not be disturbed during excavation of foundation.

ii) Name this rectangle as AEHL and do other calculations of centre line with respect to this reference rectangle.

1.4.2 Laying out base line:

i) Now while starting of actual laying out of building on ground the first and important step is to fix the base line on ground.

ii) As per planning yard office is at 12m distance from nearest rail of track so let us fix the base line at 10.115 M distance (2m fro C.L. of wall) from gauging face of inner rail track. As the base line is to be protected up to completion of work as all related distances will be measured with references to this base line care should be taken while selecting the base line that it will not be disturbed during work and it should be easily accessible for measuring the distances.

iii) Now first take any random point on gauge face of inner rail of track in front of building location say at P and now from point P we have to

draw a perpendicular line to track so measure 3M on track from this point P say this point is P1.

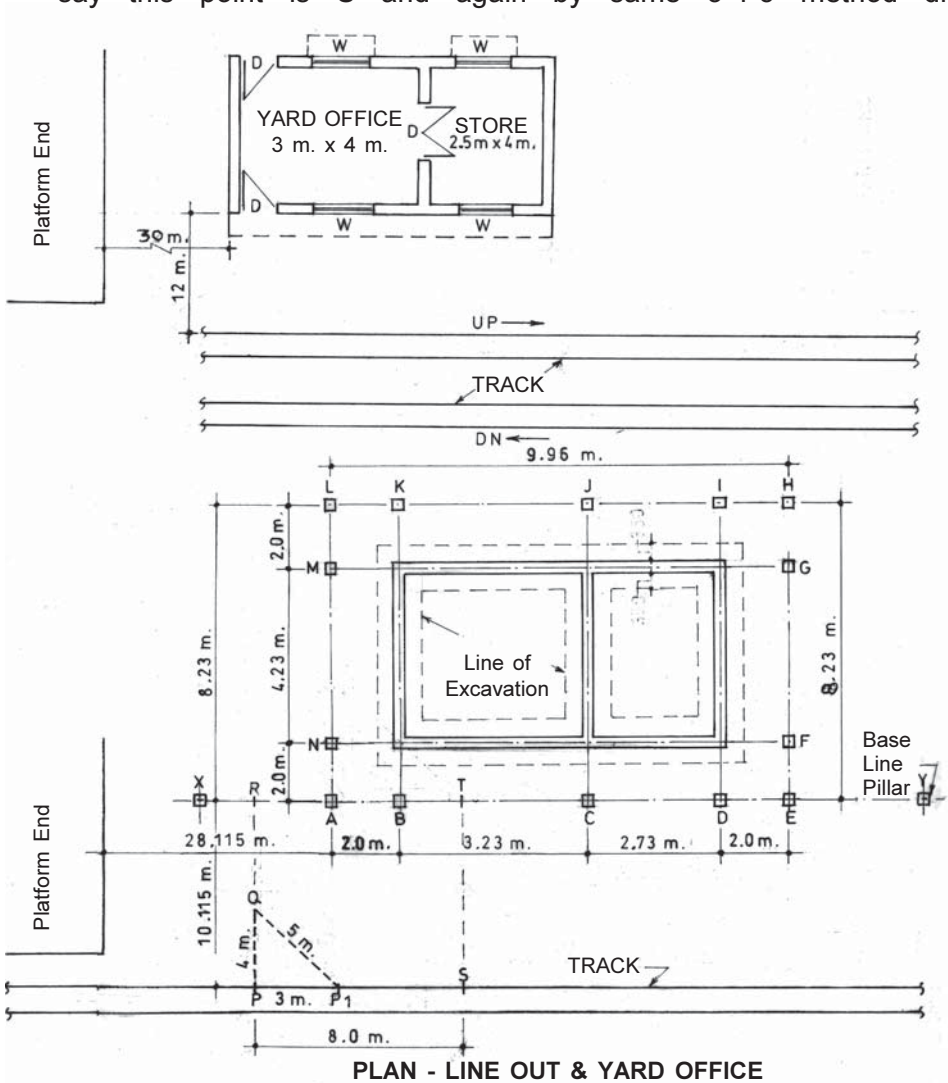
iv) Then hold zero of tape at point P and draw a chord at 4m distance towards proposed building.

v) Again hold zero of tape at P1 and cut this chord by 5M distance arc say this point is Q.

vi) Hold a string between the P and Q and this line is perpendicular to track rail and fix the point R on this line by measuring a distance 10.115M form point P.

vii) This method of plotting perpendicular from any point to the line is called as 3-4-5 method based on Pythagoras theorem.

viii) Similarly take other point say at 8M distance from point P on track rail say this point is S and again by same 3-4-5 method draw



PLAN - LINE OUT & YARD OFFICE

perpendicular and on 10.115m fix the point “T” and now the line joining point R and T is base line for the layout. Extend it up to point X and Y by line dori safe beyond the building faces.The points are fixed by driving wooden pegs in the ground and fixing a small nail for exact location on top and later permanent brick pillars are constructed. The points X and Y are the basic points of base line so location of its pillars should be away form the construction activities so that it can be protected and can be used for laying base line at any time whenever required.

1.4.3 Fixing of First corner point A:

After fixing location of base line now actual layout of building can be started.

First on the base line measure distance 28.115 m (30.0 + 0.115 - 2.0) from platform end and mark point A by driving wooden pegs in ground and fixing small nail on top for exact marking.

- **Fixing of point L**

By 3-4-5 method explained above draw perpendicular to the base line at point A and by measuring tape holding zero at A fix the position of point L at a distance 8.23 m (2.0 + 4.23 + 2.0).

- **Fixing of point E and H**

Then measure a distance 9.96 m (2.0 + 3.23 + 2.73 + 2.0) from A, fix point E. And point H will be fixed by measuring distance 9.96m from L and 8.23 form E.

1.4.4 Checking of Diagonals:-

After fixing all corner points of reference rectangle AEHL of sides 9.96m and 8.23m then check the diagonals of this rectangle i.e. it should be AH= LE= 12.92M. If any difference occur then recheck the all basic dimensions and applying correction it should be confirmed that all dimensions of rectangle and diagonals are correct then only other points can be marked.

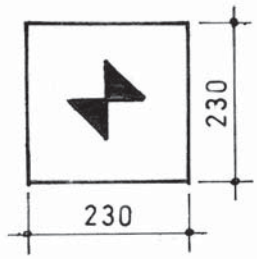
1.4.5 Fixing other intermediate points:

After checking all diagonals and all sides of this rectangle then fix intermediate points B,C,D,F,G,I,J,K,M,N by measuring distance with the measuring tape and string with respective to corner points of rectangles and drive wooden pegs and nails on top of wooden pegs

1.5 Construction of Brick pillars:

Then construct brick masonry pillars at the locations of these wooden pegs with smooth finish top plastered surfaces of these pillars so that top of each pillar will be at same level and height of pillar is generally maintained at plinth level of the building.

After proper curing of the pillars again do the same procedure of line out explained earlier which was done for wooden pegs and by painting as shown below mark exact points on the pillar top.



MARKING ON PILLAR

1.6 Marking of Centre line of foundation:

After construction of pillars and marking locations of points by painting on pillar top then hold the string joining these pillar top one by one with the pillars on opposite line, transfer these centre line of walls on ground with the help of plumb bob and lime powder on ground .

For example hold string between the points on pillar of point N and F and as there is difference of height of pillar between ground and string with the help of plumb take two points on ground along string and mark it by dots with the help of lime powder then put string on these lime powder points and line joining these points will be center line of wall along NF and join this line by dotted segments with lime powder as shown.

1.7 Marking of foundation trenches:

After complete marking of all centre lines on ground then mark excavation line with lime powder line by marking half of foundation width on either side of centre line.

Finally the plotting on ground will be as per drawing as below which completes the line out of the building. After checking all dimensions allow for excavation between these complete lime powder lines for foundation .

Care should be taken at the excavation of foundation trenches that no pillar should be disturbed while doing excavation and as far as possible earth getting out from excavation should be stacked beyond the pillars at safe distance.

Some times instead of constructing brick masonry pillars layout can be marked with the help of wooden planks and wooden ballies also but this is not standard practice.

2.0 Soils for foundations:

After setting out the trenches, the excavation for the foundation is proceeded with. The excavation may be in natural strata of ground or previously dug up or filled earth. The strata in excavation for foundations is broadly classified into the following categories,

a) **Hard rock: -** Generally any rock or boulder which requires blasting i.e. quartzite, granite, basalt etc.is termed as hard rock. It can not be

removed by chiseling or any manual means but only can be excavated by mechanical means or blasting. The hard rock is the ultimate strata which is very strong and does not erode even under high current of water under bridges, for foundations.

b) Ordinary rock:- Generally any rock which can be excavated by splitting with crow bars, picks, wedging or similar means not required blasting i.e. lime stone, sand stone, hard laterite, etc. are grouped as ordinary rock. It may be black, red or any colour and can not be excavated by pick axe but can be removed in very thin layers by chiseling. However, it can be conveniently cut and excavated with mechanical means like JCB or Proclain etc. It has very good bearing capacity and suitable for even heavy foundations. Soft rock has a tendency to get eroded under heavy current of water, under bridge foundations.

c) Coarse grained soils: - Sand and gravel deposits are normally found in riverine reaches and have good load taking capacity. These can be easily excavated with manual means. The particle sizes in coarse grained soils are between 75 micron to 80mm and are visible with naked eye. Many times the sand and gravel are found mixed with silt or clay and depending on the percentage of clay in the strata; such soils behave as fine grained or coarse grained. Normally if the coarse particles are more than 50%, it is classified as coarse grained soil only. Such soils are considered suitable for foundations.

Murum is a special type of coarse grained soil, which has about 15 percentage of fines in the soil and it may be red, brown in colour and found in lumps and it can be well compacted deposits. When dry it can be broken if forced by both hands. It has good bearing capacity and is suitable for most of the foundations.

d) Fine grained soils: - In India fine grained soils are met with in large parts of country. The particle size of such soils is less than 75 micron, such particles are not visible with naked eye. Normally they exhibit varying degree of plasticity when moist. There are three types of soils which are classified under fine grained soils, namely, Silt, Clay and Organic soils.

i) **Silt:** Inorganic silts are finely ground particles of sand. The silts may have either no plasticity or small plasticity under different amount of water content. Such soils when air dried have either very less or no strength.

ii) **Clay:** Clay is plastic when wet and possessing considerable cohesive strength. Clay particles in pure state are soluble in water and gradually settle down at bottom in the form of stiff paste. When dry, clay forms hard lumps which cannot be broken down

and powdered between the fingers. Colour of clay may be black, white, red or yellow.

Clay is absorbent and can swell to double its volume when saturated. Clays tend to hold free water in addition to their adhered water and do not drain nor dry out rapidly. Clays are subject to a significant shrinkage from the loss of moisture.

Clay having appreciable proportion of sand or slit is termed as sandy clay or silty clay.

Black cotton soils are a type of inorganic clay and they show properties of medium to high compressibility, expansion and contraction under different moisture contents. Clay soils consolidate gradually under loads and are not considered very suitable for isolated footings, as differential settlements take place in the structure during service, resulting in cracks and sometimes can result in making building unserviceable. Whenever, clay soils are encountered, detailed study of the character of the soil along with the loads that shall be coming on foundation needs to be carried out.

iii) **Organic soils:** Such soils are formed by decayed organic matter such as leaves; marine life etc. and they contain substantial quantities of fibrous organic matter such as peat, and decomposed vegetable matter. Soils having cinders, shells and other soil matter are also classified as organic soils. Such soils are very poor in mechanical properties and has to be avoided positively for any foundations.

3.0 Field Identification of soils:-

a) Grain size of soil: The representative dry sample of soil is spread on a level surface and any clods etc are broken. All particles greater than 80 mm are separated and the sample thus remaining is classified.

i) Sample containing more than 50% visible particles by unaided eye is a coarse grained soil. If other wise it is a fine grained soil. Further if the percentage of gravel (greater than 4.75 micron size) is more, then it is classified as gravelly soil. If the gravel is dirty mixed with silt and clay, it is termed as silty gravel or clayey gravel.

If, the percentage of sand is more than gravel, it is termed as sand. The dirty sand mixed with silt or clay is termed as silty sand or clayey sand depending upon, if the fines are low or non-plastic, or medium to high plastic

b) If however, the soil is fine grained, i.e. it has more than 50% of

particles not visible to unaided eye, following further tests should be done,

- **Pat test:** Make a pat or a ball of about 5 cubic cm and saturate it by adding water and hold it in the palm of hand. Shake horizontally by striking vigorously by the other hand . Notice the time taken for oozing out of water from the pat. Squeeze the pat between fingers and notice the disappearance of water. If appearance and disappearance of water is quick, the soil has low plasticity and is silt, otherwise it is clay with medium to high plasticity.
- **Thread Test:** Dry the pat of the above test by working and moulding till it has putty like consistency. The more the time taken for drying, the more is the plasticity and more plastic clay. Make a thread of about 3 mm diameter, by rolling between palms of hand. Fold and re-roll the soil several times to make a thread, till it crumbles. Gather the pieces of the crumbled thread and make it into a ball and try to roll a thread of 3 mm diameter again with whatever moisture is left in the soil lump. If the thread can not be made, and it keeps crumbling, the soil has low plasticity and low toughness i.e. it may be silt or clay of low plasticity. If it requires more effort and pressure to roll a thread at this stage, the soil has more plasticity and more toughness i.e. it is clay of medium to high plasticity.
- **Shine Test:** This is a quick supplementary test to identify the clays. A pat of soil is made of dry or slightly wet soil. The pat is cut using a sharp knife. A shiny surface indicates presence of clay and dull surface indicates soil of low plasticity, may be silt.
- **Odour Test :** The organic soils have generally deep dark colour, like black or dark grey. However, in India several clays also have such colour. The organic soils when smelled give a distinctive odour of decomposed matter. This odour gets enhanced when the soil is heated. Further, dry organic clays when wetted with water give a earthy smell and is very different from smell of organic clays.

4.0 Suitability of soil for foundation:

Following guide lines can be adopted for works of minor importance while deciding the foundation levels,

i) Soft, hard rock or weathered rock provide very good strata for foundations.

ii) Coarse grained soils are generally suitable for foundations, and foundations should be stopped and placed in such soils.

iii) The foundations should not be placed on organic soils.

iv) The fine grained soils having high plasticity show greater settlements during service and individual/ isolated foundations should be avoided in such soils.

v) Even in high or medium plasticity soils, the condition of undisturbed state of the strata is important and well consolidated, compact stratas offer much better foundation and bearing capacity than disturbed soil samples may suggest. Further, soils with higher dry specific gravity of the order of 1.6-1.8 can be considered suitable, though may be plastic clays.

vi) While placing foundations in black cotton soil, it should be checked and ensured that seasonal variations in water table in the area do not effect the soil near the foundation depth and entry of surface water to foundation level should be prevented by providing adequate width of impervious apron around the building etc.

vii) The approximate value of bearing capacity, in different types of soils be taken as under,

S.N.	Type of soil	Apprx. safe bearing capacity in KN/Sq.m
1.	Very soft clay	40-60
2.	Black cotton soil	120-160
3.	Sand clay mixture	120-180
4.	Loose gravel	200-300
5.	Compact gravel or murum	350-500
6.	Soft rock	400-600
7.	Laminated rock such as sand stone and lime stone	1250-1750
8.	Hard rock	3000-4500

5.0 Bearing capacity of soil:

The load of the structure is ultimately coming on the soil and hence it is very important to know the strength of the soil. The term bearing capacity of soil is used to indicate the maximum load per unit area which the soil will resist safely within acceptable limit of settlement.

5.1 For open foundations of some importance, some simple tests are required to be carried out and assess the safe bearing capacity of the soil at the level where it is proposed to locate the foundations. The two tests are done normally in the field,

a) Bore log

b) Plate load test

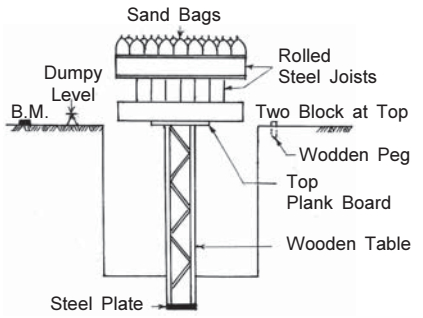
a) Bore Log: The open foundations are generally shallow and the type

of soil available up to the proposed foundation level can be collected by excavation of a pit of the required depth. Normally the depth of pit should be kept 600 mm more than foundation level. The soils can be classified into sand, clay, silt, murrum etc based on the appearance of soil and by finding particle size distribution, after drying and sieving on I.S. sieves. The particles below 75 microns are silt and clay; the particles above 4.75 mm are stones or gravel. Particles between 150 microns and 4.75 mm are termed as sand. A mixture of coarse sand, silt and clay is murum. In case of predominance of clay in the strata, further study is normally required to work out the liquid limit, plastic limit etc and also the rate of consolidation of soil under load, which can as well be done at some laboratory, if facilities are not available in the field. Clays with liquid limit up to 35 are considered clays with low plasticity, up to 50 of medium plasticity and above of high plasticity. More the plasticity, more the compressibility and more settlements.

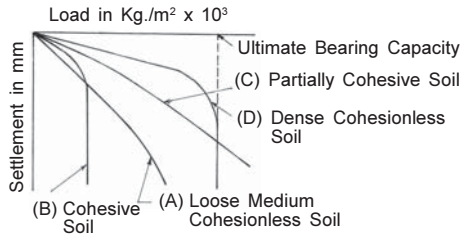
b) Plate Load Test:

i) Material required to conduct this test is as follows.

- **Size of Plate:** A bearing plate of mild steel of thickness not less than 25mm and plain dimension of varying between 300-750mm. Alternatively a concrete block of plain dimensions of 300-750mm and thickness not less than 2/3 rd width can also be adopted.
- Suitable platform with rolled steel joists and wooden planks
- Wooden pegs
- Dumpy level and staff
- Sand bags



METHOD OF LOADING



LOAD SETTLEMENT CURVES

ii) Procedure:-

1. A square pit of required size is excavated up to required depth. The side of the pit should be at least five times the side of steel plate. At centre of the pit a square hole is dug of size of vertical

wooden beam.

2. The steel plate is put in the hole and then platform is prepared as shown in fig above.
3. The weight of steel plate's wooden table and wooden beams used for platform should be carefully worked out and initial load is decided according to the type of soil to be tested.
4. A level is planted to note the settling of the steel plate with reference to permanent bench mark.
5. The load is to be kept on platform and apply the load to soil in cumulative equal increments up to 1 kg/cm^2 or onefifth of the estimated ultimate bearing capacity, whichever is less. The load is applied without impact, fluctuation or eccentricity and in case of hydraulic jack load is measured over the pressure gauge.
6. Settlements should be observed for each increment of load after an interval of 1,2.25,4,6.25,9,16 and 25 minutes and thereafter at hourly intervals to the nearest 0.02mm.
7. In case of clayey soils, the time settlement curve shall be plotted at each load stage and load shall be increased to the next stage either when the curve indicates that the settlement has exceeded 70 to 80 pecent of the probable ultimate settlement at that stage or the end of 24 hour period.Test shall be continued till a settlement of 25mm under normal circumstances or 50mm in special cases such as dense gravel, gravel and sand mixture is obtained or till failure occurs whichever is earlier.
8. Alernatively where settlement does not reach 25mm the test should be continued to at least two times the estimated design pressure.
9. A load settlement curve shall be plotted out to arithmetic scale. From this load settlement curve, the zero correction which is given by the intersection of the early straight lines or the nearly straight line part of the curves with zero deadline shall be determined and subtracted from the settlement readings to allow for the perfect seating of the bearing plate and other causes.
10. Four typical curves are shown in fig. Curve A is typical for loose to medium cohesionless soil, it is straight line in the earlier stages but flattens out after some time, but there is no clear point of failure.

    Curve B is for cohesive soil, it may not be quite straight in the early part and leans towards settlement axis as the settlement increases.

    Curve C is for partially cohesive soils, possessing the characteristics of both the curves A and B.

Curve D is purely for dense cohesionless soils.

11. From the corrected load settlement curves no difficulty should be experienced in arriving at the ultimate bearing capacity in case of dense cohesionless soils or cohesive soils as the failure is well defines as per curve D and B. But in case of curves A and C where yield point is not well defined, settlements shall be plotted as abscissa against corresponding load intensities as ordinate, both to logarithmic scales which gives two straight lines, the intersection of which shall be considered as yield value of soil.

12 The bearing and the safe bearing capacity of soil are calculated as follows

Bearing capacity of soil in KN/sq.m= Maximum load/area of steel plate

Safe bearing capacity of soil in KN/Sqm = Bearing capacity of soil/ Factor of safety

6.0 Method of excavation:

a) In shallow depths of excavations, say up to 1000 mm, the width of the trench or pit can be kept equal to width of foundation plus 150 mm on both sides. However, in larger depths, the extra width required for working and providing means of entry and exit for the workers has to be larger. Normally, 300 mm extra both sides is adequate.

b) In firm, hard soils, the sides of the trench are kept vertical up to a depth of 2m from the bottom. But for more depths it can be benched with steps of 50cm on either side at every 2m from the bottom. Alternatively the excavation may be done in slope 1:4 above initial 2.0 m.

c) Following types of soils and conditions are considered unsafe for open excavation,

   i) Friable or unstable rocks at depths greater than 2.0 m.

   ii) Soils which crack and crumble.

   iii) Loose sandy or soft soils which have been previously excavated or filled up.

   iv) Soils under hydrostatic pressure from nearby water body.

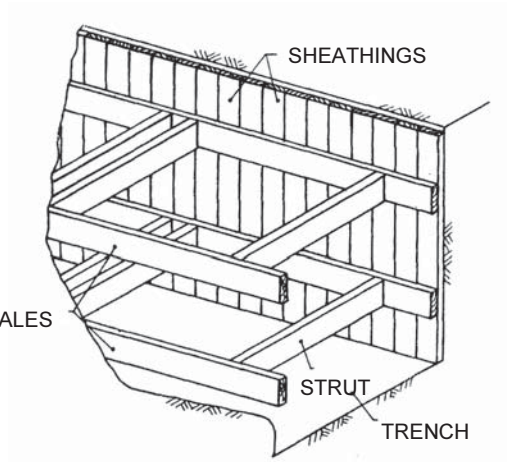
   v) Soils experiencing vibrations from nearby sources.

   vi) Adjacent loose fills near excavation site.

   vii) Surcharge imposed by adjacent buildings or lumber piles.

6.1 Shoring and timbering:- In all the susceptible locations as mentioned above in c) and for higher depths shoring is provided while progressing the excavation and also till the work is completed. Shoring is the construction of temporary planking and strutting of the sides of foundation trench exceeding 2m in depth. In case of loose and slushy soils the depths at which precautions are taken shall depend upon the nature of soil. Planking and

strutting is either close or open type depending on the nature of soil and depth of trench. For excavation in hard soil below 2.0 m the recommended size of wooden members is as under,



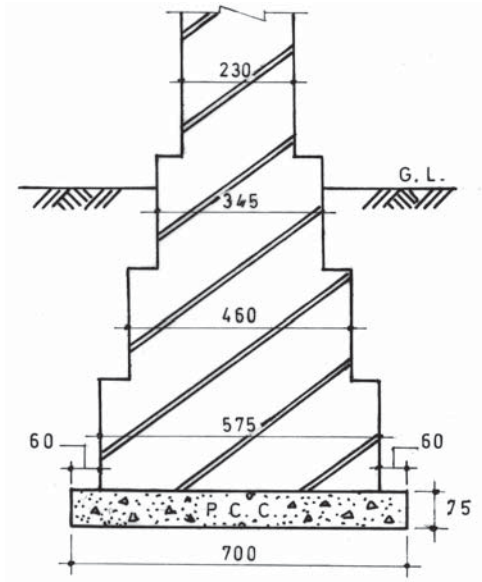
Illustrative Sketch Showing Timbering in Loose Soil

Depth	Sheathing		Wales		Struts		
	Size (cm)	Spacing	Size (cm)	Spacing	Size (cm)	Vert. spacing	Horizontal Spacing
2-3 m	5x20	2.0 m	15x15	1.5 m	10x10	1.5 m	3.0 m
3-5 m	5x20	1.5 m	15x15	1.5 m	10x15	1.5 m	3.0 m
5-6.5 m	5x20	1.0 m	20x20	1.5 m	15x15	1.5 m	3.0 m
6.5-8 m	5x15	Width	25x25	1.5 m	15x20	1.5 m	3.0 m
8-10 m	8x20	width	20x30	1.5 m	20x20	1.5 m	3.0 m

6.2 Dewatering works: In some cases water may be present at intermediate stage before reaching the required founding strata. If water is locally stagnant it can be easily removed manually but if it is due to source of water seeping from a water body or the excavation is being done below water table then special efforts should be done such as installation of pumps or number of sumps should be excavated around area and pumping be done from more than one location. In sandy soils the rate of pumping has to be controlled as the sandy soils are very good draining soils, the rate of pumping out is generally matched by percolation of water from the neighborhood and at a particular rate of pumping, the sand particles lose all shear strength and the sand blow takes place. In such locations Well- Point pumping is resorted to. Pumping from a number of well points spread over an area is preferable to heavy pumping form one central sump.

7.0 Some Guidelines for foundation work

i) **Width of footing: -** In case of load bearing walls if simple footing is shown in drawing



TYPICAL FOOTING OF WALL

1. The width of foundation should be equal to three times the thickness of wall.
2. The total load including dead load, live load and wind load coming on wall per meter length the width of foundation will be;

a) Width of foundation =Total load per meter length/allowable bearing capacity of soil.

b) In framed structure total load transferred from column to footing and to ground and safe bearing capacity of strata will define the size of footing.

ii) Depth of Foundations: The minimum depth of 40 cm to 60 cm may be adopted for temporary buildings but the minimum value usually adopted for permanent structures is 90 cm to 1.0 m.

iii) Prevention of entry of water: All open foundations should be protected against entry of surface water, by means of an impermeable apron, to adequate width around the building. The apron could be PCC or even good murum soil, duly compacted and tamped.

CHAPTER 4

BRICK /STONE MASONRY

1.0 General

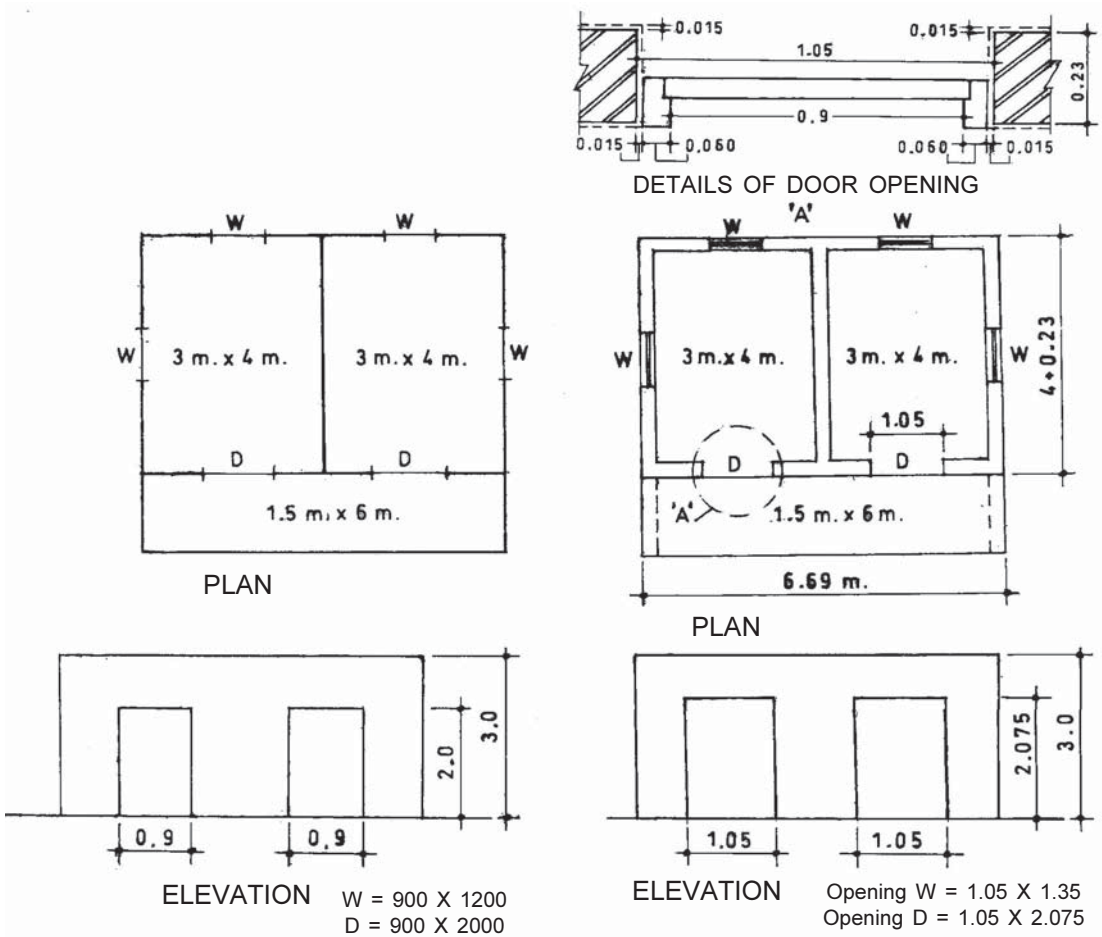
1.1 Brick masonry is a very old art for construction of buildings. It is made of baked clay bricks and set in cement or lime mortar. Presently cement mortar is normally used however in the past when cement was not manufactured, brick masonry was set in lime mortar. The choice of type of masonry, whether stone masonry, brick masonry or precast concrete blocks is governed by the availability of materials in the nearby area, cost and ease of construction. Baked/burnt clay bricks are available in most parts of country and therefore buildings in brick masonry are quite popular in India. These days stone masonry is generally not preferred because of more skilled labour requirement which is in shortage, it has a bigger footprint than brick masonry and thus loss of valuable land, besides the Ashlar, coursed stone masonry will be costlier than brick masonry.

1.2 Preparatory work for Brick masonry work

i) Arrangement of drawings.
ii) Collection of materials
iii) Collection of tools and equipment
iv) Skilled artisans and Labour.

1.2.1 Drawings:

Building detail drawings are to be prepared incorporating the thickness of brick walls and showing the inside and outside dimensions of the rooms etc. If however the drawing is provided with single line without showing the thickness of the walls, they should be converted into detailed brick masonry drawings considering the dimensions of the drawing as the inside dimensions of the rooms etc. unless otherwise mentioned in the drawings. Similarly, the dimensions of openings such as doors and windows are given as the net openings and the dimensions of the brick masonry openings should be obtained by adding the thickness of door/window frame verticals and horizontal members plus margin of 15mm on all sides for accommodating plaster and working tolerances. The normal thickness of door frame members (*jambs)* is 60mm. A typical line sketch is developed drawing for brick work as below.



Set out for the work should only be started after fully understanding the drawings and the proper orientation.

1.2.2 Materials:

- Bricks
- Sand
- Cement
- Water

All the materials should be as per specifications of the work. Field tests should be carried out and general quality of material ascertained to be proper, as given in the specifications and described in Chapter 2.

1.2.3 Tools and Equipment

Water drum, scaffolding material (Bamboo, Kathya, wooden planks) Sieving screens, plumb bob, trowel, powrah, Ghamelas, Line string(*dori*), level tube, Mason's square, tipni, Brick Hammer etc.

2.0 Mortar

2.1 The brick masonry is set in 1:6 cement mortars, if it is 1 brick (230mm) or more thick. The half brick walls are however set in 1:4 cement mortar, unless otherwise specified in the drawing.

2.2 Screen the sand on the *jali* (Screen with 4 wires per cm) and reject any oversize particles. Collect adequate quantity of cement and sand required for 1 days work as also fill water in the drum.

2.3 One bag of cement contains appx.4 *Ghamelas* of cement and for 1:6 mortar, 24 Ghamelas of sand would be required to be mixed. Similarly for 1:4 cement mortar 16 *Ghamelas* of sand would be required. Mix the cement and sand on a G.I. sheet platform, first in dry form and then add water gradually duly mixing in the cement sand mixture by means of *phowrah*, till a workable creamy paste of mortar is obtained. Proper mixing of dry ingredients as well as after mixing of water is attained by quartering method at least 4 times. This shall be obtained with a Water quantity 20 lits/bag for 1:4 mortar and 30 liters/bag of cement for 1:6 mortar, generally. Adding of extra water than required for workable consistency should be avoided at all costs.

2.4 The OPC cement (33Grade) normally sets in 30-40minutes, and the high strength cement of 43 and 53 grade set even earlier. The mortar however can be kept alive by another 30 minutes by keeping mixing it by means of *phowrah* or trowel (*Thapi*). The mortar should therefore be prepared only for the requirement of about 45 minutes. Normally for 1 skilled mason with 1 helper, ¼ bag of cement (1 *Ghamela)* equivalent mortar shall be used in 45 minutes. This should be assessed by the mason properly and fresh mortar should be prepared every 45 minutes.

3.0 Bonds in Brick masonry

3.1 Method of arranging and laying the bricks in layers so that individual bricks are joined together to form one unit and the vertical joints of successive courses do not lie in the same vertical line is achieved by various types of bonds. Maximum overlap of the bricks will provide stronger bond in the masonry .The bonds are distinguished by their appearance on the face of wall. The following terms are used in masonry bond,

Header: A brick laid with its length perpendicular to the length of the wall is called a Header.

Stretcher: A brick laid with its length in the direction of the length of the wall is called a Stretcher.

Closer: It is a cut part of the brick and is used to provide stagger in successive layers of brick work. It could be half wide brick, quarter wide brick, half length or three fourth length brick.

Queen closer: This is obtained by cutting the brick longitudinally in two equal parts.

King closer: This is obtained by cutting a triangular portion of the brick such that half a header and half a stretcher are obtained on the adjoining cut faces.

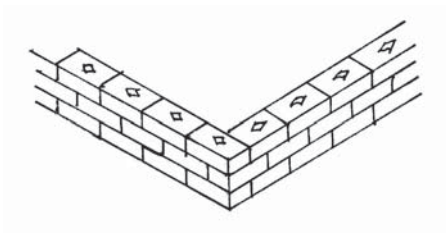
Bevelled closer: This is obtained by cutting a triangular portion of half the width but of full length.

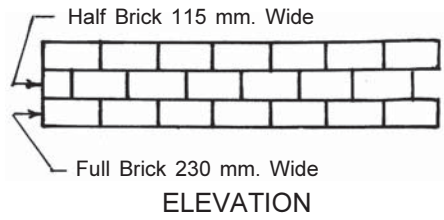
Mitred closer: This is obtained by cutting a triangular portion of the brick through its width and making an angle of 45 degree to 60 degree with the length of brick.

3.2 Types of bonds

a) Stretcher bond
b) Header bond
c) English bond
d) Flemish bond

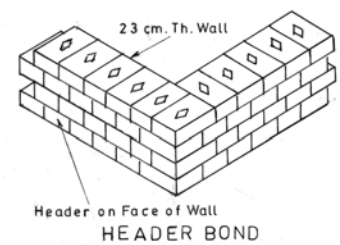
3.2.1 Stretcher bond: In this bond all bricks are laid length wise i.e. in stretcher form. This bond is therefore suitable for walls which have thickness of half brick i.e. 115 mm. In this type the alternative course/layer of bricks is started with a half brick bat.



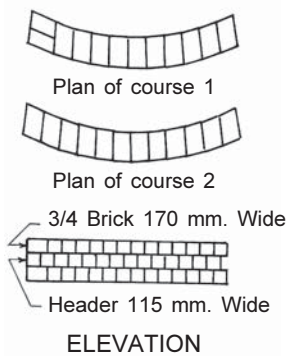


ELEVATION

3.2.2 Header bond: In this bond all the bricks are laid across the length i.e. in header form. This is therefore suitable for walls which have thickness of wall one brick i.e. 230 mm. Normally this bond is used when one brick thick wall is to be curved in plan. In this type the alternative course/layer of bricks is started with three fourth brick bat.



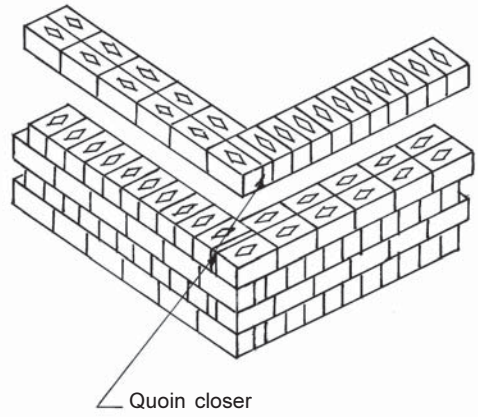
HEADER BOND



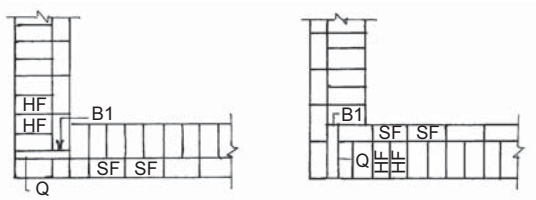
ELEVATION

3.3.3 English bond: Most commonly used bond for all wall thickness .This bond is considered to be the strongest bond. The bond consists of alternate courses of headers and stretchers. Here, the vertical joints of stretchers of alternate courses and also header courses will come one over another. In order that the vertical joint of headers is centrally over the header, it is required that a Quion closer (half brick wide) is to be inserted after first header. The header course should not be started with a Quin closer as it is likely to get disturbed during working. Since the no. of joints in header course are double the no. of joints in stretcher course, it is necessary to keep the thickness of header joints less than in stretcher courses. This bond is adopted for walls of 1 ½brick, 2 brick, 2 ½ brick thickness.

In one brick thick wall, the finish on one face can be good, however on the other face due to variations in the length of bricks, the headers shall be giving an uneven finish which will necessitate to plaster the wall at least on one side. Details of cross junctions and T- junctions in English bond with various wall thicknesses is explained in sketch on next page.

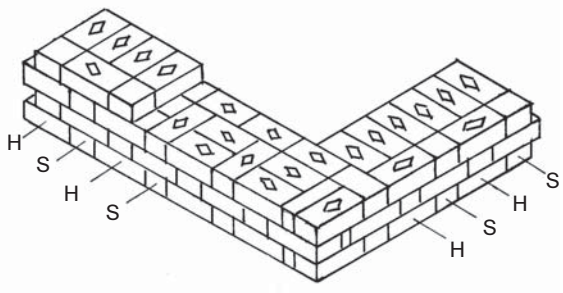


ENGLISH BOND
(STRETCHER COURSE)



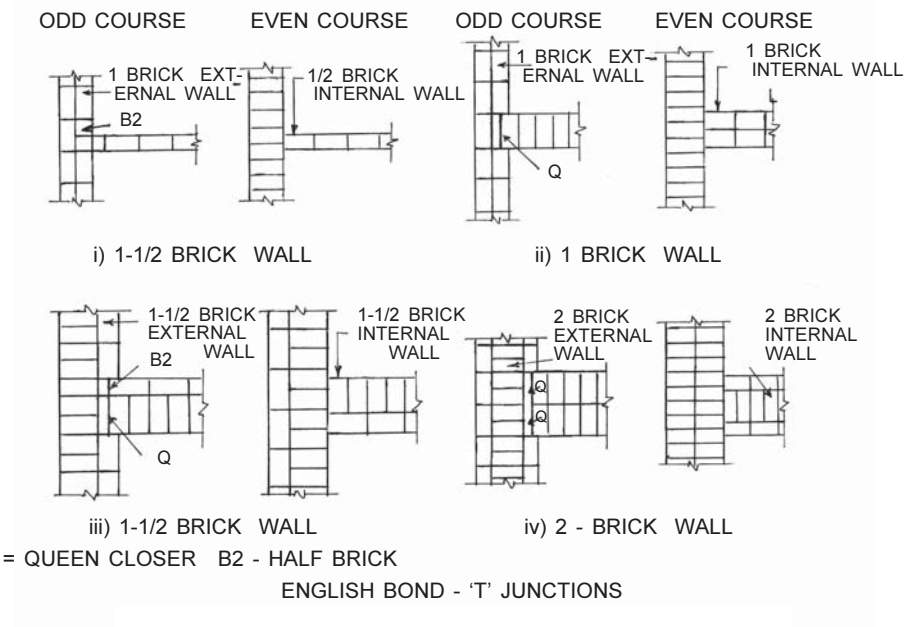
i) PLAN OF 1 1/2-BRICK QUOIN

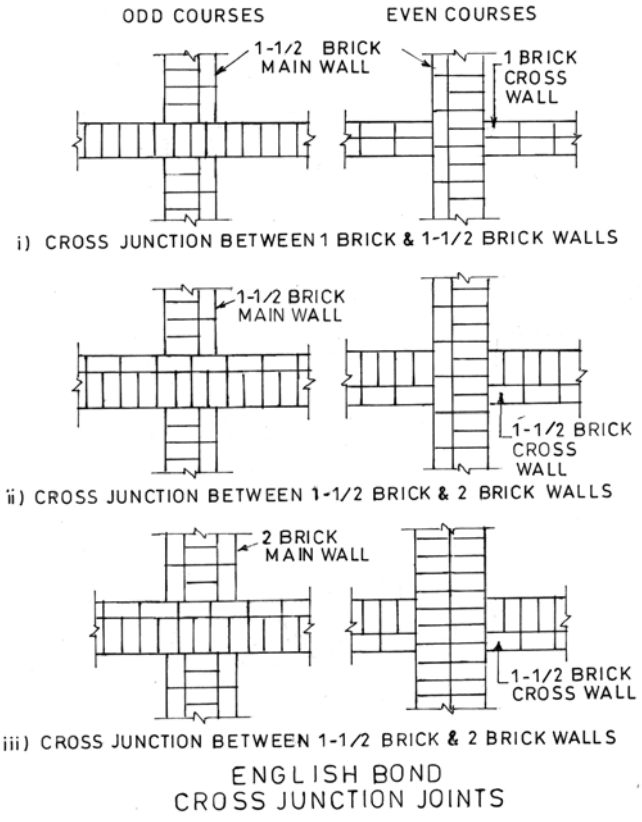
3.3.4 Flemish bond: In this type of bond each course is made of alternate headers and stretchers. Alternate course of bricks start with a header followed by a Queen closer. Here the finish on both the sides can be pleasing as the stretchers on the face can be matched with the varied length of stretchers by adjusting the thickness of joints.



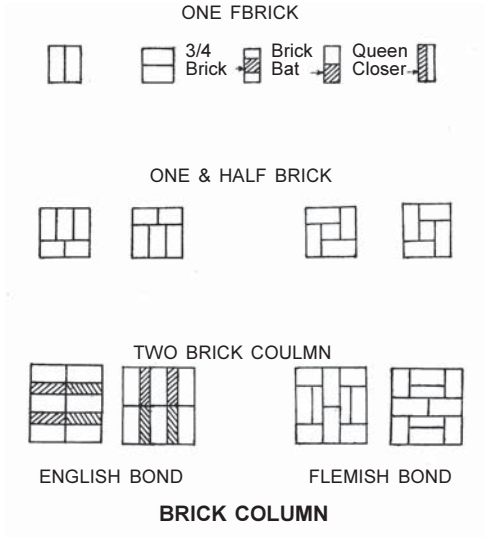
FLEMISH BOND

The details of “T” and ‘X” intersections in English bond is given below:





4.0 Brick Column: Typical arrangement of English bond in brick columns is given in the Fig. Brick columns are provided either to break the long length of the wall or for taking the concentrated load of beams, trusses etc. The ratio of length to width of the columns should be restricted to 12. Thus for a load bearing brick column supported by cross wall, one brick column is adequate only up to a height of only 3.0 meter height. But if it is a stand alone column without any lateral support the same will be inadequate and should be provided only after proper design by an Engineer. The details of brick column in English and Flemish bond are given in the sketch.



BRICK COLUMN

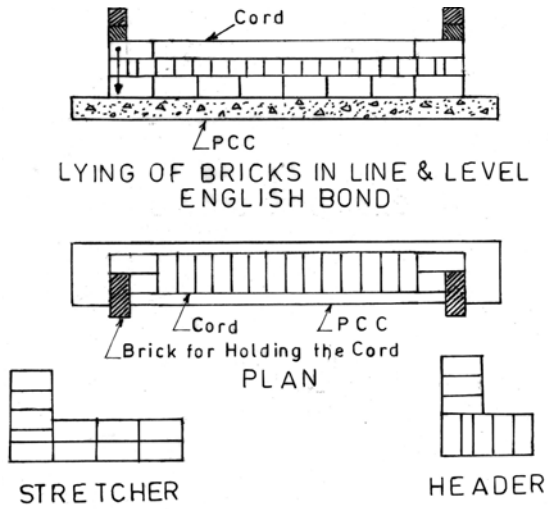
5.0 Brick laying procedure-Step

5.1 One Brick or more thick

1. All bricks to be used are thoroughly soaked in water for at least 2 hours, so that they will not absorb the water from the mortar.
2. Reject all deformed, broken, over burnt, under baked and defective bricks. The lot of the bricks may pass the tests on sample basis but the mason should only use suitable bricks in work, as the laboures will give some defective bricks also.
3. The mason should normally start the work standing inside the brickwork, since the *line dori* is fixed at the edge of wall away from the mason, and this edge is matched during progressing the work, the outside wall surface will be even and the inside surface, i.e. nearer the mason will have imperfections due to variation in size of bricks. The inside surface is generally covered under the plaster, whereas the out side surface may be pointed only.
4. Bricks should be laid to have their frogs facing upwards to ensure that it will be completely filled with mortar.
5. Spread the mortar over an area to be covered by the edges of the wall and the depth of spread mortar should be leveled by trowel (*Thapi*) to a thickness of 12-15 mm.
6. First construct the two corners of wall. One brick is laid first at the corners and pressed by hand so that thickness of bed joint remains only about 10 mm .The first closer is also fixed as corner bricks, duly

applying mortar on the side of closer, then excess mortar from joints is cleaned . The corner construction should be done with great care, since the corner construction at each end works as a guide for filling in between bricks of various courses.

7. A line dori is wound on two bricks and placed above the bricks fixed at the two corners, such that the same matches the far edge of the wall constructed earlier.
8. Check the level and the alignment similarly check placement of edges of the bricks.
9. Then fix other headers or stretchers in 1St course, after the inside face of brick is provided with mortar before next brick is laid and pressed against it, duly pressing with hand and hammering with backside of trowel and check level and alignment also after laying first course.



10. Excess mortar on both sides should be removed and cleaned and the joints should be raked by means of trowel.
11. Again spread mortar over first course. The vertical joints should be filled fully and neatly by pushing mortar with the help of trowel. The mortar layer is to be spread over the entire surface between two edges of first course, with the help of trowel. It has to be ensured that all joints horizontal and vertical are fully filled with mortar and no voids are left.
12. Lay down the corner at the two ends of the wall, Check the plumb and alignment thoroughly.
13. Stretch a line string over the top of the first course laid at each corner of wall. The course is then raised. The procedure is repeated to second, third and all courses till the wall is constructed to the required height.
14. Joints shall be raked smooth and cleaned with trowel when mortar is still green.
15. At a time only 1 meter height of brick masonry to be constructed for 1 brick thick wall and 0.6 meter for half brick wall. This is to avoid unequal settlement by squeezing out of mortar.
16. Curing of the brick work should be done for minimum 7 days,

preferably for 10 days by throwing water by buckets or by water pipe. Curing should be started only after about 12 hours after closing of work to avoid washing off of cement from mortar. Each day's work should be given the date by lime wash or paint so as to identify and ensure curing for adequate no. of days.

17. Before starting the work next day all loose material, dirt and set lumps of mortar should be removed with a wire brush or trowel and surface wetted with water.

5.2 Half brick work

The procedure for laying half brick work is identical to the above with following additional measures,

Normally half brick walls are used for partition walls and are not used as load bearing walls. Half brick walls should not be constructed in lengths or height more than 3.0 meter. If it is required to construct longer or higher walls on architectural considerations the length should be broken by means of a brick column of 1 brick thick, after 3.0 meters. Similarly, the height should be broken by providing a RCC (M15) band of 100mm width, and 75 mm depth, with 2 HYSD bars of 8mm diameter contained in 6mm diameter stirrups @ 150mm center to center, all around the wall at a height of 2.5meter or lintel level. The band can also be made using 1:3 cement mortar, in lieu of concrete.

It is a good practice to avoid providing wide openings in the half brick walls (more than 450mm wide). In earth quake zone III, IV and V, half brick wall should be provided with steel reinforcement, as described in Para 9.0 and 10.0 below.

6.0 Scaffolding

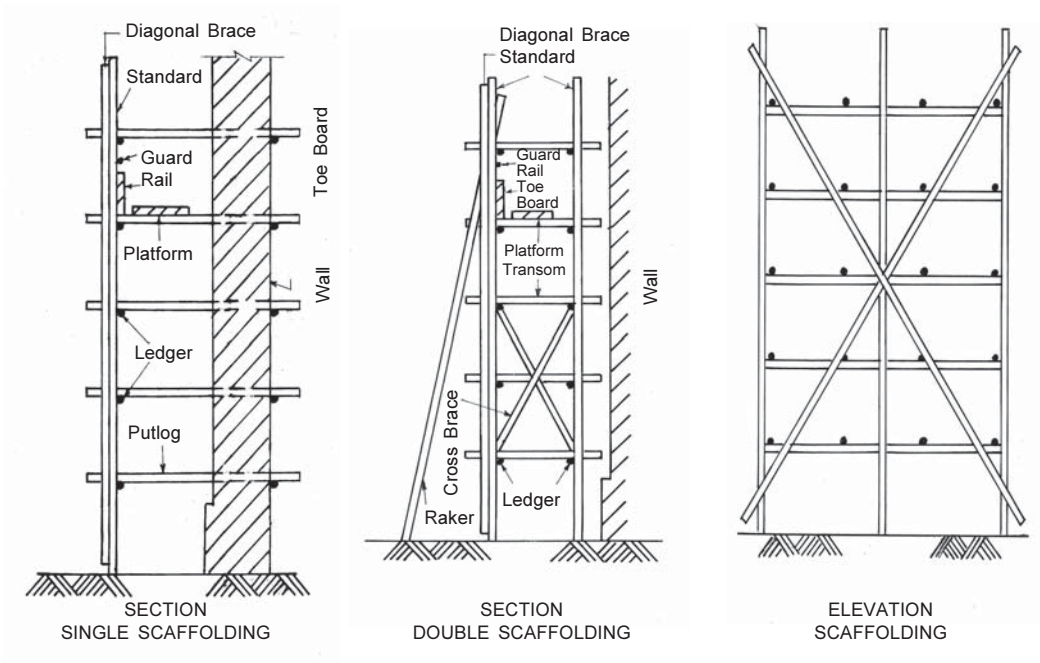
Temporary support structure is required to be provided when masonry work is to be done above approximately 1.2 meter height for working platform for the mason and other labours and stacking material. This is called scaffolding. Scaffolding is generally made using matured bamboos of 75mm diameter or sal balla of about 60 mm diameter. Now-a-days the steel shuttering with iron pipes is normally used on construction site, the scaffolding can be also made using this material.

6.1 Scaffolding is of two types, v.i.z. a) Single scaffold or b) double scaffold. In masonry work normally single scaffolds are used. For exposed brick work and tile works as also for tall buildings, however double scaffolds are to be used.

Single scaffold has one row of verticals (standards) at a distance 1.2 to 1.5m away from the wall. The distance between the various verticals along the length of wall is about 1.8 to2.4 m. the horizontals (Stringers) running parallel to the wall are tied to the verticals at a spacing of about 1.5 to 1.8 m

apart. Putlogs are members with one end tied to the stringers at the junction of verticals and stringers and other end is supported through a hole on masonry. The extension of verticals can be done by providing a lap of minimum 600mm.

Double scaffolds are made without hole in the masonry for supporting



the putlogs. Another row of verticals and stringers are placed near the wall and the putlogs are rested on the two frames. Some diagonal braces are also provided to offer lateral stability.

6.2 Following items should be kept in view for carrying out scaffolding work,

i) Ensure use of good quality material bamboo, hard wood balla or iron pipe.

ii) Erect the base bamboos on a hard and firm ground, with minimum anchorage of 45 cm in ground. If this is not possible, the verticals may be supported in barrels of about 600mm height filled with soil well rammed. The iron pipes are provided with a base plate at bottom and anchoring in earth can be dispensed with.

iii) All members to be tied with fiber rope(*Kathya*) with non-slip knots, should be wet while tying, for better tightness.

iv) See that the scaffolding is in plumb and not inclined

v) Holes in masonry for bamboo support should be made in the header bricks i.e. by removing a header. Scaffolding erection should be

carried out with help of skilled workmen.

vi) Ensure that all the planks laid for making the platform on scaffolding are strong enough to take the mason's load. Wooden planks of size 200x35mm of adequate length are suitable up to 3m span.

vii) All planks rested on the scaffolding must be tied with wet *kathya.*

viii) Keep minimum 90 cm distance between the scaffolding and the wall to be plastered.

ix) Ensure that all the supporting bamboos, putlogs, are passed through the wall and tied internally with other vertical and horizontal bamboos.

x) Provide proper wooden wedges in the masonry hole for tightness of bamboo should be provided.

xi) After the masonry work and plastering is completed all the holes in masonry should be made good by placing a header with the same mortar as used for work.

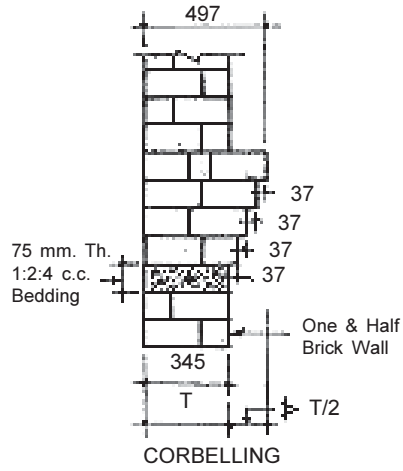
7.0 Corbelling:- A brick corbel may be constructed to support floor beams, girders, jack arches etc. Following precautions are necessary to ensure the stability of a brick corbel.

i) The total amount of projection of the corbel should not exceed half the thickness of the wall.

ii) The brick corbels may be continuous or isolated. The latter is used for the supporting heavy concentrated loads over the brick columns and in order to distribute this load more effectively, a bedding plate of cement concrete or stone is provided.

iii) Each corbel course should not project more than a half the thickness of brick (37mm) at a time. This is to allow a 1/2:1 dispersion of load.

iv) The headers must be used to form all the corbel courses and they should break joint with the course below.



CORBELLING

8.0 Cutting grooves, chases and holes

Many times it may be required to cut brick masonry to provide for water supply/ sewerage pipe lines, electric cables conduits or to provide space for shelves etc. in the masonry. No horizontal chase/groove be provided in load bearing half brick wall. As far as possible, even in 1 brick wall horizontal chases/runs should only be provided in floors, roofs, horizontal cuts in long runs should be avoided. Vertical runs however may be allowed.

i) The vertical runs /chases should not be provided directly under bearing of beams lintels. Two chases should be spaced about 2metre apart, but not located within 345 mm of an opening.

ii) Horizontal chases when unavoidable should be provided away from the middle one third height of the wall. The minimum distance between two horizontal chases should be 500 mm.

iii) No chases /cut grooves should be inclined, this is prohibited.

iv) The depth of horizontal groove should be less than 1/6th the thickness of wall and vertical grooves could be 1/3rd the thickness of wall. The width of a vertical chase should not be more than the thickness of wall.

v) The through hole/recess in brick masonry should be avoided directly under the concentrated load, such as beam supports etc. This can however be provided by placing a lintel at such location. At other locations, a recess up to 300 mm wide can be provided without a lintel. In case of a circular hole up to 450mm diameter, no lintels be required.

vi) The grooves/chases after placing the conduit/pipe should be sealed with, 1:4 cement mortar or 1:3:6 concrete depending on the size of the cut.

8.1 If a hole up to 200x200 mm is to be provided while during construction, the same can be left in the masonry and after placing the required conduit centrally in the hole, the space around should be filled with 1:3:6 concrete making it flush with the faces of wall.

9.0 Measures required in Masonry constructions in Seismic zones

9.1 As per the seismic activity map published in 2002, entire country is in Zone II and above. More than 50% of lands in India lies in seismic zones III, IV, or V and in such areas special measures are required to be adopted for safety against seismic conditions.

To minimize losses in earthquakes, our buildings in their entirety should be tailored to ride safety and appropriate relationship between structure and non structure must be logically sought. This can be achieved by incorporating various earthquake resistant construction features with minor modifications in traditional building system, which can be easily understood and adopted by local artisans.

In order to improve seismic performance of masonry building, considerations should be given to some of the parameters like site selection of site i.e. it should be sufficiently away from steep slopes and should be founded on firm and uniform soil. Similarly general construction practice with large overhang, projections and floating column, attachment of heavy mass at the top of building should be discouraged. Similarly workmanship is yet

another factor which affects its performance and hence emphasis should be given on good quality of workmanship.

9.2 Categories of Buildings: Masonry building have been classified in 5 classes namely, A,B,C,D and E ,for the purpose of achieving seismic resistance depending upon seismic intensity zone and importance of building.

Importance Factor	Seismic Zone and Building Category			
	II	III	IV	V
1.0	A	B	C	D
1.5 ($)	B	C	D	E

($) The important service and community buildings such as hospitals, schools, monumental structures, emergency buildings such like telephone exchange, control office, railway station, radio/television station, fire station, power stations and large community halls like cinemas, assembly halls etc. shall be building with importance and the factor shall be 1.5.

9.3 Mortar for Masonry

Recommended mortars are as under,

Category	Proportion of cement sand mortar
A	1 Cement: 6 Sand or richer
B &C	1 Cement : 6 Sand or richer
D&E	1 Cement : 4 Sand

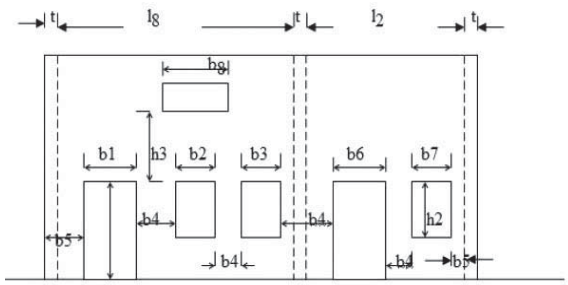
9.4 Masonry walls

i) Un- reinforced load bearing masonry walls should not be built of greater height than 15m subject to a maximum of four storeys.

ii) The bearing walls in both directions shall be straight and symmetrical.

iii) Stepped joints should be provided between perpendicular walls by making the corners first to a height of 600 mm and then building the wall between them.

9.5 Openings in walls



Recommended dimensions of Openings and Piers

i) Guidelines for size and position of openings are as under:

S.No.	Position of Opening	Details of Opening for Building Category (mm)		
		A & B	C	D & E
1	Minm.distance from the inside corner of outside wall (b5)	0	230	450
2	Maxim. Ratio of total opening to length of wall			
a)	1-Storey bldg.	0.60	0.55	0.50
b)	2- storey bldg.	0.50	0.46	0.42
c)	3 or 4 storey bldg.	0.42	0.37	0.33
3	Minim. Pier width between two openings (b4)	340	450	500
4	Minim. Vertical distance between two openings (h3)	600	600	600
5	Maxim. Width of ventilator (b8)	900	900	900

9.5 Half Brick load bearing walls

If thinner walls like half brick wall are to carry load, reinforced concrete columns and collar beams will be required to be constructed to have full bond with the walls. Columns should be at all corners and junctions of walls and spaced not more than 1.5 m apart but so located as to frame up the doors and windows.

10.0 Strengthening the Buildings to make them fit for Seismic Resistance

10.1 Provisions of bands

Lack of proper connection between various elements of the buildings, like walls or between walls and roof has often resulted in damage to masonry buildings during earthquakes. Bands of reinforced concrete or reinforced brickwork provided in all the load bearing walls at different levels together with vertical reinforced concrete elements which are not necessarily load bearing , provide excellent connections for the building to act as one unit under earthquake motion, resulting in increasing considerably its seismic resistance and minimizing damage.

Reinforced Concrete Band
(Width is same as width of wall)

10.1.1 Horizontal Reinforcement in /Bands in walls

Horizontal reinforcing of wall is required for tying the perpendicular walls together. This is achieved in masonry buildings by providing bands continuously through all load bearing longitudinal and transverse walls at plinth, lintel and roof –eaves level.

a) Plinth bands are generally provided where soil is soft for taking care of uneven settlements.

b) While lintel band is the most important band and is to be incorporated over all doors and windows and should be provided in all storey preferably at same level of building.

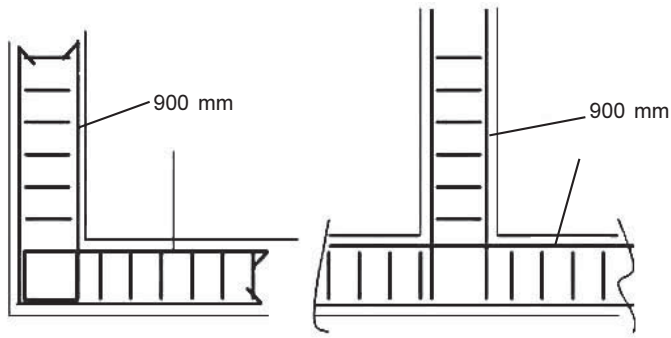
c) Roof bands are required at eaves level of trussed roofs.

The cross sectional dimensions for band shall be full width of wall, not less than 75mm depth in 1:3 mortar or M15 concrete. The reinforcement required for various building categories depend upon its category and span. The cover shall be 10 mm and continuity provided at corners and junctions. Table below shows the size and reinforcement (HySD bars) detail required in RC band for spans up to 8 m.

Span (m)	Building Category							
	B		C		D		E	
	No. of bars	Dia (mm)	No. of bars	Dia (mm)	No. of bars	Dia (mm)	No. of bars	Dia (mm)
5 or less	2	8	2	8	2	8	2	10
6	2	8	2	8	2	10	2	12
7	2	8	2	10	2	12	4	10
8	2	10	2	12	4	10	4	12

10.1.2 Dowels At corners and junctions

In D and E category buildings, steel dowel bars are also provided at corners and T-junctions of wall at sill level of the windows to a length of 900 mm from the inside corner in each wall. Such dowels are in U stirrups of 8 mm diameter, laid in 1:3 mortar with a minimum cover of 10 mm.



10.1.3 Vertical Reinforcement in walls

Vertical reinforcement at corners and junctions of wall, which are up to 340 mm (1 ½ brick) thick wall, shall be provided as per table below. For thicker walls area will be proportionally increased. Vertical reinforcement shall also be provided at jambs of door and window openings.

No. of storey	Storey	Diameter of HySD single bar in mm. at each location			
		Cat.B	Cat.C	Cat.D	Cat.E
One	-	Nil	Nil	10	12
Two	Top	Nil	Nil	10	12
	Bottom	Nil	Nil	12	16
Three	Top	Nil	10	10	12
	Middle	Nil	10	12	16
	Bottom	Nil	12	12	16
Four	Top	10	10	10	Not permitted in 4 storeys
	Third	10	10	12	
	Second	10	12	16	
	Bottom	12	12	20	

11.0 UCR masonry work

11.1 The UCR i.e. Uncoarsed Rubble Masonry also known as Random Rubble Masonry is widely used for plinth work and compound wall work. This is also used in walls of inferior class of structures where aesthetics is not a factor of importance, such as Godowns, Garages, Labour quarters, Retaining walls, compound walls etc. This is more economical than any other type of masonry. Normally the UCR masonry is set in 1:6(1 part of Cement and 6 parts of sand by volume) Cement mortar.

11.2 Material required for 1 Cum of Masonry,

Stones - 1.25 Cum

Sand - 0.4 Cum

Cement - 1.6 bags

Scaffolding material - as per height of wall

11.2.1 Stone

i) Stone should be locally available, within a reasonable distance.

ii) When the stones arrive from the quarry they are broken down in to sizes that suit the width of the wall. Normally the stones used should be small enough to be lifted and placed by hand. Generally the length of stone shall not be greater than the thickness of wall, and not less than 15 cm. The height of stone may be up to 30 cm.

iii) Stones should be hard tough and durable

iv) Through stones to be used in successive layers, at 1.0m to 1.5m apart in every course. Through stones in all alternative courses shall be properly staggered and shall not be over one other. The position of all through stones shall be marked at both faces, for identification.

v) Corners stones should be dressed well in right angles.

vi) Sufficient number of corner stones and through stones for 1 days work should be prepared, if required by dressing, before starting the work.

11.2.2 Sand, cement, water and Scaffolding should be available before starting the work. The specifications are given in Chapter 1 'Materials' and scaffolding under Chapter 3 'Masonry' be referred.

11.3 Preparation Before UCR Masonry Work

i) Set out the structure by means of Line dori and pins taking reference from existing structure. If there is no reference structure, the set out will be given by Junior Engineer. Mark the trench lines for excavation with lime powder (*fakki)*, minimum 300mm more than the width of PCC base course or 500mm more than thickness of wall in the foundation.

ii) Excavate the trench up to the depth required.

iii) Level the bottom of pit and remove all loose soil/earth. Water the trench and ram it with a wooden rammer.

iv) Check the dimensions and orientation of the pit/trench

v) Place PCC (1:4:8) using *Ghamelas* and spread by *Panjas*, 75mm thick or as given in the drawing, within wooden batten shuttering, duly supported from the side of the pit trench. Ram it properly with the rammer, till traces of cement slurry show on the surface. Check the level.

vi) Cure the PCC for at least 3 days, by pouring water by buckets or by water pipe. It is however recommended to cure for 15 days, if the work can be planned and 15 days time is available.

vii) Mark the centre line of the wall foundation by nailing or by cement mortar, at least at about 3 meter distance apart.

11.4 UCR Masonry work

i) Water the stones well before use. It is advisable to water the stones at least twice a day, i.e. after every 4 hours while working under sun. Also wet the PCC surface.

ii) Prepare mortar 1:6 or as specified in drawing, in a mortar tray using ½ bag of cement only.

iii) Spread mortar on the PCC surface where wall to be constructed, approximately 25mm thick.

iv) Lay corner stones of both end of wall at least in two layer in plumb. If the wall is a long continuous one, like compound wall, the corner stones should be placed at 15m spacing to provide expansion joint at 15m interval.

v) String the line *dori* along the corner stones, at the inner face of the wall.

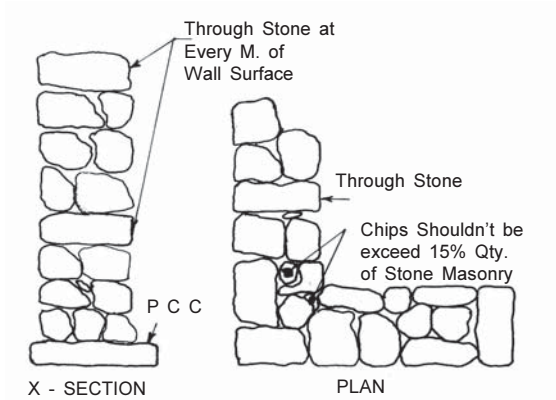
vi) Stones shall be laid on their broadest face with proper shaping and dressing wherever required with the help of *tacha*. Hammer the stones by means of the hammer to embed the stones in the mortar.

vii) Over the first layer of stones, lay small clean stones /*Kapchi* to fill up hollow spaces in masonry wherever depressions occur. Joints should be well packed with the help of trowel.

viii) Lay next layer of mortar about 20mm (3/4") thick

ix) Move the line dori up on a fresh set of corner stones. Ensure the verticality of corner stone by means of Plumb bob and repeat the procedure.

x) Header stones or through stones (minimum 3/4th thickness of wall) have to be laid in each layer at a spacing of 1.0 to 1.5 m. It is to be ensured that the headers are staggered and not in one line i.e. not one over another. The header stones should be of depth ,about 1/3rd thickness of wall. To identify the headers for use in masonry they shall be marked with an identifying mark with chalk.



UCR MASONRY WALL

xi) The height of the masonry work should be maintained in one level, with the help of level tube. Masonry should not be constructed more than 1.0 meter height in a day.

xii) At the close of the day's work, lay some vertical stones, projecting out in vertical direction, for better bonding of 1st and 2nd days work.

xiii) Before starting the work on next day, the surface, the stones should be wetted with water. Old mortar should be cleaned and loose mortar removed.

xiv) It should be cured at least for 7 days, preferably for 15 days. The joints should be pointed after proper curing and raking.

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CHAPTER 5

PLASTERING WORK AND POINTING WORK

1.0 General

Plaster is a layer of cement- sand mortar or sometimes mixed with lime, applied over any coarse textured wall such as masonry work .This also acts as a damp proof coat over the masonry work. Plastering also enhances the appearance of the building.

1.1 Material required for plastering

S.No.	Item for 10Sq.m.	Cement (Bags)	Sand (Cum)	Sanla (Kg)
1.	12.5 mm thick with Sanla finish			
	1:4 Mortar	1.60	0.3	21.0
	1:6 Mortar	1.10	0.3	21.0
2.	20mm thick with Sanla finish			
	1:4 Mortar	2.60	0.6	21.0
	1:6 Mortar	1.60	0.6	21.0
3.	15 to 20mm thick with sand faced finish			
	1:4 Mortar	2.40	0.5	-
	1:6 Mortar	1.60	0.5	-
4.	20-25 mm double coat with sand face finish			
	1:4 Mortar	4.10*	0.9	-
	1:6 Mortar	2.70*	0.9	-

* Includes cement @2Kg per sq.m. for spreading neat cement slurry on first coat

1.2 Tools required for plastering

- Mortar pan(ghamela)
- Spade (Phavada)
- Chisel
- Hammer
- Trowel
- Water level tube
- Wooden float
- Metal float

- Aluminium hallow box section
- Right angle
- Measuring tape
- Line dori
- Plumb bob
- Scaffolding material (Bamboos, planks, kathya etc.)
- Chicken mesh, plumbing nails, cutter wire nails,
- Drilling machine
- Screen for sand
- Measuring box for measuring sand
- Wire brush
- Sponge for sand face plaster
- Metal tray for mixing mortar

2.0 Thickness of plaster: Thickness of plaster should be kept minimum just required to properly cover up the rough surface, due to uneven size of the bricks. If it is decided to plaster both internal and external faces of wall, then the matched edge is kept towards the internal face and the external face is much more rough and uneven. Plastering up to 15mm thick shall be done in single coat. Plastering above 15mm thick up to 25mm thick shall be done in two coats. For 20mm thick plaster base coat shall be 12mm and finishing coat shall be 8mm.In case of 25mm thick plaster base coat shall be of 15mm and finishing coat shall be of 10mm. Plastering above 25mm thick shall be used exceptionally with the approval of Divisional Engineer.

Plastering shall be started from the top and worked down towards the floor. All put log holes shall be properly filled in advance of the plastering including fixing of door frames projecting the thickness of plaster from the level of brick work.

3.0 Types of plasters: As per the locations of plastering the plaster may be divided in two major groups such as Internal plastering and External plastering.

3.1 Internal plastering: Internal plastering is the plaster for walls on the internal surfaces. It is meant for painting, smooth finish is most important. There are two types by which we can achieve smooth finish plaster such as sanla plaster and smooth finish cement plaster.

a) Sanla plaster: For smooth surface of plaster from inside generally sanla or neeru is applied after normal plastering work in wet condition only.
b) Smooth finish cement plaster: Wherever specially required generally water tanks plaster, chajjas outside plaster the finish coat is obtained by neat cement paste.

3.2 External plastering: External plaster work is usually finished rough

as the smooth surface shows up defects more easily than a rough surface. Also weathering is more uniform as a rough surface. Roughness is also found to help prevent penetration of rainwater in the walls. Hence external plastering is generally made rough.

The types may be classified as

a) Sponge plaster (Sand faced finish)
b) Textured finish
c) Pebble finish
d) Machine applied finished.

a) Sponge plaster (Sand faced finish): The first coat is carried out in cement mortar 1:4 of 12mm thick and the second coat in proportion 1:6 and the thickness will be 8mm and sponge is used in the second coat and it is applied when the second coat is wet and it is so worked that the density of sand grains appearing on the surface is equal and uniform.

b) Textured finish: These are very popular with some builders. They possess advantage over smooth rendering in regard to crazing and the attractive appearance that can be achieved with very little cost. In textured finish the top 1.5mm of the final coat is textured with special tools after it is all allowed to stiffen for a few hours. Special tools can be made for texturing. An old hacksaw blade or wooden float faced with expanded metal sponge, hairbrush, etc can produce pleasing effects

c) Pebble finish: In this type of finish the finishing coat is made 12mm thick and clean pebbles of size varying 10mm to 20mm are dashed against the surface so that they are held in position by the mortar already applied. These pebbles are then slightly tapped with a wood float to ensure a good bond. The surface gives a pleasing surface only if the pebbles have a good colour combination.

d) Machine applied finish: There are many machines which can throw plaster on the base coat and give appropriate finishes. They use the usual plaster material and are cheap in cost.

4.0 Proportions to be used:

Plaster should be plastic and adhere to the masonry work. Hence it should be richer than mortar for brickwork. However, it should not have more cement than required otherwise it will crack due to shrinkage. The commonly used mixes for plastering various surfaces are given below.

For internal plaster in ceiling - 1:3

For internal plaster for walls - 1:4

For external plaster - 1:4 or 1:6 or as per mentioned in Drg.

5.0 Preparation of External plaster:

Before starting the external plastering some important points to be inspected such as,

i) Scaffolding work should be erected by skilled workers keeping 90 cm distance from the wall.

ii) External side gaps in masonry and joints of the beam and wall which was not possible earlier without scaffolding should be filled properly. This should be done with rich cement mortar 1:3

iii) Take the plumb or line from top to bottom at the all edges.

iv) Keep the thickness of the plaster to minimum if beam or column is bulged out, then chiseling is to be done with a sharp chisel and hammer.

v) Fix chicken mesh to all joints of masonry and RCC work, cut the chicken mesh in minimum 20 cm width by cutter chicken mesh should be of 24 gauge and 12mm hole. Fix the chicken mesh on joints of RCC and masonry wall by plumbing nails on RCC members and wire nails on masonry wall .Half the width of the chicken mesh will be on the masonry wall and half will be on the RCC members.

vi) Check all the chajjas for smooth opening of outer windows. Also check the window frames for plumb line and level

vii) Check the top level of the parapet walls before plastering

viii) Take the level dots (Thiyya) before starting the external plaster patches of 15cm x 15cm about 2m apart of specified thickness of plaster with the help of plumb bob and line dori. First fix the thiyya in left corner of wall and fix the bottom level thiyya with the help of plumb bob and intermediate thiyyas will be fixed by holding line dori between these two.

ix) All RCC surfaces should be hacked for roughening the surface with the help of tachhya (a special type of hammer for hacking)

5.1 Procedure of external plastering work:

Before starting of the plastering work for a day's works should be planned with availability of mason and material, preparation of site and then only start the work.

i) Take the sieved sand by measuring box in the tray as per proportion 1:4 and add cement bag and first it should be dry mixed then add sufficient water to get the required consistency of mortar. The mixed mortar should be used within half an hour.

ii) Wet the surface fully before applying plaster to it.

iii) Apply plaster level and finish the same with the half of float and trowel. Generally first coat is of 12mm thick. Ensure that no uneven

surface is observed and check the surfaces with line dori on respective thiyyas.

iv) Roughen the surfaces with wires for better bonding to second coat.

v) The first coat shall be roughened and shall be kept damp for at least two days.

vi) The second coat shall be finished smooth to texture even surface uniform in line and plumb. and uniform texture should be given with the help of sponge.

vii) The time gap between the first coat and second coat should not exceed 5 days.

viii) Curing of plaster shall be carried out at least for 15 days and minimum 4 times a day.

6.0 Internal plastering: Before starting the internal plastering work there is need of some preparation work to be done and following precautions should be taken before starting the work.

i) Doors and window frames which are fixed at the time of brick work needs to be checked for line, level, plumb, position, sizes etc. if not necessary rectification work to be done. Ensure that door frame is projecting by 12mm outside the wall and RCC lintel so that after plastering wall surface will be flush to door frame.

ii) See that the hold fast of windows and door frames are concreted properly and nailing of column strip to the column should be proper with full depth of nail; the nail should not be bent.

iii) Ensure that 15mm margin from all four sides of the window is provided.

iv) Chicken mesh should be fixed to all vertical and horizontal joints of RCC and masonry wall.

v) Check the top levels of lofts and its thickness.

vi) In case of concealed wiring check whether all electric, TV and Telephone conduiting work is finished as per requirement.

vii) See that the fan hook is exposed and straight in line and level.

viii) See hatching work is properly done or not if any unwanted portions of RCC to be chipped off then it should be chipped off. (It should not be less than 50 nos notches per sq. ft.)

ix) Remove unwanted concrete mortar from the floor to mix plaster mortar, on clean surface.

x) All the walls and ceilings surfaces should be saturated with water a day before plastering.

xi) Check the silt content of sand and if it is found to exceed 8% then wash the sand before screening.

xii) Ensure that all holes in the external scaffolding are finished with proper rich concrete mortar.

6.1 Procedure:

The material required for scaffolding for internal plaster is not as heavy as for external plastering but the M.S chairs, wooden planks, kathya should be arranged.

i) Take the Thiyyas of plaster in all rooms at the top and bottom levels. as per required thickness.

ii) Dump sand required as per measuring box as per the proportions of mix

iii) Mix the ingredients in proportion and use the required quantity of water. Do not add extra water and do not allow the cement slurry to wash out.

iv) Mix only required quantity at a time for use within half an hour.

v) Cut the cement bags with a hack - saw blade and not with a phavada.

vi) Start plastering of ceiling first and then walls.

vii) Apply sanla or neeru to all the walls after two hours except where tiles in dado are to be fixed.

viii) Leave and cut the plaster correctly 23 cm from the floor level for skirting fixing.

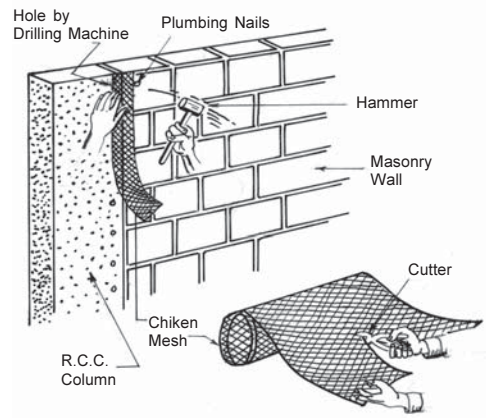
ix) Neatly finish all the corners of windows, door column etc with pure cement.

x) Clean all windows, fan hooks, door frames etc after plastering.

xi) See that IPS smooth finish is done on the top of the loft.

7.0 Precautionary measures to avoid cracks in plastering

Cracking of plaster is a phenomenon observed in most buildings. If enough precautions are taken, the plaster cracks can be minimized. Joints between concrete surface and brick work as happens between beams and walls and also columns and walls of a framed building require special attention. As the expansion of brickwork and concrete is different, we should either introduce a discontinuous joint by providing groove or use of chicken wire mesh should be fixed at joints as shown in fig.



JOINT OF BRICK MASONRY
WITH CONCRETE

Following are some precautions to minimize the plaster cracks. Please note that the precautionary measures are to be taken from the masonry stage of the work.

i) At the time of masonry, apply a thin layer of rough cement sand plaster (Chhat) at the junction of masonry and column. At this junction cracks are likely to develop due to different coefficient of expansion of two materials. Application of thin cement sand layer reduces the chances of cracks developing.

ii) Do not erect more than 1.0 m of masonry work, at a time. For 10 cm, and 15cm thick masonry walls provide RCC band at every 1.0m height. This will reduce the settlement of masonry and cracking at the top level, at junction of beam and masonry.

iii) Treat masonry and floor beam junction with the help of Kadi mall (Packing of 6-10mm stone with rich cement mortar at junction of RCC beam Column and masonry,) and chicken mesh.

iv) Do not allow the use of stale mortar as its initial setting time is over, leading to cracking of fresh plaster.

v) Do not allow excessive water for mixing mortar as cement slurry may flow out of the mortar reducing strength and leading to cracks.

vi) Do not allow plastering over fully dry masonry surfaces as it absorbs water from the plaster mortar, leading to drying of mortar and cracking of fresh paste.

vii) Do not allow excessive thickness of plaster in a single coat.

8.0 POINTING WORK

Pointing is required to improve the appearance of the entire masonry work and to protect the exposed mortar joints from the effect of atmospheric actions, provide necessary blockage to rain water to seep the wall etc.There are following 4 types of pointings used in masonry work,

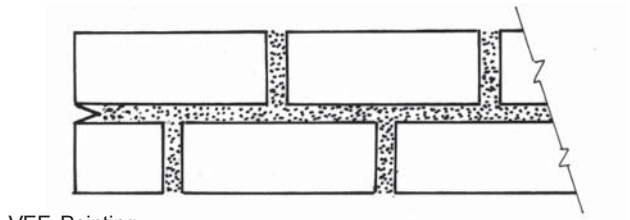
a) Flush pointing: This is most common form of pointing used in India. The pointing is flush with the surface of masonry i.e. there are no projections or grooves. Some times a line indentation is made on the pointing by means of a nail to improve the appearance. Here the excess mortar is removed and the joint is flushed with the surface of the stone and cement paste is applied on the joint and small line is drawn with the help of nails. This is provided in stone as well as brick masonry.

b) Vee Pointing: This type of pointing gives better appearance than flush pointing. Here after flush pointing, a steel rod bar of square section is pressed into the pointing line with angular edge to form a Vee, about 6mm deep. The groove can also be formed using round bar of 12mm dia .This type of pointing not only gives a better

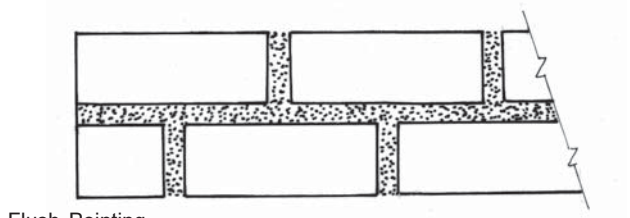
appearance but also is stronger as any soft mortar of pointing gets compacted by pushing of the bar. This can be provided in both stone as well as brick masonry.

c) **Sunk pointing:** After raking the joint mortar, a thin layer of mortar is pressed with a proper tool into the joint, leaving about 6-8 mm depression from the masonry surface. This gives a very good appearance, specially in dressed stone masonry.

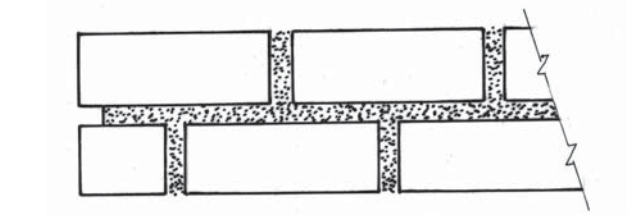
d) **Raised pointing Or tuck pointing**:- This is provided at locations where architectural finish so requires. It requires more labour and is normally provided on decorative stone work and rarely on brick masonry. Tuck pointing projects from the wall facing with its edges cut parallel so as to give a uniformly raised band about 6mm height and width 15mm or more as directed.



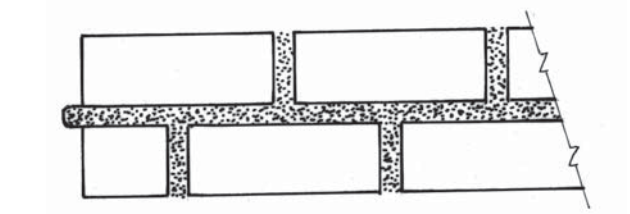
VEE Pointing



Flush Pointing



Sunk Pointing



Raised Pointing

Styles of Pointing

Methods of Pointing

1. Rake the joints at least 25 mm depth in case of stone masonry and 18mm in case of brick masonry, by means of chisel and hammer. It is preferable to carry out the raking of joint on the same day of laying masonry, when the mortar is still green.
2. The dust and loose mortar from masonry joints should be removed by means of painter's brushes.
3. The surface should be washed with clean water and kept wet for a few hours before starting pointing..
4. The mortar of 1:2 cement sand proportion or as shown in the drawing is carefully inserted in joints with a small trowel and slightly pressed to bring the new and old mortar closer.
5. The superfluous mortar shall then be cut off from the edges of the lines and the surface of masonry shall also be cleaned off all mortar. The finish shall be such that the pointing is to the exact size and shape required and the edges are straight, neat and clean.
6. Special finish is given to other type of pointings as described above i.e. for Vee, Sunk or Raised pointings.
7. Curing should be done by spraying water by buckets or by pipe for minimum 7 days, preferably for 15 days.

CHAPTER 6

FLOORING AND TILING

1.0 Introduction

1.1 Flooring is the horizontal surface of a building which supports the occupants and the activities they pursue in the building. Broadly, the flooring should meet the following requirements,

a) strength and durability of surface

b) Maintainability and appearance should be pleasant

1.2 Types of floorings: There are a large no. of types of floorings being used, generally classified based on the material used in the floor. Some of the common floorings are,

i) Indian Patent Stone (IPS Flooring)

ii) Bricks laid on edge

iii) Terrazzo /Marble chips flooring

v) Tiles/ and natural stones slabs

a) Marble mosaic flooring (Grey, white, Pink etc)

b) Polished stones like Kotah, Shahabad, Tandoor etc.

c) Marble and granite flooring

d) Rough Shahabad flooring

e) Ceramic tiles, glazed and vitrified

f) Chequered tiles.

g) Interlocking blocks

2.0 I P S Flooring (Indian Patent Stone Flooring)

2.1 IPS, Indian patent stone flooring or Cement Concrete flooring is a very basic type of flooring adopted in India. It provides good wearing properties, can be easily cleaned and maintained. It is generally used for all floors except where decorative flooring is preferred. Generally the mix of concrete used for I.P.S. is 1:1.5:3 (1 part of cement, 1.5 parts of sand and 3 parts of stone aggregate by volume), however richer mix of 1:1:2 is also used specially when the thickness of IPS is on the lower side. Depending upon the nature of use of the flooring, the thickness of concrete is decided. v.i.z. 25 mm, 40mm or 50mm.over base concrete (1:4:8), 75mm-150mm thick over well prepared sub-base. In residential units a base concrete of 75 mm may be satisfactory whereas for heavy duty areas such as workshops, garages it may be 150mm. Similarly the IPS thickness can be 25mm for residential

areas and 50 mm for workshops, garages and godowns where heavy items are to be stocked.

2.2 Material

Item for 10Sq.m floor area	Stone chips (Cum)		Sand (Cum)		Cement (Bag)	
Concrete Grade	1:1.5:3	1:1:2	1:1.5:3	1:1:2	1:1.5:3	1:1:2
a) 25mm thick (10mm chips)	0.22	0.22	0.11	0.11	2.04	3.05
b) 40mm thick (20mm chips)*	0.36	0.36	0.18	0.18	3.00	4.88
c) 50mm thick (20mm chips)*	0.45	0.45	0.225	0.225	3..6	6.1

2.3 Tools Required: All tools required for masons work are required and should be available at site of work.

2.4 Preparatory work prior to IPS

i) Prepare the sub-base by watering and ramming, ensuring that no pockets of loose material are left. Level the surface and any depressions be removed by spreading sand and ramming. In heavy duty floors such as workshop floors, garages etc boulder soling and/or ballast layer of 150mm may be provided and rammed properly.

ii) Floors in verandahs, court yards, balcony, bath room, kitchen, terraces etc should be provided a cross slope for easy drainage. Normally a 1 in 60 slope is adequate. However the slope in W/C area should be 1 in 30. In terraces and court yards however a slope of 1 in100 is considered adequate depending on the nature of surface finish. While the slope for bath rooms, kitchens, balconies, verandahs are provided in one direction i.e. towards the drainage outlet but in larger areas such as court yards and terraces multi-direction slopes with a ridge or peak forming at centre and slope being given towards the edges, where outlets are located, are provided.

iii) It will not be possible to provide slope in the IPS layer due to limited thickness available, it is therefore to be provided in the base course, in case of ground floor and in the cushioning layer of 40-50mm lime/ cement concrete provided over RCC slab in upper floors. All the service pipes and ducts are to be laid in the base course / cushioning lime concrete.

iv) Flooring work has to be started only after all doors frames have been fixed, internal plaster and ceiling plaster has been done. Incase of any drainage outlets are required, the same should be provided beforehand.

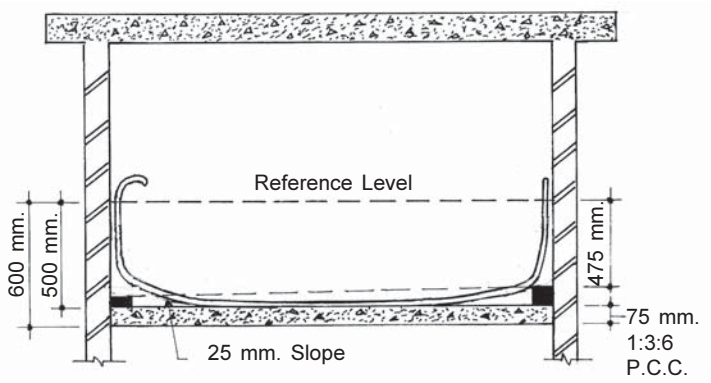
v) **FLOOR LEVEL MARKING**

1. **Marking reference level:** On main door of the house/building mark fixed line generally at 60 cm above desired finished floor level and transfer this fixed marking to all other door frames of all

the building where flooring is to be done with the help of level tube.

2. The level tube is filled with water and no air bubble should be inside. By matching ends of level tube see water level is same at both ends, then fix one end water level on reference mark which is to be transferred and match water level exactly with the reference level and mark the water level on other end, on all the other door frames. Similarly transfer this level to all walls and with the help of line *dori* and *geru* mark, make permanent level lines on walls.
3. After marking levels in all the rooms proceed for base work i.e. mix of 1:4:8 concrete (i.e. one *ghamela* cement, with 4 *ghamela* sand and 8 ghamelas of stone aggregate of 20mm) make *thiyyas* i.e. level dots below every level marking in corners.

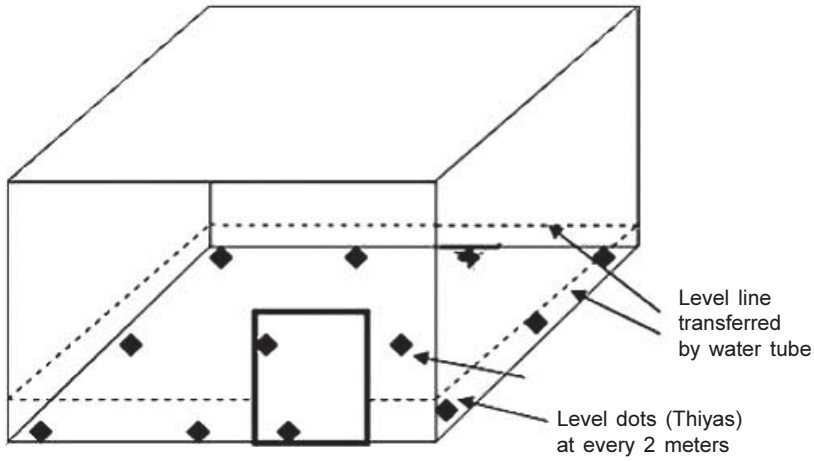
If any desired slope is required to be kept that should be kept in these *thiyyas* only. In living rooms, generally no slope may be required, however while washing the floor room there should be way for water to be drained out at door only, thus a mild slope of 1 in 150 may be provided . For other places like bathroom, kitchen etc. the slope of 1 in60 should be such that the water flows toward the outlet made for the purpose. Fix *thiyya* near the door first at say 500mm below from level line then the level of corner *thiyya* on opposite wall will be 475 mm from level line so 25mm slope, in a room of 4.0 meter length will be maintained. And then by holding line dori on top of these two thiyyas intermediate *thiyyas*, at 2m interval will be taken with the help of line dori.



REF. LEVEL WITH THE HELP OF LEVEL TUBE

vi) After proper setting of these *thiyyas* of cement concrete proportion 1:4:8 should be laid throughout the room the work should be started from the opposite corner away from the door or entry. After laying the mix, mason should compact this concrete by screed board i.e. with heavy *chabi* made up of 3”x4” size wood so that cement slurry will come on top surface.

vii) Cure the surface by pounding water till starting the IPS.



SCHEMATIC VIEW OF MARKING OF LEVEL DOTS IN ROOM FLOOR

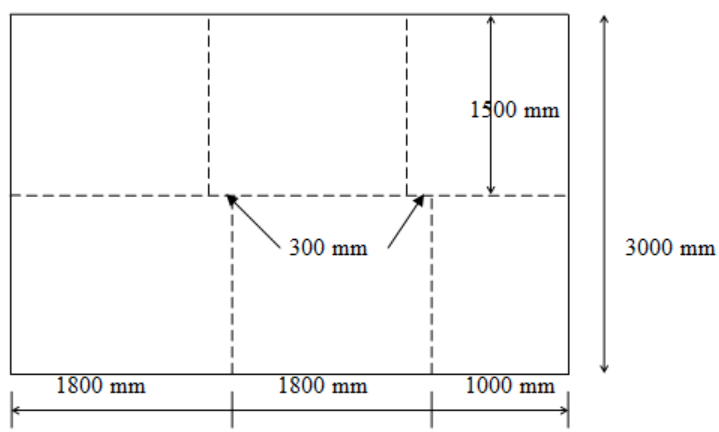
2.5 Laying the IPS

i) The IPS should be laid within 24 hours of laying the base course, preferably.

ii) The surface should be cleaned and surface water if any from curing process mopped up and removed.

iii) Place *thiyyas* to mark the thickness of flooring required at different areas, as described above. The *thiyyas* should be made with 1:1.5:3 (1 part cement, 1.5 parts sand and 3 parts 10mm or 12mm stone chips) or whatever grade of concrete is being used for I.P.S. concrete.

iv) The floor is to be divided in panels to minimize shrinkage cracks. The size of panel should not exceed 3sq. m. for indoor and 2 sq.m. for out door flooring. The one dimension of panel should not exceed 1.5 times the other dimension. It is desirable that the corners of adjacent panels are staggered by a minimum of 300mm such that weak spots do not get concentrated at one place.



Floor division in Panels

v) Glass strips 4mm thick or aluminum strips 2mm thick are fixed in 1:4 cement mortar with their tops at proper level according to the slope and allowed to harden for minimum 36 hours.

vi) Concrete 1:1.5:3 or 1:1:2 as the case may be, is laid in one operation in all the panels. It is compacted by means of wooden screed board made up of *chabi,* leveled with a straight edge and finished with a wooden float or trowel.

vii) After the concrete has just hardened, the concrete is finished with a steel float or the trowel at least 3 or 4 times with about half an hour interval between each finish.

viii) The final troweling should be done before the concrete has become too hard but at a time when sufficient pressure is required to make impression on the concrete surface.

ix) There should not be any line of metal float on the finished surface and care should be taken that no dry cement should be spread on the slurry that works out due to troweling, to dry it. It should dry naturally and it should be finished on the smooth surface as time goes.

x) Cure the surface by poundings or wet Hessian cloth spread over the surface for 15 days.

xi) The work of skirting should normally be carried out simultaneously with the floor work. A band of cement mortar 1:3(1 part cement and 3 parts sand) at the bottom of wall is called skirting. The normal height of skirting is about 100mm to 150mm. It is normally projected out from the wall plaster by about 6-8mm.The wall plaster up to the height of skirting is dismantled and the joints raked, before providing skirting. The junction with floor and the corners of skirting are rounded to a radius of about 25mm. This makes the junction of floor and wall waterproof and avoids vermin to make holes etc.

2.6 Variations in concrete floorings

i) The strips of glass/ aluminum/ brass are normally provided in floor where good aesthetics is of importance. This can be dispensed with in most of the floors for other than residential units, office buildings. In those cases, IPS has to be done in panels but temporary strips with wooden battens or iron angles can be used to contain the concrete in a panel. Here the concrete will be done in staggered panels at a time and not on the whole floor as described above. After about 24 hours the side supports can be removed, any damaged edges made good in 1:2 cement mortar, the same allowed to harden for about 24 hours and concrete poured and finished in balance panels following the same method, except fixing of iron angles or wooden battens, as described earlier.

ii) If glossy finish is required on the IPS floor, soon after leveling and

first troweling, neat cement slurry of creamy consistency, 2-3mm thick, is spread over the floor surface and allowed to soak into the concrete. The surface is smoothed and finished with steel float or trowel over this slurry. 3-4 rounds of troweling and final troweling is done in the same manner as earlier described. This gives a non-porous and glossy finish to the floor. It should however be not done for heavy duty floors, as the strength of the top layer is somewhat lower than the normal I.P.S. This requires additional about 2 kg of cement per sq.m. of floor area.

iii) Mechanical powered trowels can be used, which give a good level and smooth surface and the work can be speeded up significantly.

iv) Vacuum dewatering machines are available in market on sale, as well as on hire, which remove excess water from the top layer of wet concrete without removing the cement or sand particles. This is done soon after concreting, ramming or vibrating with screed vibrator, and leveling first round troweling, when the concrete is fresh. This not only increases the strength of the concrete but also increases the abrasion resistance of the floor. Shrinkage cracks are also minimized using this system.

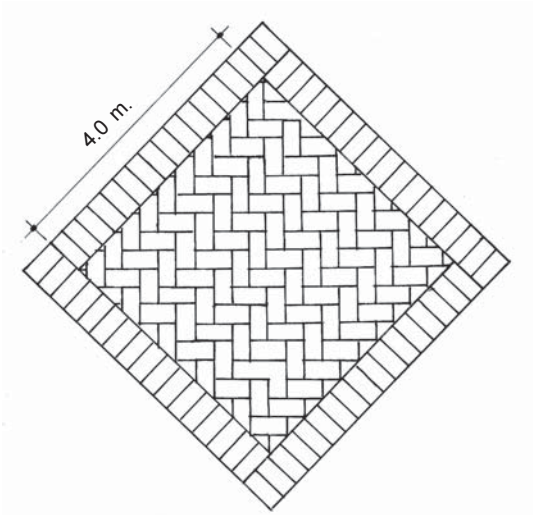
v) The concrete flooring suffers from a draw back that they are not stain proof and washing with water may also not remove the stains, as the surface, if not given glossy finish, is rough and requires vigorous sweeping. There are several concrete densifier and chemical hardeners being marketed by concrete chemical manufacturers, which claim to produce a highly polished look, increase the abrasion resistance and are chemically resistant and stain proof. Such treatments are done on industrial floorings and public utility areas.

vi) To avoid the shrinkage cracks and increasing the abrasion resistance of concrete floors, polyurethane fibres or polyesters fibres are also added to concrete, in small percentage. Such concretes are called ‘Ferro cement concrete’. The quantity of fibres to be added is prescribed by the manufacturers.

vii) The casting of concrete flooring in panels to avoid shrinkage cracks and work as expansion joints, though a necessity, yet is quite time consuming and slow process, specially when large areas like platform surfaces, circulating areas, pavements, industrial floorings etc are to be done. To overcome this time consuming activity, the concrete is laid continuously without construction joint and with the help of concrete cutting saw, the flooring is cut into panels of required size, when concrete is not fully hardened i.e. preferably within 7 days. The gap so created is filled with bitumen based sealants thereafter.

3.0 Brick flooring

3.1 Dry Brick flooring: The unimportant areas such as back yards, frontage of residential houses, temporary storage spaces, platforms of way side stations etc which can not be kept unpaved, to avoid dust, keep the surface level and to provide cleanable surface are given brick flooring. In this normally over baked bricks are used, but normal 2nd quality is also used. The ground is leveled, watered and rammed, before putting a layer of coarse sand in a layer of 50 mm thickness. The sand layer is watered and leveled. The bricks are laid on edge in panels of about 4.0 x 4.0m in a diagonal herring bone fashion separated by orthogonal row of one bricks. The gap between diagonal bricks and orthogonal bricks is filled with brick spalls and gap between all bricks is filled with coarse sand. The flooring has to be sprinkled with spray of water regularly to keep the dry sand settled.



DIAGONAL HERRING BONE FLOORING

3.2 Brick Paved Flooring: Pedestrian pathways, courtyards, parking lots for light vehicles, cycle stands, storage area for loose and bagged consignments etc are given brick paved *pucca* flooring. The base is prepared in the same way as above i.e. by leveling, watering and ramming. Instead of spreading sand, a base course of lime, *surkhi* and brick bat *koba* concrete layer of 75 mm thickness is provided over the leveled ground. The same is rammed and cured for about 7 days. Lime *surkhi* mortar in 1:4 proportion is prepared and the bricks on edge are set in 40mm thick mortar in the diagonal herring bone fashion of panel size 4.0mx4.0m, with orthogonal row of one brick. The gap between bricks is filled with sand or *surkhi* and flush pointing done on the joints. The proportion of pointing mortar is 1:4. The surface is cured with water spray by hose or throwing water with buckets. The brick *koba* concrete with lime and *surhki* can be replaced with cement concrete of 1:3:6 proportion.

4.0 TILES AND STONE FLOORING

4.1 Tools required for tiling/natural stones

- Trowel
- Wooden screed
- Mortar pans
- Aluminium box 3m long

- Spirit level
- Right angle
- Line string
- Small chisel and hammer
- Tile cutting machine
- Stone polishing machine
- 200 liter water drum
- Wooden mallet
- Level tube, 10m long
- Farma for dressing work

4.2 Site testing of material

4.2.1 Mosaic tiles

Detailed requirement of material is given in Chapter 2. Field tests be done as under,

i) Ensure that the tiles and skirting are of same lot.

ii) Stack the tiles lot wise if any difference.

iii) Corners of the mosaic tiles and skirting are sharp and unbroken.

iv) Check the diagonals and No variation in size is allowed.

v) Check the tile for its straightness and corners should be true with the help of right angle.

vi) Hand polish a mosaic tile and skirting from the received lot with the help of a polish stone or brick bat .Ensure that they match, also see that the chips are neatly and evenly distributed.

4.2.2 Marble, Kotah,Tandoor and granite polished stones

Detailed requirements of material are given in Chapter 2. Field tests be done as under,

i) Check the thickness and colour and quality as per specification.

ii) Check the entire marble lot by striking each piece with a metal piece it should give a clear ringing sound. Reject any cracked marble/granite slabs pieces.

iii) Check the size and diagonals and edges.

iv) The entire lot should be from same lot, having no difference in colour and appearance.

4.2.3 Ceramic tiles (Glazed or vitrified)

Details of requirement of material are given in Chapter 2. Field tests be done as under,

i) Check the brand name and thickness size and diagonals and edges as well as straightness of sample. There is marking on the box

whether the quality of tile is A class, B class or C class. Only A class should be accepted unless otherwise prescribed in specifications.

ii) Confirm the tile is free of any cracks or blemish.

iii) The corners should be square and the edges true and straight.

4.3 Preparatory work for laying tiles/Slabs

a) Surface preparation

i) Tiling work should be under taken after completion of Internal plaster of ceiling and walls and after fixing of door frames.

ii) For flooring work the surface should be clean and leveled. There should not be any cement mortar lumps on the slab or corners of room.

iii) There should be sufficient skirting margin from the final floor level; generally it should be 150 mm. If not plaster should be removed.

b) Taking Reference levels

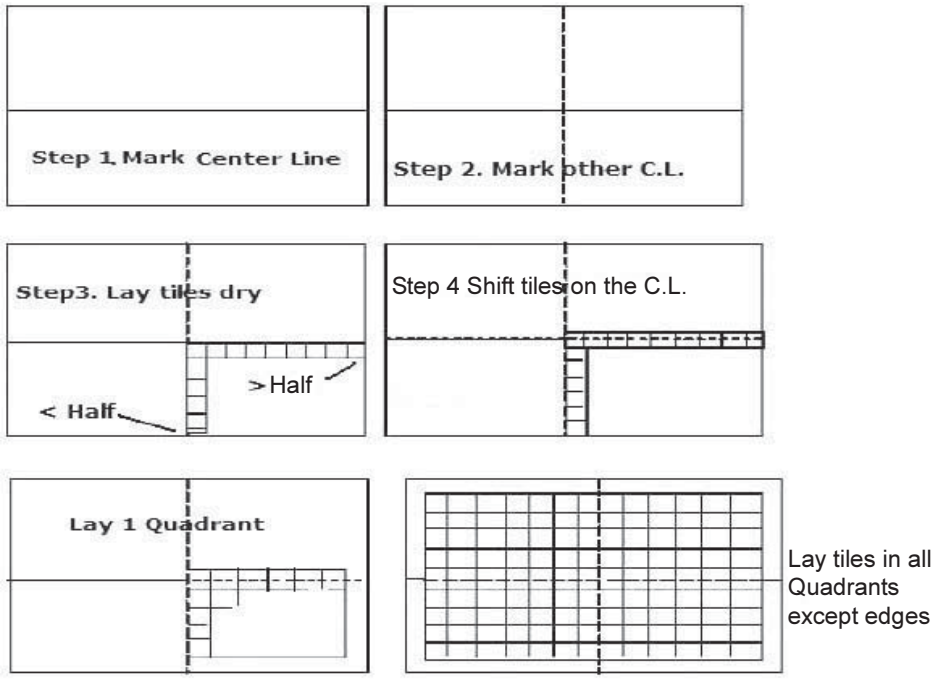
1. On the main door frame of the building, mark a fixed line generally 60 cm from floor level and transfer this fixed marking to all other door frames of all rooms with the help of level water tube, also transfer this level on the walls and mark horizontal line on all the walls, about 600 mm above final floor level, temporarily with the help of red colour or geru.
2. After taking level markings in all the rooms proceed for base work. Take *Thiyyas* below every level marking in the corners and with the help of these corner *thiyyas* take thiyyas in the centre of the room by holding a line dori diagonally in the room on top of corner thiyyas The centre to centre spacing between the two *thiyyas* should not exceed 2.0m
3. If any slope is to be given it should be given in these thiyyas only. Suppose in bathroom we have to give slope of 50 mm, in this case if thiyya near door is 600 mm below the level line then fix thiyyas at Nahani trap at 650 mm below level line and holding string on the top of the *thiyyas* in-between *thiyyas* can be fixed.

c) Setting of Right Angle

This is the most important part of preparation for flooring work and requires extreme caution.

i) Stretch a line *dori* dipped in chalk /lime powder between the center point of two parallel sides, preferably shorter sides. Snap the *dori*, this will mark the centre line of the floor and divide it in two parts. Next stretch the line *dori*, dipped in chalk or lime powder between the other parallel sides. Snap the *dori*; this will divide the floor in 4 parts as per step no. 1 and 2. Check the

angle subtended by the lines at the centre of floor. It should be right angle. If not make the necessary adjustment.



ii) Lay the tiles along one line in dry condition and see that the last tile near the wall is half or more than half. Care is taken that required gap of 1.5 -2.0 mm is kept between two tiles for grouting. Similarly check in other direction also.

iii) If the last tile in either direction is less than half length of tile, shift the first tile by half length away from center and again mark the center lines with changed position of line. This adjustment shall reduce the wastage to minimum, and provide an appealing layout. (Step 4 in Fig.)

4.4 Cement mortar bedding: Cement mortar bedding shall consist of one part of Portland cement and four parts of coarse sand by volume thoroughly mixed manually or by mechanical mixer. The quantity of water added shall be the minimum necessary to give sufficient plasticity and workability for laying. The mortar shall then be evenly spreaded over the base for at least two rows of tiles and about two meters length (between *2 thiyyas*) on central arms of one quadrant. The thickness of the bedding shall normally be not less than 12mm and not more than 40mm in any one place. The work should be progressed in one quadrant till reaching near the wall.

4.5 Laying tiles/slabs

i) a) The stone slabs should be set preferably on the initially set mortar bed i.e. within about 2-3 hours of placing the mortar. This is essential in case of polished natural stones like Kotah, Tandoor, Marble, Shahabad, Granite etc where the difference in depth may be significant and the slabs will require to be hammered by mallet at the corners to attain a level setting in the mortar. Here, after matching the level and line of the slab, the slab should be removed and any extra depression occurred should be made good by adding extra mortar.

b) However for Mosaic tiles, concrete tiles, ceramic tiles etc the depth difference is negligible and level surface can be achieved even in final set mortar layer, and the tiles should be laid within 24 hours of laying the bed mortar.

ii) Prepare the cement slurry of honey like consistency for about 3-4mm thickness. The cement consumption for slurry is approximately 4.0 Kg/ m^2. Spread the cement slurry on the mortar bed evenly, over as much area as could be covered with tiles in half an hour.

iii) The work should proceed from center towards the wall, taking each quadrant at a time. The first quadrant to be taken is the farthest from door. If more than one mason are working, work can be taken up in all the quadrants simultaneously also, after the center lines are fixed by the senior mason. After deciding the laying of tiles and marking the center lines, lay the mortar bedding etc.

iv) a) Match all the four corners of the stone slabs on the previously marked location, properly with the help of wooden mallet and keep the joints as close as possible and in straight lines. The level of the tiles is to be checked and maintained using a straight edge or a screed board about 3 m long.

b) For manufactured tiles, there is no need to dry set it as in case of slabs. Match the 4 corners of tile on the mortar bed after spreading slurry evenly, with the help of mallet and keep joints as close as possible, only leaving some gap about 1.5 mm, for grouting. The level of the tiles is to be checked and maintained using a straight edge or a screed board about 3 m long. It is moved with a sawing action, the two ends resting on guides set at correct height.

v) It is to be ensured that even the mason and workers should not step on the set tile for at least 6 hours. Even after 6 hrs. the workers should if required, move on wooden boards kept on the finished work. The mason and workmen should work from the area where tiling is yet to be done. Since the gap between the last tiles near the wall will

be less than 1 tile, it is a good practice to leave space for movement of workers and fix the last tile only the next day along with fixing the cut pieces to close the gap with the wall.

vi) Next day fill the gap or joints between tiles with cement slurry and colour pigment, if required.

vii) After completing the tiling work of the floor, check the overall level. Any unevenness can be rectified with a wooden mallet.

viii) The gaps between walls and the floor are fixed with cut pieces of the mosaic tiles. These cut pieces must be made with a tile cutting machine to avoid wastage of tiles, as also to get proper smooth cut edge and should not be less than half of tile.

ix) Clean the floor and do not allow any body to enter the floor for at least 24 hour.

xi) Then cure this flooring and skirting for 14 days. After the first 7 days of curing the workmen etc can be allowed entry but floor should be used only after 14 days.

xi) Wherever big areas of floor are to be tiled, the level of the central portion of the floor shall be kept about 10mm higher than the level marked at the walls unless specified otherwise. This is normally done to avoid the optical illusion of a depression in the central portion of the tiled hall.

4.6 Skirting fixing

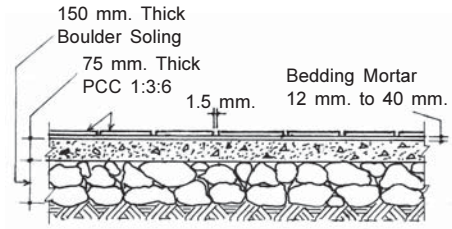
After mosaic tile joint filling start fixing the skirting work as follow

i) Wooden *pharma* as shown in figure below should be prepared out of wooden batten. With the help of this wooden *pharma* skirting tile is fixed projecting only 8mm from the wall plaster.

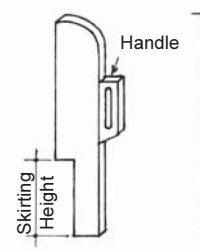
ii) Fix skirting tiles at two ends of the wall with *pharma*, projecting only 8mm outside the wall plaster

iii) Then between the skirting tiles are fixed with the help of line *dori* and wooden *pharma*, Plaster of the long walls may differ slightly in line.

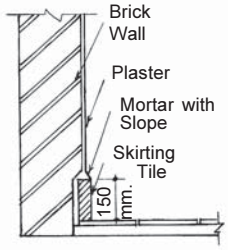
iv) At the column positions skirting needs to be cut/sliced in



TYPICAL X-SECTION OF FLOORING & ITS BASE



WOODEN PHARMA



DETAILS OF SKIRTING

vertical direction.

vi) Ensure that the skirting lines are perpendicular to the mosaic tile line.

vii) The floors where slope has been provided for easy drainage of water, the height difference at the walls should be accounted for in the skirting, and the wall tiles if required should follow a horizontal line.

4.7 Wall Tiles

i) The preparation for work is similar to fixing tiles on floor. The tiles should be checked for the quality, corners being intact, thickness should be within permissible limits, diagonal being same, colour being uniform and no defects visible etc.

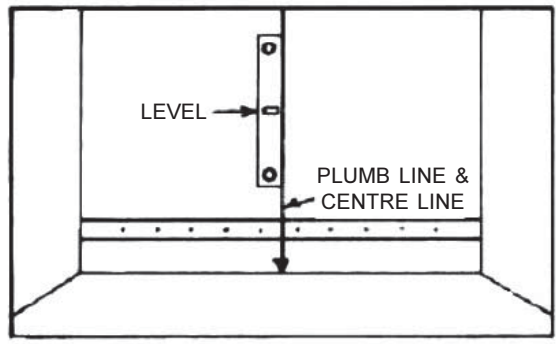
ii) Apply base course about 15mm thick of cement mortar 1:4 on the wall. Level it with wooden float and check with aluminium square tube. Roughen the surface with wire brush. Let it dry for about 6 Hrs

iii) The tiles should be soaked in water for at least 3-4 hrs. prior to use.

iv) The wall should be clean and free of any loose material. If it is an old wall with plaster, the plaster should be removed and wall is cleaned and soaked with water.

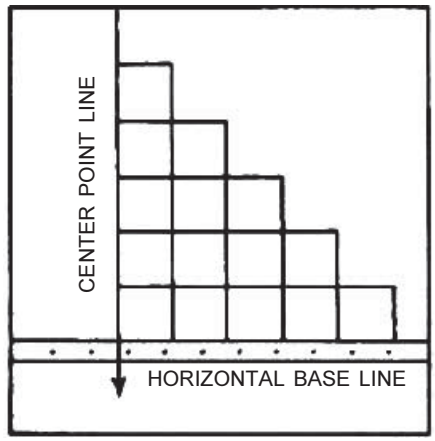
v) Transfer the level about 600mm above the floor level by means of level tube. Normally skirting is not provided in bath rooms. Transfer the level line to exactly 1 tile above the floor. If any slope is in the floor, then this has to be made good in the lowest tile, and accordingly the level line be adjusted.

vi) Fixing the center line of the wall is the next most important item. Mark the center of the width of the wall. With the help of plumb bob, draw a vertical line passing through the center point. Place the tiles on the floor from this point towards one edge, keeping a gap of about 2mm between each. If the gap at the end is less than half a tile, move the central tile by half away from center. This would provide, more than half width tile at the edges. This will minimize the wastage and moreover the layout will be more attractive.



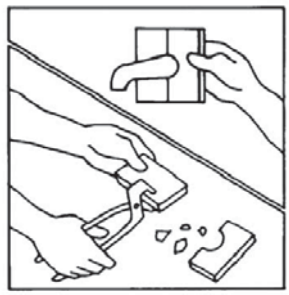
vii) The lowest tile line leaving the first bottommost tile, has been marked. The fixing has to be started from this line onwards. Many masons prefer to nail a batten below this line, so that the tiles do not slip and the line is clearly established.

viii) Cement slurry of honey like consistency is prepared (Appx.4 Kg of cement is required per sq.m). The slurry is applied on the wall and also on tiles and the tile is pressed on the wall, starting from center toward the edge, in a diagonal direction as shown in fig. below, leaving the last piece of tile. Care is taken to leave a gap of 1.5 to 2 mm between each tile, so as to pass water to the mortar for curing.



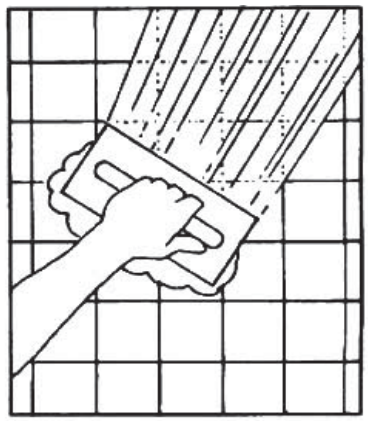
ix) After all tiles have been laid, wipe the slurry to any unoccupied space and check for level of surface visually. If any unevenness is noticed bring it to level by gently hammering by mallet at the corners. Allow about 6 Hrs. for drying. Fix the end tiles in the vacant space.

x) The tile around any pipe or tap should be provided cutting the tile in two pieces and making half circle cuts by pincers, as shown in figure.



xi) Let the mortar harden, while curing be started care being taken not to disturb the tiles, for about 24 Hrs.

xii) Fill grout of 1:2 rich mortar with white cement in the joints. It is done by taking the grout mixture over rubber edged trowel and rubbing diagonally across the wall, filling the gaps on the way, as shown in figure.



xiii) Wipe any excess grout by sponge or thick cloth, the extra grout from joint can be removed. Polish the surface by rubbing with a soft cloth. The joints should be sealed with a Silicon based sealant, for better looks and grout not showing during use.

4.8 Grinding and Polishing of tiles

4.8.1 It should be borne in mind that the grinding and polishing is done to bring out the grains in mosaic/ terrazzo tiles and giving extra shine to the

tiles and not a means to correct the unevenly placed tiles. The ceramic tiles glazed or vitrified, plain cement or coloured tiles, chequered tiles are not to be grinded and special care has to be taken that the tiles are laid perfectly level by hammering by mallet at four corners.

For other manufactured tiles and natural stone tiles, grinding may be done either by hand or by machine. The manual grinding of tiles may be commenced not earlier than 2 days from time of completion of laying and not less than 7 days for machine grinding. The following consideration has to be made while planning to grind the tiles,

a. Mosaic/ terrazzo tiles are supplied, duly polished and have a very thin layer of wearing coat and further grinding is likely to result in losing the grain and the wearing coat. It is therefore very essential that tiles are laid in perfect level and without any ups and downs.

b. All the stone tiles, like Kotah and marble also come with pre-polish and do not require any rough grinding. The grinding should be necessary only to give additional shine and to remove the scratch marks etc. that occur during handling. There might be minor level difference in neighboring tiles which has been left at the time of laying tiles, can also be removed using finer Corborundam block.

c. The Granite tiles are a special item, and the polish given in the factory can not be matched by any level of grinding at site. It is therefore of utmost importance that these tiles are laid fully perfect, requiring no need for further grinding and polish. If however, this can not be done some grinding and polishing at site will be inevitable.

d. It should be remembered that requirement of rough grinding on tiles is a proof of improper laying.

4.8.2 i) If the grains in mosaic/ terrazzo tiles are not visible or the marble, Kotah , Shahabad stone tiles are not pre polished, the first round of grinding should be with 48-60 No. Corborundum stone, however where this is not the case 48-60 No. stone should not be used. And subsequent grindings with finer stones are as given below.

ii) Where the grinding is done by machine, and the unevenness is more than 1mm, the first grinding shall be done with the machine fitted with special rapid cutting corborundum blocks of medium grade (No,120) till the floor is smooth within a unevenness of fraction of a mm. The surface shall be well watered during the course of grinding.

iii) After the first grinding, the surface shall be thoroughly washed to remove all grinding mud. It shall then be covered with a grout of cement. Coloring matter should also be added in case of mosaic/ terrazzo tiles, in the original proportion in order to fill the pin holes

that may appear after grinding. The surface shall then be allowed to dry for 24 hours and wet cured for 4 days.

iv) The second grinding shall be done with machine fitted with fine grade corborundum stone (No.320), the surface shall be again cleaned and repaired and allowed to cure again for about 4 days.

v) The final grinding shall be done with the machine fitted with fine grade corborundum blocks (No. 400) to get an even and smooth surface without pinholes.

vi) Where machine grinding is not feasible or possible, such as near the walls, hand grinding shall be done in the same manner for machine grinding except that corborundum stone of coarse grade No. 60 shall be used for first rubbing, stone of medium grade (No.80) for second rubbing and fine grade(N0,120) for final rubbing.

vii) After final grinding, whether by machine or hand the surface shall be washed clean and rubbed hard with felt or Namdah block (Pad of woolen rags) and slightly moistened oxalic acid powder. Generally 5 grams of oxalic acid powder per Sq.M. of the surface shall be adequate.

viii) The floor shall then be covered with oil free dry saw dust which shall be removed after all constructional work such as painting, distempering other works.

4.8.3 However, with a good workmanship there shall be no level difference and hence no need for grinding the tiles with Corborundum block of size 120 No. and grinding should only be done using Corborundum block of 320 No. and 400 No. for giving extra shine to the floor.

5.0 Interlocking Paver Blocks:

Proper installation of the Paver blocks results in a pavement that is firm, yet flexible. The joints between pavers allow the walkway, driveway, etc. to move without cracking. In addition, they can be easily removed to allow for repairs or access to utilities. Unlike asphalt, concrete, pavers are basically maintenance-free and do not need to be regularly sealed or replaced.

When installed properly, the combination of the pavers, bedding sand, edge restraint and joint sand causes them to bind, allowing them to work as a unified, flexible pavement.

5.1 Steps to install Paver Block flooring:

i) The formation on which the pavers are to be laid must be firm and well compacted to 95% Proctor density. If it is either poor formation or not compacted, a minimum of 150-200 mm thick WBM for walkways and 300-450 mm thick for vehicular circulating areas and vehicle driveways should be laid. For each lift, of about 150 mm, make at

least two passes in the vibratory mode then at least two in the static mode with a minimum 10 T vibratory roller until there is no visible movement of the WBM layer.

ii) The sand bed should be a maximum of 50 mm thick. One ton of sand will cover about 10 sq. m area with 50 mm thick layer of sand. One'll also need some additional sand (about 5%) for the joints between the pavers. The gradation of sand should be as under,

a) The bedding sand shall consist of a clean well graded sand passing through 4.75mm sieve and suitable for concrete manufacture. The bedding sand should be from either a single source or blended to achieve the following grading.

Sieve Size	%age passing
9.52 mm	100
4.75	95-100
2.36	80-100
1.18	50-100
600 micron	25-60
300 micron	10-30
150 micron	5-15
75 micron	0- 10

b) The sand shall be of uniform moisture content and within 4% - 8% by weight when spread and shall be protected against rain when stockpiled prior to spreading. Saturated sand shall not be used.

c) The spread sand shall be carefully maintained in a loose dry condition and protected against pre-compaction both prior to and following screeding.

d) Sand should contain not more than 3% by weight of clay and silt & the materials shall be free from deleterious salts or contaminants.

iii) Any pre-compacted sand or screeded sand left overnight shall be loosened before further laying of paving units take place.

Paving units shall be placed on the uncompacted screeded sand bed to the nominated laying pattern, care being taken to maintain the specified bond throughout the job. The first row shall be located next to an edge restraint. Specially manufactured edge paving units are permitted or edge units may be cut using a power saw, a mechanical or hydraulic guillotine, bolster or other approved cutting machine. Cut pavers, subject to tyre traffic shall be no smaller than 1/3 of a whole unit.

iv) Paving units shall be placed to achieve gaps nominally 2 to 3mm wide

between adjacent paving joints. No joint shall be less than 1.5 mm or more than 4mm.

v) Frequent use of string lines shall be used to check alignment. In this regard, the "laying face" shall be checked at least every two metres as the face proceeds. Should the face become out of alignment, it must be corrected prior to initial compaction and before further laying job is proceeded with.

vi) Remove excess sand on the surface by sweeping pavers clean.

vii) Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 1800 kg (18 kN) centrifugal compaction force. This will require at least two passes with the plate compactor.

viii) Do not compact within 1.0 m of the unrestrained edges of the paving units.

ix) Apply additional sand to the openings and joints, filling them completely. Remove excess aggregate by sweeping then compact the pavers. This will require at least two passes with the plate compactor. If the gap between the pavers is not fully filled, more sand should be filled in the joints and the surface vibrated.

x) All pavers within 1.0 m of the laying face must be left fully compacted at the completion of each day.

xi) To infill spaces between 25mm and 50mm wide, a concrete having screened sand, coarse aggregate mix and strength of 30 N/Sq mm shall be used. Within such mix the nominal aggregate size shall not exceed one third the smallest dimension of the infill spaces. For smaller spaces dry packed mortar shall be used.

xii) The final surface tolerance of compacted pavers shall not deviate more than ±10 mm under a 3 m long straightedge.

xiii) The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.

5.1.1 Field Quality Checks

i) After sweeping the surface clean, check final elevations for conformance to the drawings.

ii) Lippage: No greater than 3 mm difference in height between adjacent pavers.

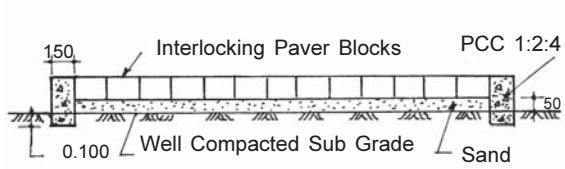
Note: The minimum slope of the finished pavement surface should be 1 in 100. The surface of the pavers may be 3 to 6 mm.above the final elevations after compaction. This helps compensate for possible minor settling normal to pavement, while in service.

iii) The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.

5.2 Edge Restraint

Edge restraints need to be sufficiently robust to withstand override by the anticipated traffic, to withstand thermal expansion and to prevent loss of the laying course material from beneath the surface course. Paver blocks on traffic pavements tend to move sideways and forward due to breaking and maneuvering of vehicles.The tendency to move sideways has to be counteracted at the edges by special edge blocks and kerbs. The edge restraint should present a vertical face down to the level of the underside of the laying course. Laying of PCC with 1:2:4 along the open edge as shown in fig will serve the purpose of edge restraint.

The surface course should not be vibrated until the edge restraint, together with any bedding or concrete launching, has gained sufficient strength. It is essential that edge restraints are adequately secured.

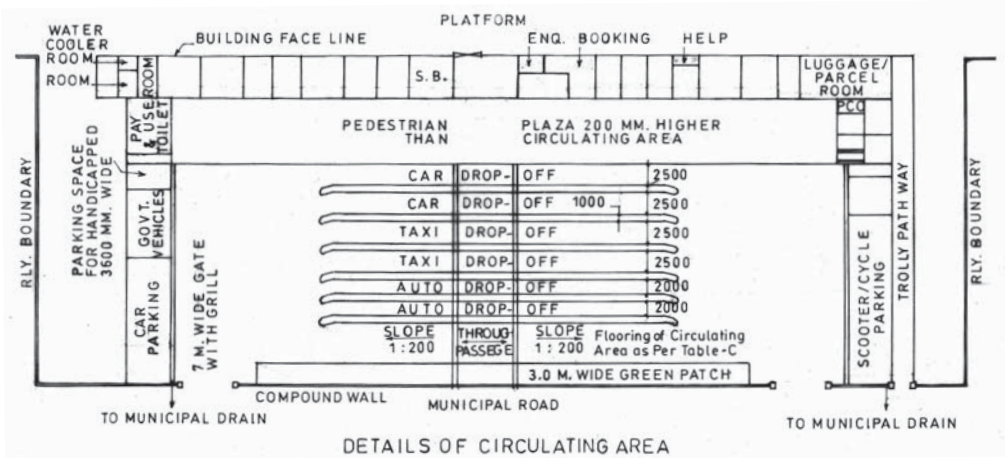


EDGE-RESTRAINT OF PAVING BLOCKS

6.0 Guide lines for flooring for different types of work

To meet the expectations of passengers and commuters in this regard and generally the funds required for improving these is not a constraint. The attempt has therefore to be to provide materials and construction which is long lasting and pleasing to the eyes. Use of modern materials and construction techniques therefore gain importance.The classification of stations are given in Appendix.

A typical plan of station building is shown and some guidelines for their flooring are as follows.



DETAILS OF CIRCULATING AREA

6.1 Pedestrian Plaza: The 6m to 9m strip of land for adequate width in front of station entrance should be earmarked as pedestrian plaza, i.e. in this area no vehicles or heavy trollies like Parcel trollies, should be allowed. This can be increased up to 15m on very important stations, depending on the no. of passengers being dealt by the station during rush hour. This should be achieved by raising the level of this strip of land about 200mm higher than the circulation area. Providing fences or railing to demarcate this area has to be avoided at all costs. This should be provided with coloured paver blocks (Reflective type) in A,B & C classes of stations. This will help in easy and quick patch repair to heavy wear and tear. No stalls structures should be allowed to be erected in this area.

6.2 Trolley Pathway: A trolley pathway 1800-2400mm wide should be provided at the margin of the circulating area and pedestrian plaza on either of the sides of the area in A,B,.and C classes of station right up to the entry point. Entry of trolleys to the platform preferably should not be same as that for passengers. A suitable ramp be provided for the trolley pathway in the pedestrian plaza reach of movement of trollies and wheelchairs etc.This area should be paved with inter-locking paver blocks(Non reflective type)

6.3 Cycle/Motor cycle parking areas: Black topped surfaces, if not rolled properly with a heavy roller tend to deteriorate very fast. Most of the time the cycles/Scooter stands are in confined /isolated locations where proper rolling can't be achieved. Therefore black topping such areas should be avoided, unless it can be ensured that the same can be done without any restrictions. This area should be provided with "Brick on edge" or properly set flag stones, if locally available. A slope of minimum 1 in 100 should be ensured for drainage. If the bricks/flagstone of proper quality are not available locally,IPS concrete of 100mm thickness and M30 grade, over compacted sub grade can be provided.

6.4 Circulating area

1. **A, B and C class stations:** All important stations i.e. A & B class stations should be provided with rigid pavement in RCC as per Highway standards (Medium loading) Concrete of M30 grade with 200 mm thickness case in panels of area not exceeding 6 sq.m duly compacted by needle and screed vibrators and mechanically toweled shall be good enough for all such areas. Proper slope of the pavement along with open saucer drains should be provided. Adequate number of service ducts, minimum two no of dimensions 600 mm wide x 450mm deep should be provided at the margin of the circulating area right up to the entrance to carry service cables, water pipelines etc.These should be kept filled sand and covered with precast RCC slabs (to carry vehicular load) duly flushed at the road level. Suitable underground sewerage pipe should also be provided at

the time of construction at appropriate places, it the same cannot be provided out side the circulating area.

The various usage areas, such as trolley pathway, pedestrian plaza, limit of circulating area, parking of vehicles, cycles/scooter stand, drop off area, information kiosks etc. should be demarcated by use of kerb stones/blocks and painted lines. The use of fencing /compound wall should be restricted only to demarcate the outside land with railway land.

2. **D and E class stations: The** comparatively less important stations i.e. D & E class stations should be provided with flexible pavement i.e. in bituminous asphalt. The other item of drainage, service ducts, sewage pipes shall be applicable as per site conditions.

6.5 Platform surface: The platform surface should not only be amenable to easy cleaning by the methods adopted but also withstand all the rough and intended use to which it is subjected to by the passengers and the parcel loaders etc. A,B and home platforms of important suburban stations generally will be required to be cleaned and washed with machines, and it is therefore imperative that the surface of platforms should not be only hard, scratch proof but also smooth/ polished. It is to also keep in mind that the smooth/polished surfaces tend to become slippery, when wet. It is therefore necessary that the portion of the PF surface. which is either not covered with shelter or for any other reason expected to be wet by showers should not be made polished smooth. The area of PF surface near the coping stone, the two ends of the PF , where the shelter terminates, areas just in front of FOB landings also tend to be wet during monsoon period, due to wet shoes of the passengers entering the platform from outside road etc are such locations.

The time tested IPS concrete flooring of 50 mm thickness with non slipping pattern provided over well rammed/ consolidated sub grade and base concrete is the cheapest and best flooring system for PF surfaces/FOB surfaces. It however suffers from the drawback that minimum time of 7-10 days of curing is required.

There has been several advancements in technology and new type of flooring materials are now available for use. These surfacing materials are having claim for durability apart from meeting the present day requirement of high level of cleanliness.

Kota stone slabs duly polished are commonly used on platform surfaces under covered PF shelter, which meets most of the requirements for PF, however these also get damaged by movement of parcel trollies/vendor trollies specially if the wheels of the trollies are not tyred.The kota stone slabs also do not offer good resistance to impact load and in the parcel loading/unloading areas tend to break and get damaged quite fast. As per

Rlys standing instructions, trollies without rubber tyres should not be allowed to ply on the PF surfaces.

The loading and unloading of parcel areas are generally on the two ends of the platforms in front of SLR's .Therefore the 75 m area of PF length on both sides should be made with "Hardonite" flooring. Remaining uncovered portion of the platform should be provided with mastic asphalt or IPS flooring.

Platform surfaces on other C class stations and D class stations can be provided with time tested mastic asphalt flooring which provides non – slippery surface.

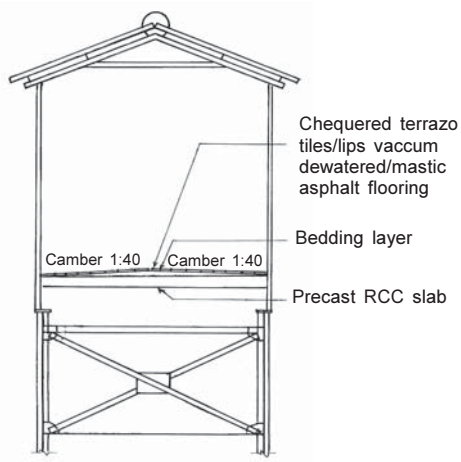
Platform on E class stations should be provided with either "brick on edge" or flag stone flooring depending upon the local availability of good material.

F class stations with scanty traffic are not subjected to much wear and tear and therefore need to be provided with sufficiently leveled surface only that does not require much of maintenance efforts. At the same time surfaces provided with either moorum or with local earth allow vegetation to grow so a layer of 100mm thick light rolled quarry should therefore generally be provided in the uncovered areas.

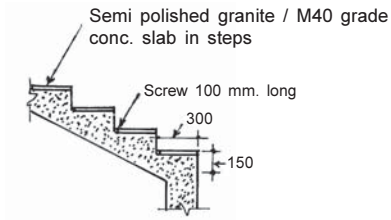
6.6 Steps on the landing of FOB's

The steps on the FOB landings are one of the most used surfaces and tend to wear out vary fast. Good rich concrete properly compacted and with non slipping pattern provided with a nosing angle is a good system of flooring, but this also suffers from the draw back of blocking the FOB for no. of days for construction and curing. On these locations precast concrete slabs should be used. Monolithic mosaic steps which are precast slabs having wear resistant top layer, is a suitable material for reasonably heavy traffic locations and hence should be provided on A,B and D class stations.

A, B and D class stations, on suburban stations where the FOBs are used by large no. passengers, Granite slabs with non skid grooves be adopted.



DETAILS OF FLOORING ON FOB



DETAILS OF STEPS FOR FOB

In order to streamline and standardize the system for adoption of various items following guide lines are useful.

Appendix

Categories of stations for provision of passenger Amenities.

Stations shall be classified in the following categories.

Category A:

Non –suburban stations with an annual passenger earnings of Rs. 6 .0 Crores and above.

Category B:

1. Non – suburban stations with an annual passenger earnings between Rs. 3.0 crores to Rs. 6.0 crores.
2. Stations of Tourist importance or an important junction station (To be decided by GM)

Category C:

All suburban stations.

Category D:

Non-suburban stations with passenger earnings between Rs.1.0 and 3.0 crores.

Category E:

Non-suburban stations with earnings less than Rs. 1.0 Crore.

Category F:

Halts

CHAPTER 7

CEMENT CONCRETE

1.0 Introduction

Cement concrete is very widely used in construction of small and big structures. Concrete can be moulded in any shape and has good strength in compression. Concrete designed properly, mixed properly and placed and vibrated properly cured properly, gives a near homogeneous material, which not only has capacity to take load, resist all kinds of environmental attacks, requires no maintenance and last very long. The use of steel reinforcement bars in concrete to take care of the tensile forces makes the material versatile and a favourite of Engineers. When steel reinforcement is used in Plain cement concrete (P.C.C.) to resist the tension in the structure, the material is termed as Reinforced Cement Concrete or R.C.C. Concrete is prepared in two different ways

a) Volumetric mix/Nominal mix and

b) Weigh batching mix/Design mix .

1.1 Nominal concrete is mixed in volumetric proportion of cement, sand and aggregate specified like 1:1:2, 1:1.5:3, 1:2;4, 1;3;6; etc. i.e. volumetric proportion of cement , sand and coarse aggregate. This proportioning is based on a conventional system, where the ratio of coarse aggregate to sand is always 1:2 by volume and there is no limit for adding water. The latest code, namely I.S.456-2000 gives the freedom to the Engineer to vary the proportion of coarse aggregate and sand within limit of 1:1.5 to 1:2.5 keeping the total quantity (Weight) of Coarse aggregate + Sand as per the quantity given in the code. Further, amount of water to be added to different grades of concrete is also specified, which is as below,

Crushing Strength of concrete (N/mm2)	Equivalent vol. proportion as per convention	Quantity of Aggregate (C.A.+Sand)	Quantity of Cement (Kg)	Water to be added (Liters)
5.0	1:5:10	800 kg	50 or(30 liters)	60
7.5	1:4:8	625 kg	50 or (30 lts)	45
10.0	1:3:6	480 kg	50 or (30 lts)	34
15.0	1:2:4	330 kg	50 or (30 lts)	32
20.0	1:1.5:3	250 kg	50 or (30 lts)	30

It is to be noted that bulk density of sand and coarse aggregate is significantly different in different parts of country. In Western India like Mumbai generally, bulk density of surface dry but saturated sand= 1.850 and coarse aggregate= 1.900. The weight of total sand + C.A, per bag of cement(1 bag of cement weighs 50 Kg or vol.=0.035 cum), based on conventional method of volume mixing will be much different than the weight of aggregate given by I.S.code.

Case 1: For 1:2:4 concrete against 330 Kg of aggregate required to be added as per I.S. code, the quantity of aggregate required to be added as per volume mixing in Mumbai=0.035x2x1850+0.035x4x1900= 395 Kg. Thus, when 330 kg of aggregate is only added as per IS code, the concrete will be much richer than 1:2:4.

Case 2: Similarly, in poorly graded aggregates as also some other parts of country, the density of natural sand and C.A. may be less and the volume of aggregate required may be much lower and may give leaner concrete than 1:2:4.

It is also accepted that the strength of low grade concrete such as prepared by nominal mix, depend on the strength of the mortar surrounding the coarse aggregate, so with stronger stone aggregate, the strength of concrete is not expected to be high. Based on I.S. code, due to different specific gravities of sand and C.A. in different parts of country, the cement requirement for producing the same strength concrete will be different. Hence, the practice is to produce nominal mix concrete, by following the conventional volumetric system only. However, the ratio of sand to coarse aggregate can be changed in the range of 1:2.5 to 1:1.5, depending on the requirements and water quantity is added only as per code. It is seen that the low grade concretes 1:2:4, 1:3:6 etc. have a better workability, if some of the coarse aggregate is replaced with sand.

The proper proportioning can be done by an experienced Engineer after considering the quality of sand and coarse aggregates. A less experienced Engineer should adopt a ratio of 1:2 only for sand and coarse aggregate.

1.2 Design Mix concrete is in which the weight proportions of cement , sand, aggregate and also water are determined by tests in laboratory and the proportions depend upon the grading and size of coarse and fine aggregate, grade of cement used , level of quality control at site etc. The design mixes are designated as M10, M15, M20,etc. The figure following M denotes the strength of concrete in MPa or Newtons/mm^2. Controlled concretes give higher strengths by about 25 percent for the same proportions of ingredients. Concrete consolidated by vibrations give still higher strengths by about 10 percent than when consolidated by hand.

1.2.1 For most of the bigger works Design mix concrete only has to be used, however for small piece meal works nominal concrete is still being used. It is however mandatory to adopt Design mix for all concretes of strengths greater than 20 MPa.

1.2.3 Compressive strength of concrete is tested by 15 x15x15 cm cubes cast from concrete, after 28 days. Compressive strength of concrete is assessed by the crushing to destruction of the test cubes which require the use of compression testing machine and is usually carried out in laboratory.

1.2.4 Strength of concrete increases with age. For ordinary Portland cement concrete strength at 3 days is about 1/3rd of the strength at 28 days, Strength at 7 days is 2/3rd of the strength at 28 days and strength after one year is much greater than the strength at 28 days. Strength at 28 days is taken as the standard strength for design purpose.

2.0 Raw Material used in PCC and RCC

- Cement
- Fine aggregate/Sand
- Coarse aggregate
- Water
- Shuttering/Centering/Form work
- Steel Reinforcement bars
- Admixtures if required

2.1 Cement

Ordinary Portland cement is the most widely used binder for making concrete. For high grade concretes high strength cements, OPC of grade 43 and 53 are used . Pozollona Portland cement and Ground Granulated Blast Furnace Slag Portland cements (GGBFS) are also permitted for use in PCC and RCC. All cement should be got tested in reputed test house when procured in bulk, in addition to the manufacturers test certificate accompanied with the consignment. For big works piecemeal supply from dealers should be prohibited, however for small works it can not be avoided. In addition to lab tests for a consignment, field tests should be carried out by the Junior Engineer as described in Chapter 2.

2.1.1 Depending upon the environmental exposure conditions of the structure, i.e. mild, moderate, severe, very severe and extreme, minimum quantity of cement and the grade of concrete has to be used. The exposure conditions are defined in I.S.456-2000. The specifications are as under,

S. No.	Exposure condition	Plain cement concrete			Reinforced cement concrete		
		Minim. Cement (Kg/m^3)	Maxim. W/C ratio	Minim. Grade of concrete	Minim. Cement (Kg/m^3)	Maxim. W/C ratio	Minim. Grade of concrete
1	Mild	220	0.60	-	300	0.55	M20
2	Moderate	240	0.60	M15	300	0.50	M25
3	Severe	250	0.50	M20	320	0.45	M30
4	Very Severe	260	0.45	M20	340	0.45	M35
5	Extreme	280	0.40	M25	360	0.40	M40

2.2 Coarse aggregate

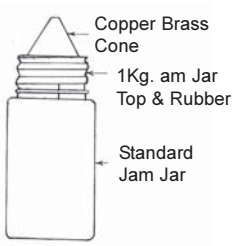
Normally stone aggregate is used as coarse aggregate in concrete. Crushed Stones which pass through I.S. sieve of opening of size 80mm and are entirely retained on 4.75mm I.S.Sieve are known as coarse aggregates. The maximum size of aggregate to be used in concrete depends upon several factors, such as dimensions of the structure, the steel reinforcement details i.e. the space between reinforcement bars to pass the aggregate of concrete , the grade of concrete. 20mm and 10 mm size coarse aggregates are normally used in RCC work. For mass concrete 40 mm size can be used.

2.2.1 The strength of concrete can not theoretically be more than the crushing strength of stone aggregate used in it and it is therefore important that proper stone aggregate is used in concrete. The properties of stone aggregate and the tests required to be done at site are described in Chapter 2.

2.2.2 The volume of concrete is mainly due to the coarse aggregate, and fine aggregate contribute to volume very marginally. It is very essential that for compact and dense concrete the coarse aggregate should be well graded. For High grade concretes therefore coarse aggregates of two sizes v.i.z. 20 mm down and 10 mm down (or 10mm down and 6mm down in case of maximum size of aggregate is 10 mm) are mixed in a pre-decided proportion.

2.2.3 For Weigh-Batching Concrete, the proportioning of various components of concrete have to be mixed in exact proportion. The coarse aggregate should be fully saturated but surface dry while mixing in concrete. The aggregate should be sprinkled with water for about 12 hours prior to mixing to ensure that it is not dry inside. But it may not always be possible to ensure that it is surface dry in the field. It is therefore necessary to assess the amount of surface water in coarse aggregate before use in concrete. This water has to be reduced from the total requirement of water for mixing concrete.

Pycnometer is used to determine the surface water in the aggregate. Pycnometer is a small glass flask like container, which can be sealed at mouth. If, 's' is the specific gravity of the saturated but surface dry aggregate, Wb is the weight of pycnometer full of water, Wa is the weight of moist aggregate sample and W is the weight of pycnometer with the sample and topped up by water, the moisture content of aggregate is:



PYCNOMETER

$$100x\{[Wa/(W-Wb)]x[(s-1)/s]-1\}$$

It is however noticed that the maximum water content of coarse aggregate rarely will increase above 1% of weight of aggregate, except in the bottom layer of 300mm. It is therefore , generally the practice not to use the bottom 300mm layer of stack and reduce addition of water to concrete equal to 1% weight of coarse aggregate, when the aggregate is surface wet.

2.3 Fine Aggregates

Naturally occurring Sand is generally used as the fine aggregate in concrete. However, the fine aggregate is also manufactured by crushing stone in a crusher wherever natural sand is not available economically. Fine aggregate mixed with cement provides workability to the mix, and fills voids between coarse aggregate, for producing compact and dense concrete. Particles passing through 4.75mm sieve and retained on 75 micron I.S.sieve are called sand. For design mix, the sand gradation has been divided in 4 zones and it should fall in either of 4 zones, if required by blending with crushed sand or sands of two sources. However for nominal mix, the gradation is not given so much importance and all sands within 4.75mm to 75 micron size are used. It is however necessary to ensure that the sand contains at least 10% of fines below 150 micron and 20% below 600 micron size.

2.3.1 The properties and the tests to be done for accepting sand for concrete are given in Chapter 2. It is to note that in the volumetric mixing of concrete, the bulking of sand has to be assessed accurately and the proportion of sand increased accordingly. Simultaneously the addition of water in the concrete has to be reduced by the moisture content of sand, this can be assessed by the Pycnometer test as described for coarse aggregates.

2.4 Water

Water used for mixing of concrete should be clean, free of oil, alkalis, salts, sugar organic materials etc. In general water that is fit for drinking is good for concrete. Sea water should not be used in concreting. It has been clarified in Chapter 2, that the quantity of water in concrete should be kept minimum, required for chemical reaction of cement with water known as,

hydration of cement, and for providing lubrication to concrete only and excess water causes porosity in concrete and resulting in low strength as well as reduced resistance in concrete to fight the environmental factors, such as carbonation of concrete by CO_2, chloride penetration, sulphate attack etc.

2.4.1 The workability of concrete increases as the water content of the mix is increased. Water lubricates the concrete mixture, but increase in water content would cause a decrease in strength. Excess water in concrete weakens the concrete, produces shrinkage cracks, and decrease density. Generally speaking, lower the water content, stronger the concrete. But the quantity of water must be sufficient to produce a workable concrete required for the particular method of compaction to be adopted. The best mix is one which gives maximum workability with minimum amount of water.

2.4.2 The water cement ratio (by weight of water to cement) required for full hydration of cement, which gives the cementing property to cement, is about 0.26 only. If W/C ratio is less than 0.26, complete hydration of cement can not occur. For nominal mixes the following proportions are stipulated for concretes of various strengths.

Grade of Concrete	Quantity of dry aggregates (Coarse+Fine) in Kg./ 50 Kg of cement (Maxim)	Proportion of fine aggregate to coarse aggregate by weight	Quantity of water (liters) per 50 Kg of cement (Maximum)
M5	800	Generally 1:2, subject to a upper limit of 1:1.5 and lower limit of 1:2.5	60
M7.5	625	-do-	45
M10	480	-do-	34
M15	330	-do-	32
M20	250	-do-	30

For Design mix concrete the water required for mix is worked out on basis of several factors, such as grade and proportion of aggregate, fineness of cement, workability required, use of admixtures etc.

2.5 Formwork : The temporary structure erected to support the concrete in its required shape and form, till it hardens and becomes self supporting is called form work, centering or shuttering. Designing and fixing form work is a specialized job and needs dealing accordingly. The major requirements are,

a) it should be water proof, so as to avoid loss of water from concrete.

b) It should be strong enough to withstand, the load of wet concrete, the load of workers, and the impact effect of ramming or vibrating the concrete.

c) It should not bulge or sag under load, beyond acceptable limits.

d) All joints should be true and sealed to avoid projections requiring finishing .

e) It should be easily removable.

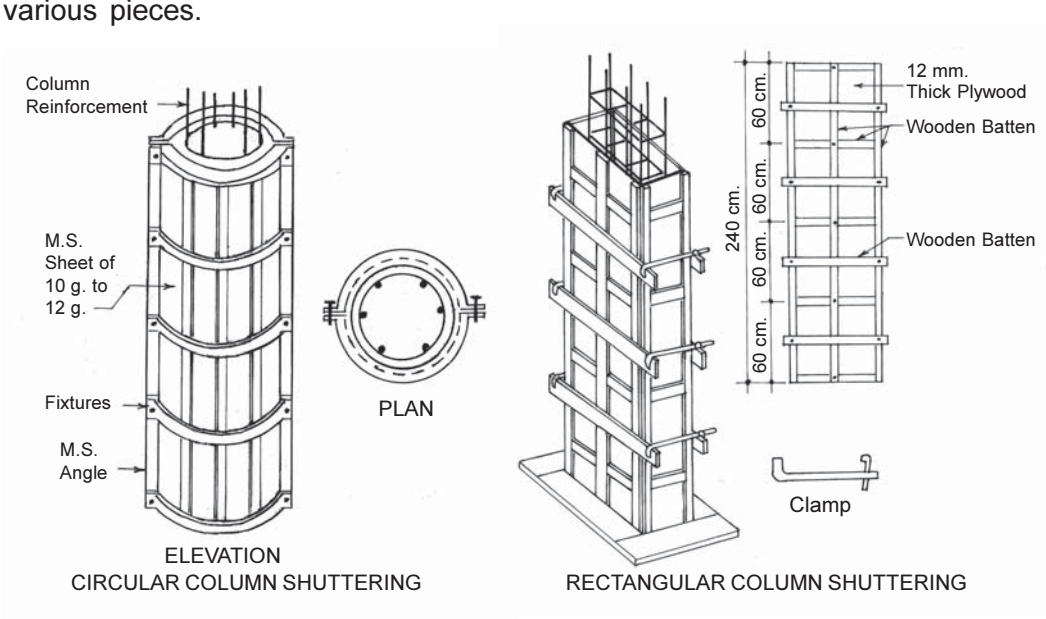
f) It should give the desired surface finish.

2.5.1 The form work is generally either of wooden planks and battens, battens and ply-board or steel plates with steel angles.

2.5.2 Steel Plate: Common size of steel plate is 900x600 mm, but plates of size 1200x600, 450x900, 230x900 mm are also used. The size of angles used on edges and at every 450 mm are 25x25x5 mm. The thickness of plate is variable but normally not less than 4mm. Specially fabricated pieces are made for locations like haunches, curved mouldings, etc., using the same thickness of plates and angles. The steel form work requires more investment initially but can be used for many number of times.

STEEL SHUTTERING

This is easy to erect and de-shutter and man power required is much less compared to other form works. Nuts and bolts are used to clamp the various pieces.



Ready fabricated *farmas* for round and square columns are available in different sizes and segments of 1200mm. Adjustable clamps called *shikanja* are used to rigidly clamp the *farmas.*

2.5.3 Ply wood: Generally Form work ply wood is used for columns and beams. It is also used for slabs when good finish is required, but it may work out costlier than steel plate shuttering. The thickness of water proof ply should be 10-12 mm. and the length 2.4m.

2.5.4 Props: Props can be hard wood *balla* of diameter not less than 75mm. or it can be of steel pipe . Adjustable props, and Propex for higher height used with the form work reduce the manpower requirement and speeds up the fixing of form. Typical details of shuttering for circular column, rectangular column, slab and beam are shown in sketches under 2.5.2.

2.5.5 Do's and Don'ts:

i) All plates or ply should be uniform thickness.

ii) Check the level of the slab, beam with the help of level tube or dumpy level. The level should be marked on every column.

iii) Check the plumb of the side of beams at each end and with the help of line *dori* fix straight line of beam sides.

iv) The beam support is provided by means of battens (*topi*). Check the level and position of *topi* with respect to depth of beam. Width of *topi* should be same as width of beam.

v) Provide bracing to the beam bottom support after leveling the beam and supports should be perfectly vertical.

vi) Check the joint of beam and column, the joint should be in plumb.

vii) Check the depth of beam and slab. A chalk mark and nails should be driven in the side plate/ply to mark the top of the beam /slab.

viii) The Slab plates should be supported at every 0.6m by props. At the joint of two plates or ply's , a *chabi,* a wooden batten 100x100 mm, should be provided for ease of de-shuttering.

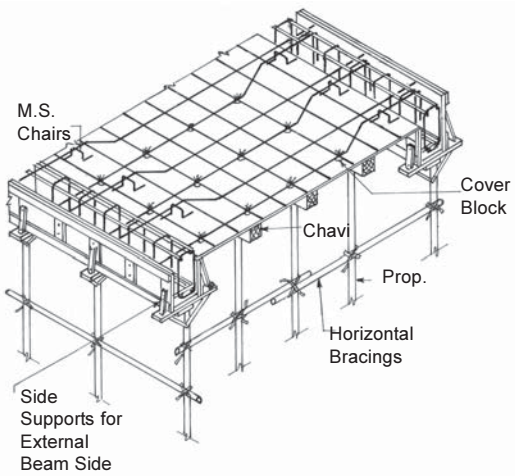
ix) Do not put brick or concrete block below prop, wooden wedges to adjust height, only should be provided.

x) Fill the gaps between plates and ply by putty and sealing tape from inside only.

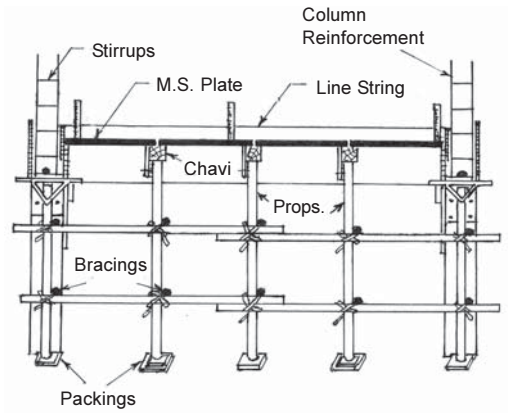
xi) Shuttering oil should be applied (Black oil can also be used) to inside of shuttering, just enough to cover the surface. Excess oil be avoided.

xii) All loose materials like, spare binding wire, paper, pieces of sticking tape, spare chairs, spare cover blocks etc. lying over form work should be removed and surface fully cleaned before pouring concrete.

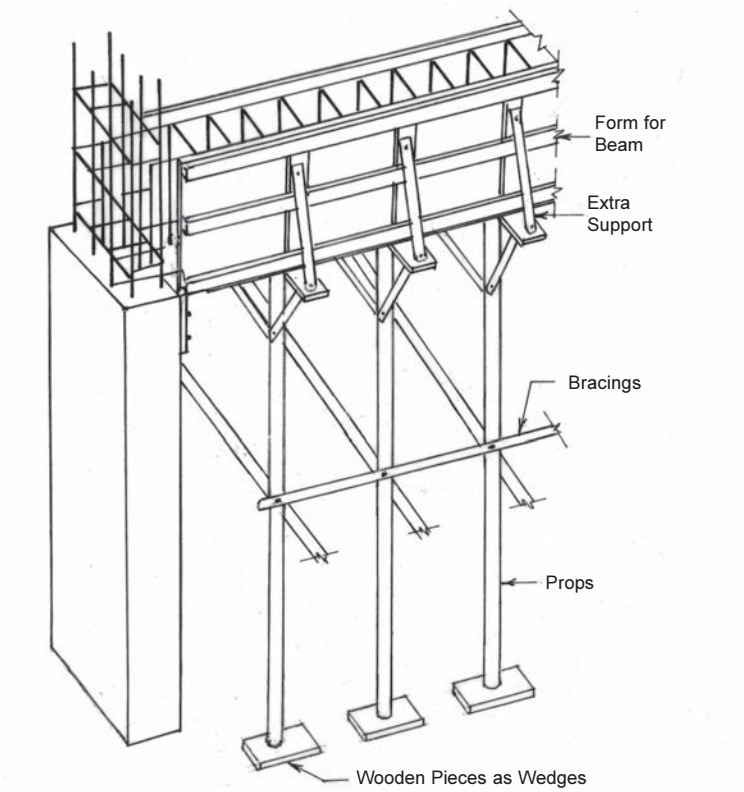
All props should be tied with horizontal bracings of bamboo or steel pipes, at every 1.2 meter height.



SHUTTERS FOR BEAM & SLAB



SLAB SHUTTERING & CHECKING



FORM WORK DETAILS FOR BEAM

2.5.6 The Form work shall be made based on finished dimensions of the structure as given in the drawings, but following maximum tolerances can be accepted,

Item	Deviation from specified dimension
Cross section of columns and beams	+12 mm -6 mm
Footing	
a) dimension in plan	+50 mm & -12mm
b) Eccentricity	0.02 times the width of the footing in the direction of deviation but not more than 50 mm
c) Thickness	± 0.05 times the specified thickness

2.5.7 The normal time of stripping the form, in case of concrete using OPC cement, and adequate curing has been done, is as under,

S.No.	Type of Form work	Minim. Period
a)	Vertical formwork to column, wall, beam	16-24 Hrs
b)	Soffit form work to slabs(Props to be refixed immediately after removal of form)	3 days
c)	Soffit form work to beams (Props to be refixed immediately after removal of form)	7 days
d)	Props to slabs i) Span up to 4.5 m ii) Span over 4.5 m	7 days 14 days
e)	Props to beams and arches i) Span up to 6m ii) Span over 6m	14 days 21 days

Note : In case of PPC, Fly ash cement or GGBFS cement is used in the concrete, minimum 30 to 50% additional time be allowed before de-shuttering. The time should be established by testing of cubes at the time of de-shuttering.

2.6 Bending/Placement Steel Reinforcement:

2.6.1 It is to be kept in mind that

a) Reinforcement co-acts with concrete by transfer of forces in concrete to steel through steel concrete bond. The bond will fully develop only if the bar is clear of any rust, scales, oil or grease. For extending the length of bar, adequate overlaps are a must, the laps should be staggered and the overlapped bar should not infringe the cover. The end of the bar should be provided with a hook, in case of TOR steel it may not be required as the development length for TOR bars is comparatively less. Also, steel bars should be properly embedded in concrete, keeping the prescribed covers.

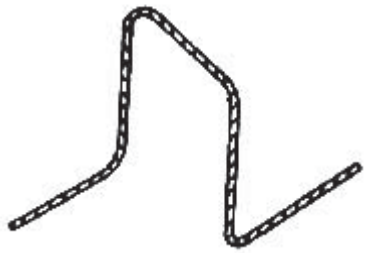
b) Another important thing to be understood is that for steel to become active, enough elongation in steel should take place and concrete cracks at much less strains/elongation, implying there by that near the reinforcements the concrete will crack as a rule. The higher the diameter of bar wider will be the crack width. Do not replace the designed bars with higher diameter bars without consulting the design office.

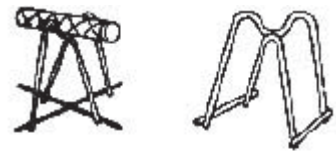
c) Confinement of concrete within the steel cage not only mobilizes full strength of steel but also provides ductility to the structure, thereby delaying the collapse or failure of structure. It is therefore important that the stirrup reinforcement is provided enclosing all the main reinforcement and the stirrups are closed shaped and under force should not open out.

d) Concrete provides a passive environment to steel thereby protecting the steel from corrosion. Thus the concrete in general and specially in the vicinity of steel has to be good quality, without any honeycombs etc. It is therefore necessary to place reinforcements in such a manner that passage of flow of concrete is not obstructed by cluttering of laps etc at one place and adequate cover is provided to reinforcement.

e) All the binding wires should be bent inward and not towards the cover, to avoid initiation of corrosion from the binding wire which may get exposed.

f) In case of slab, raft, foundation mats etc. adequate no. of chairs should be provided to separate the upper layer of bars from the bottom bars. All bent up bars need to be supported by chairs. Some additional chairs may be required for placing planks and walkways taking the load of workers walking for concrete placement and vibration.




HIGH CHAIRS FOR INDIVIDUAL BARS


CONTINUOUS HIGH CHAIRS FOR SEVERAL BARS

g) The horizontal distance between two parallel main bars should not be less than a) diameter of the largest bar used b)5 mm more than nominal size of aggregate. In the case of more than one layer of bars, the vertical distance between two layers should not be less than 15mm and it should be ensured by providing a spacer bar between the two layers.

h) The thickness of clear cover should not be less than following,

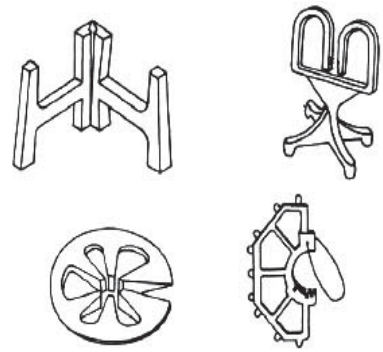
   a) At the end of reinforcing bars, twice the diameter of bar or 25mm whichever is more.(In longitudinal direction)

b) For beams columns , for all reinforcement not less than 25 mm or diameter of bar whichever is more.

c) For slabs the clear cover can be reduced to 15 mm or diameter of bar which ever is more.

d) In severe climatic areas like coastal areas, in Industrial area where chemical gases are emitted or structures where chemicals are to be stored or will affect the structure, increased covers shall be provided. The cover blocks on the sides of beams, columns, walls should have shapes that do not obstruct the flow of concrete. Circular cover blocks in such locations are preferred.

e) The cover blocks should never be made from cement mortar. The cover blocks should be made with the same grade of concrete as the structure and submerged cured for 15 days, however smaller size aggregate may be used. PVC cover blocks are also being used, available in market. The adequate no. of cover blocks, should be fixed to the reinforcement cage through the binding wire provided in the cover blocks.



Plastic cover blocks

2.6.2 Some points to remember :

i) Splices in flexural members should not be at sections where the bending moment is more than 50% of maximum bending moment (Moment of Resistance of section), and not more than half the bars shall be spliced at the section. Where this condition is not met for any reason special precaution shall be taken. Increase the lap lengths and provide closely spaced stirrups around the splice length.

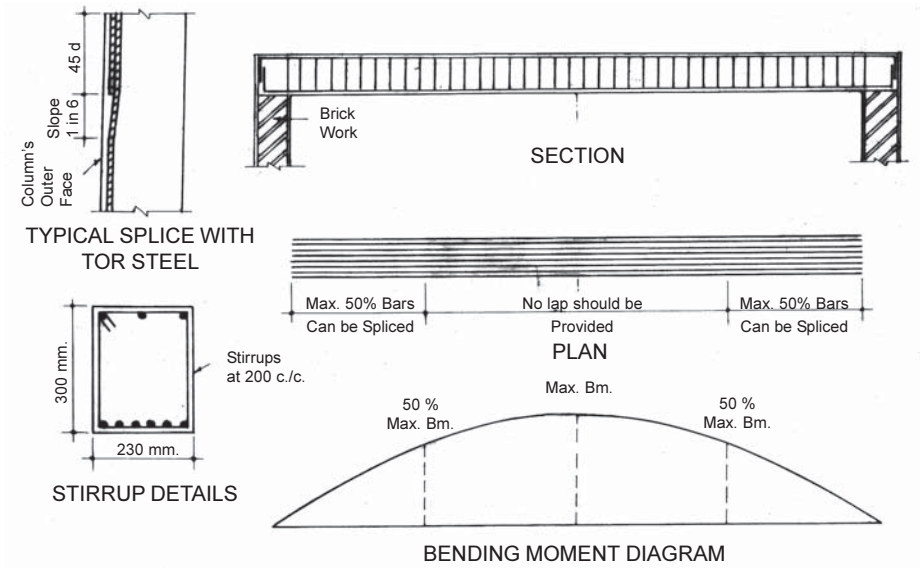
ii) Lap splices shall not be used for bars greater than 36 mm. The bars should be welded for full strength of bars.

iii) When bars of two different diameters are to be lapped, the lap length for smaller diameter bar shall be considered.

iv) Do not substitute the bars by different diameter bars based on area of bars, without consulting the design office.

v) The location of splices in the reinforcement should be decided in consultation with design office.

vi) Tor steel should not be bent, opened and then again bent. However this restriction may not be applied on TMT bars.



2.7 Admixtures: An admixture is a chemical product when added to wet concrete during mixing brings a specific modification to the normal property of concrete. The admixtures may be added to concrete to modify any of the following properties,

- Water reducing for increased workability
- Retarding setting time of concrete
- Accelerating setting time of concrete
- Any combination of above

2.7.1 Most commonly used admixtures are Super plasticizers, which when added to concrete mix can produce high workability with lesser quantity of water. The various super plasticizers are marketed by firms under trade names and make sometimes bloated claims. Many of the super plasticizers have side effect and retard or accelerate the setting time of concrete though long term gain of strength is not affected.

2.7.2 Earliest water reducing agents were based on Lignosulfonate formaldehyde, which exhibit air entrainment in concrete, which is known to reduce strength of concrete. Lignosulfonates also are known to increase shrinkage cracks and are therefore not very desirable, though they are the cheapest available in market. Naphthalene formaldehyde or Melamene formaldehyde based super plasticizers are mostly used in important works. Naphtalene based super plasticizers may retard the setting time of cement. It is also required to check that admixtures do not contain some material like chloride which may corrode the steel reinforcement. Most of the admixtures behave differently under different temperatures. Further different cements are

also known to act differently on the admixtures. It is therefore necessary to try the effect of the admixtures, on some trial mixes, before adopting the type and quantity in concrete. Normally 1-2 % of super plasticizer , by weight of cement may be required to reduce water requirement up to 15%. This will allow keeping low the water/cement ratio, with increased flowability of concrete and increased strength. Thus the additional cost of admixtures is more than compensated due to less effort in compaction and increased strength.

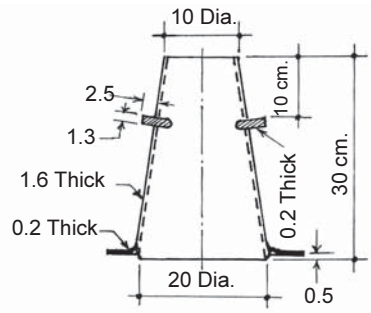
2.7.3 The super plasticizers are available in liquid form and are added with the water while mixing the concrete.

3.0 Properties of Wet concrete

3.1 Workability :-For concrete to occupy all the corners, space between reinforcement rods, and take the shape of the shuttering, it must be plastic enough to collapse and flow either on its own weight or by some applied force, like vibration. The ability of concrete to flow and reach the places within the shuttering form and capable of being compacted is called workability of concrete. The workability of wet concrete is generally a function of water and fine aggregate .It should neither be too flowing nor too stiff. If it is very flowing, it will be difficult to manage proper placement of concrete, and compaction, besides such concrete will exert more force on the form work requiring strengthening of form work or distortion of the same and leakage. Similarly a very stiff concrete will require heavy vibration for movement, which can also lead to segregation of concrete, and not desirable. A good concrete has a balance of various factors, and for general use concretes, Slump Cone test gives a good measure of workability of concrete.

3.1.1 Slump Cone Test:

This test is performed to determine the workability of fresh concrete and to check the uniformity of concrete from batch to batch. The test is conducted where the nominal size of aggregate does not exceed 40mm.It requires special mould and tamping rod of steel 16mm dia 600mm long and rounded at one end.



Typical Slump Mould

3.1.2 Procedure of test:

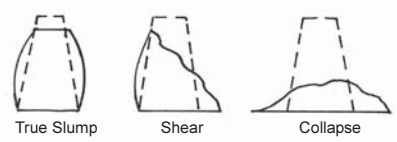
1) Clean the internal surface of mould. The inside of the mould and base should be moistened.
2) Fill the mould with concrete in 4 layers.
3) Tamp each layer with 25 strokes of the rod.

4) Distribute the strokes uniformly over the entire cross – section of the mould.
5) Strike off excess concrete after the top layer with a trowel.
6) Remove the mould slowly and vertically.
7) The concrete will slump or slide.
8) Measure the height of slump in mm. up to nearest 5mm.

3.1.3 The three different cases of slump could be observed as given in Fig.

Shear type slump or collapse may occur in case of lean mixes and where the cohesion in mix is unsatisfactory. This can be improved by increasing smaller size of aggregate and of fine aggregate.

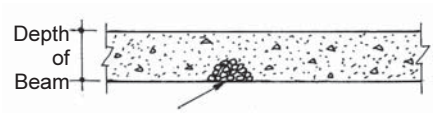
3.1.4 The normal requirement of slump, description of workability and the type work are given in table below.



SLUMP CONE TEST

Description of workability	Slump in mm.	Reqt. Of work type
No slump	0	Normally not used
Very Low	5-10	In precasting yards for slender sections using vibrating table vibrators, such as PSC sleepers, electric poles, blocks etc
Low	15-30	For light reinforced sections or Plain concrete
Medium	35-75	Commonly used for RCC work and PSC work
High	80-155	For pumping concrete, tremie concrete and also very heavy reinforced areas of structure.
Very high	160 to collapse	Normally not used

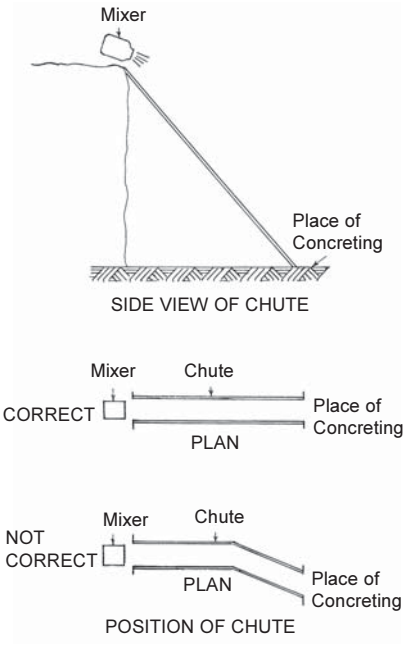
3.2 Segregation of concrete: There are two types of segregations in concrete. In the first, the coarser aggregate tends to separate out as they tend to move faster and farther along a slope or settle more than finer particles. The second form of segregation, is manifested by separation of cement paste from the mix. The first type segregation may occur in lean mixes when it is comparatively dry mix. The second type occurs when the mix is too wet. This can be improved by reduction in water content.



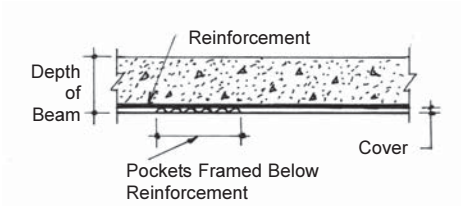
SEGREGATION

3.2.1 Dropping of concrete from a height and passing over a chute, particularly involving change of direction and discharging against some obstacle leads to segregation. Concrete should be placed direct in the

position and must not be allowed to flow or worked along formwork. Use of vibrator to spread the heap of concrete over a large area also will result in segregation and is prohibited. Vibration for long time also results in coarse aggregate moving to bottom and cement and fine aggregate moving upwards, has to be avoided.



3.3 Bleeding of concrete : It is a kind of segregation of concrete where the water of the mix rises to the surface and other constituents settle down causing settlement of concrete. This normally occurs in poor proportioned mixes, where the fine aggregate is not properly graded (less than 150 micron size are not available in sand). If this water is remixed while troweling, a weak surface will result. Further, while movement of water upwards, some of the water gets trapped under the coarse aggregate or reinforcement bars, thus creating zones of poor bond of reinforcement bars. Some times the rising water also carries fine particles of cement with it, forming laitance; this also results in poor strength at the surface. If, concreting is being done in tall members such as columns or piers or walls, intermediate layers of weak spots will be present along the height of the member.



BLEEDING

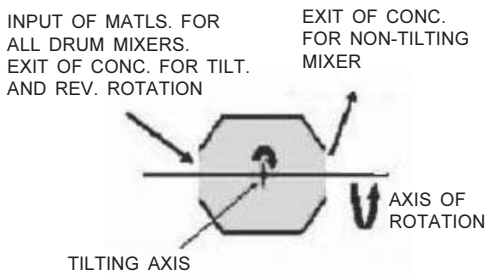
3.3.1 This is avoidable by keeping 15% quantity of fines below 150 microns in sand and presence of fine particles in Pozzolana cement or fly ash cement also reduces bleeding. In slabs, pavements etc vacuum dewatering the wet concrete helps to remove the bad effects of bleeding. In case of concreting in columns etc where height is built up in a no. pours, it is essential that the fresh poured concrete is vibrated along with previously poured concrete up to about 200mm to minimize the weak spots.

4.0 Mixing of Concrete : Concrete is a mix of various components viz. cement, coarse aggregate, fine aggregate, water. To ensure that concrete behaves like a homogeneous material at macro-level, it is essential that surface of all aggregates is uniformly coated with cement. This is to be achieved during mixing of concrete and also should not be disturbed while transferring or placing the concrete.

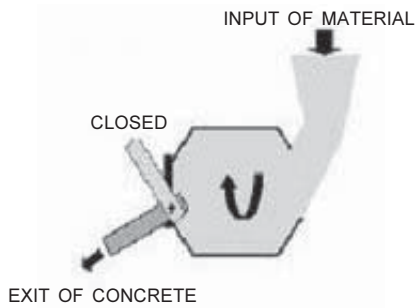
4.1 Hand Mixing : Hand mixing should be resorted to in rare cases where very small quantities are to be mixed. In this, fine aggregate, be spread over a hard non-porous base, Cement is then spread over the aggregate, and the dry material is mixed by turning over from one end of tray to the other and 'cutting' with a shovel till the mix appears uniform. Coarse aggregate is then spread over the sand cement mix and mixing is done by showel or spade till the uniform colour appears. Turning 3 times is normally required. Add water gradually such that neither water escapes by itself or with some of the mix. The mix is turned again, normally 3 times, until it appears uniform and consistent. 10% extra cement should be added in hand mixed concrete.

4.2 Concrete Mixers: All concrete mixers whether manual or motorized work on the same principle. On very large sites continuous mixers are used which perform the best, however on most of the sites batch mixers are only used i.e. a batch of material is discharged before any more material are added. They are drum mixers or Pan mixers.

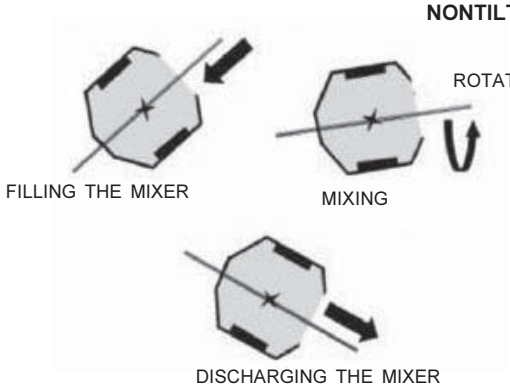
a) In tilting drum mixer, the drum is tilted for discharging. In the non-tilting type, the axis of the mixer is always horizontal, and discharge is obtained either by reverse rotation or by inserting a chute into the drum.



SCHEMATIC DIAG. OF DRUM MIXER



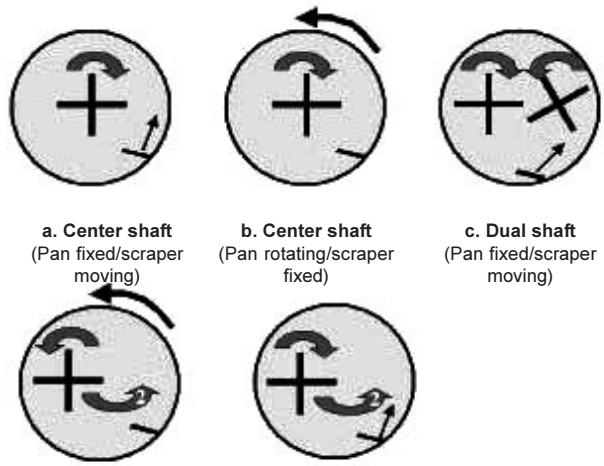
SCHEMATIC DIAG. OF NONTILTING DRUM MIXER



ROTATING TYPE TILTING MIXER

b) Pan mixers are generally not mobile and are used in pre-casting yards or in laboratories. They rotate about a vertical axis and the paddles rotate independently on another vertical axis and are very good for rich and cohesive mixes.

In Pan mixers a certain amount of mortar adheres to the side of the drum and stays there being beyond the reach of the blade, till washing the mixer at the end of the day. This results in the first batch of mix being with less mortar and should not be used as such. First batch should be with the usual quantity of water, cement and fine aggregate but omitting the coarse aggregate. The mix in excess of what sticks to the side of drum can be used elsewhere or even used in placing over cold joints. As an alternative, a certain amount of mortar should be introduced in the mixer prior to starting concreting.



a. Center shaft (Pan fixed/scraper moving)

b. Center shaft (Pan rotating/scraper fixed)

c. Dual shaft (Pan fixed/scraper moving)

d. Center shaft (Pan rotating/scraper fixed. The shaft is also rotating following Arrow 2)

e. Planetary motion (Pan fixed/scraper moving. The shaft is also rotating Arrow 2)

DIFFERENT CONFIGURATIONS OF PAN MIXER (The arrows indicate the direction of the Pan, Shaft & Scraper.)

c) In all mixers, a water meter is to be installed and the water must be fed through the meter. It is preferable, if the water meter is preset for the quantity of water to be fed and the supply is automatically cut of at preset quantity.

4.3 The mixing time for the mixer is specified by the manufacturer for each mixer. It is however to note that it is the no. of rotations and not the time which is relevant. Normally 20 rotations shall be adequate, about 5 rotations with dry ingredients and 15 no. after adding water. The average strength of concrete increases with time of mixing specially up to 2 minutes. The mixing time normally is kept as 2 minutes or as per the manufactures specification.

4.4 The sequence of loading the aggregates in the mixer, normally does not affect the strength of concrete. However, the coarse aggregate is generally loaded after the fine aggregate and cement, just as in hand mixing. The water in any case is the last to be added.

5.0 Ready Mixed Concrete

5.1 Ready mixed concrete is like normal concrete, the main difference is that it is manufactured in a central plant away from the work site and has to be transported in transit mixers from central plant to the work site. Ready mix concrete is advantageous when the work is being done in congested built up sites or on road construction where very little space may be there for collection of aggregates and setting up a batching plant. It has another advantage that since it is manufactured under factory environment, a good control on quality and process can be exercised. Ready mix concrete is also useful, when good quality concrete in small quantity is required.

5.2 The ready mixed concrete can be of two types, based on the stage of mixing the concrete. The first type is, where the concrete is fully mixed at the central plant and the transit mixers (truck mounted) are used for transporting the concrete and agitating it by revolving slowly, during transit, to avoid segregation and undue stiffening of concrete. The second type is, where the weigh batching only is done at central plant but no water is added. The adding of water and mixing is done either on the way or after reaching the site prior to delivery, in the transit mixer. The second type has an advantage of a longer lead to the work site and less chances of damage to concrete in case of delays on the way. In India however, only the first type is being used.

5.3 The transit mixers have a slow speed of revolving between 2 to 6 revolutions/minute compared with a normal concrete mixer revolving in the range of 10-16 rev/min. No. of revolutions in the mixer govern the uniformity of mixing, and rate of rotation governs the rate of stiffening. If transit mixer is to be used for mixing concrete, it may require about 100 revolutions i.e. about 15-20 minutes. The concrete can not be allowed to initially set while in transit, and the transit mixer can delay this up to 90 minutes, by agitating the concrete during transit. This 90 minutes however also includes the time required for placement and vibration of concrete in the form work. If the lead from central plant to work site is more than 60 minutes, retarders are to be added to delay initial setting of concrete. Certain foreign codes allow this, i.e. retard the initial setting beyond 2 hours up to 6 hours, but this requires additional 5 to 20% cement to be added, depending on the total time of cement and water being in contact, beyond 2 hours.

5.4 Checks to be exercised by site Engineer: The site Engineer should ensure following checks, on ready mixed concrete,

i) The various ingredients used in concrete by the plant should be acceptable as per specifications of the work. Many R.M.C. plants use PPC or Blended cements, which may effect the period for stripping form work, some plants use blended fine aggregates or only crushed stone sand, which are acceptable but if soft stones have been

crushed for sand, the sand particle may tend to get pulverized in transit mixer, specially if the lead is long. The use of admixtures and their effect on wet and hardened concrete also should be gone into.

ii) The time of transportation from R.M.C. plant to the site should be clocked by actual dry run, in the same period of the day when concrete is required at site. Time for possible hold ups on route should be worked out and accounted for working out the use of retarders in concrete, if required.

iii) The slump required in concrete at the time of delivery at site has to be clearly specified, and before taking delivery of concrete at site following records accompanied with the transit mixer are checked and verified,

a) The voucher should confirm that the mix manufactured for your work is only being received by you.

b) Time of mixing of concrete at RMC plant.

c) Time of arrival of truck at site, i.e. how much old is concrete. There should be no abnormal delay in transit.

d) There should be no segregation or stiffening of concrete. The concrete should have a creamy consistency and water should not have separated from concrete. It is always advisable to conduct Slump cone test and check the slump required.

e) Some RMC plants keep some amount of water from required, in reserve, i.e. while mixing the concrete they add few liters of water less and add it just prior to delivery at site ,to improve workability. In such a case minimum 30 revolutions of transit mixer are required after adding water.

f) In case of any of the above not being satisfied, the concrete is not as per specification and liable to be rejected.

6.0 Placing of Concrete

Though concrete mix is correctly designed, batched, mixed and transported, placing it in a systematic manner is important, for optimum results. The old conventional method is to place the concrete by labour with ghamela on their head. However this is being replaced on bigger sites by the use of overhead cranes, conveyors, and pumps etc. While, the method of carrying the concrete from concrete mixer to the site of concrete may change, all the other steps of placement remain practically the same. Following points should be meticulously observed for proper placement of concrete.

i) The concrete should be placed at the location directly, and allowing it to flow in the form work, dragging it along the form work with vibrators or other means is to be prohibited.

ii) Check the correctness of reinforcement before placing the concrete.

iii) Do not pour concrete from a height of more than 1.2 M to avoid segregation.

iv) Cover to reinforcement should be checked.

v) Proper *machan*, planking should be prepared for the workers to reach all the site to control the rate of pouring as well the proper location.

vi) Joints between planks, ply -woods must be properly and effectively plugged, so that the matrix will not escape when the concrete is vibrated.

vii) Inner face of the form work should be oiled properly for easy de-shuttering.

viii) The reinforcement should be clean and free from oil, grease etc.

ix) For higher columns instead of pouring the concrete from top, it is advisable to use tremie/funnel pipe, drop chute to direct the concrete through reinforcements and ties to avoid segregation.

x) Check the location, centerline, plumb of the formwork.

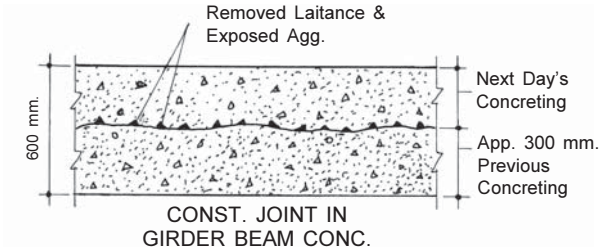
6.1 As far as possible, concreting in one member should be completed in one continuous operation only, without giving any gap of time. Breaking, the concreting operation for lack of adequate and proper shuttering material, labour for concreting etc. gives rise to unnecessary joints, which not only give problems in performance e.g. in case of slabs, locations where joints have been introduced are likely to leak during rains, in case of beams, no such joint be provided along the span which will introduce weakness in the beam besides the surface finish will be required to be made up with plaster. Such joints also are potential locations for seepage of water and other environmental attacks, thereby making the reinforcement vulnerable to corrosion. Only in reinforced columns, where the green concrete is not strong enough to take the self load beyond certain height, should be cast up to 1.2m high in one pour. This height can be increased in high grade, super plasticized concrete up to 3.0 m.

Wherever the concreting is not completed in one pour, a properly designed construction joint be provided. The location and details of such joint should be provided by the design office. A few guidelines are however as under,

1) All construction joints should be planned in advance jointly by field engineer and designer.

2) The construction joints along the length should be avoided in beams, slabs and longitudinal members. If joint is unavoidable, due to the capacity constraints, it should be provided across the depth of the beam closest to the neutral axis of section, where the stress is minimum. It is at mid height for rectangular section and for any other

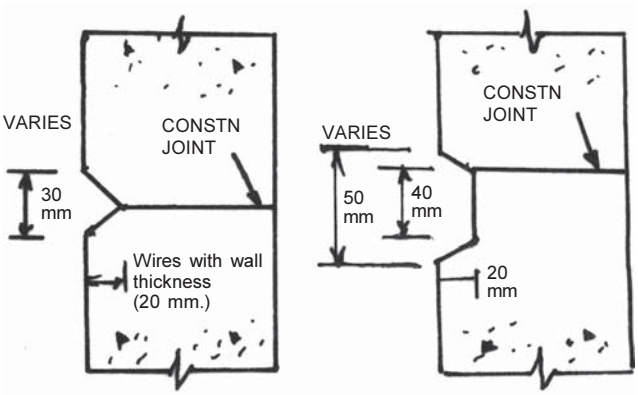
shape like 'T' or 'L' beam it would be closer to the flange, and can be worked out based on C.G. of the section.



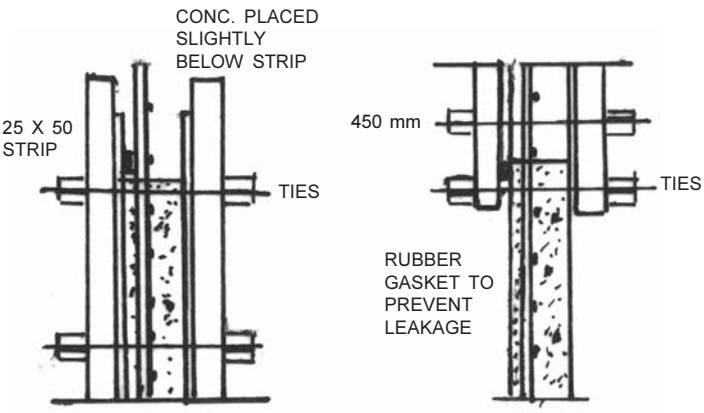
CONST. JOINT IN
GIRDER BEAM CONC.

3) All construction joints should be provided at minimum stress locations. In R.C.C. sections, for beam or slab the central one third portion has minimum shear stress, the construction joint, if inescapable in length should be provided in this region only. The surface where construction joint is provided must maintain proper bond between the concretes placed in two stages and must not intercept the reinforcement bars. To avoid misalignment at the soffit of slab or beam at the construction joint, it is important that form work line and level should be checked prior to placing second days concrete.

4) For horizontal construction joints provided in walls, piers, columns etc. the special measures are required to keep the alignment proper and avoid any bulges etc. One of the things to be ensured is that the tie rod holding the forms should be very close to the construction joint and a wooden strip of 25 mm width going round under the ties helps avoiding any bulge at the joint.



A RECESS BE CREATED BY WOODEN STRIP



FIRST STAGE
SECOND STAGE

6.2 Pumping of Concrete: Concrete can be pumped using concrete pumps up to a distance of 1000 meters and a lift of 120 meters or suitable combinations of the two. The ratio of horizontal and vertical distance depends on the consistency of concrete mix and the velocity in the pipe. The greater the velocity, the smaller the ratio, at 0.1m/sec the ratio is 24, while at a velocity of 0.7 m/sec it is only 4.5. In heavily reinforced slender sections it is preferable to keep low velocity, so as to control the placement properly. However, in pavements etc or mass concreting, higher velocity can be managed. Pumping concrete is specially useful in congested areas, in inaccessible spots and special works like tunnel lining etc.

6.2.1 The delivery pipes vary from 75 mm to 200 mm diameter. 200 mm diameter pipe with an adequate capacity concrete pump can deliver up to 125 cum concrete per hour, where as a 75 mm pipe will deliver about 20 cum per hour.

6.2.2 The mix for pumping should neither be harsh or sticky, too dry or too wet. A slump of 75mm to 150 mm is recommended. A extra stiff concrete will exert pressure on the wall of pipe and not move smoothly in it. Extra flowing concrete can be segregated. The slump of concrete at the feeding end should be such that the slump at discharge end is adequate for placement and vibration.

6.2.3 There are some specific requirements of pumped concrete,

a) As the work progresses, the pipe line length is to be reduced and discharge nozzle re-fixed. There are special type of couplings available which make this job easy and do not consume much time. However trained people are required to handle the pump and pump concrete.

b) The concreting has to be done without interruption, other wise the pipe gets choked by setting of concrete and can't be afforded.

c) Other requirement is that, prior to start of pumping concrete, the pipe is to be lubricated by cement mortar of same grade as of the concrete at the rate of 0.25 m3 per 100m length of pipe of 150 mm diameter. For other diameter pipes, the quantity can be reduced or increased in the ratio of perimeter of pipe.

d) The size of the pipe should not be less than thrice the size of the coarse aggregate and oversize aggregate should not be permitted.

7.0 Vibration of concrete

When concrete is freshly placed in the forms, it contains about 5 % of air bubbles for high workability concrete and about 20% for low slump concrete. Continuing vibration expels most of the air resulting in consolidating the concrete. Over vibration should be avoided as it may lead to segregation. While tackling heavy reinforcement areas it is a good practice to rod the

concrete with rods simultaneously with vibration.

7.1 Compaction of the concrete is the process adopted for expelling the entrapped air from the concrete. If the entrapped air, is not removed completely, it will considerably reduce the strength of concrete. Generally 5% voids reduce the strength of concrete by above 30% and 10 % voids reduce the strength by over 50%. Following methods are adopted for compacting the concrete,

7.2 Hand compaction: The different ways of compacting the concrete manually are, Rodding, Ramming, and Tamping.

a) **Rodding:-** Rodding means packing the concrete with about 1.5m to 2m long and 16mm dia rod, between the reinforcement and sharp corners and edges. This is in addition to vibration by any of the vibratory compaction.

b) **Ramming:** Ramming is permitted for non reinforced foundation concrete. Wooden rammers or steel rammers are used. Ramming is done till traces of laitance appear on the surface.

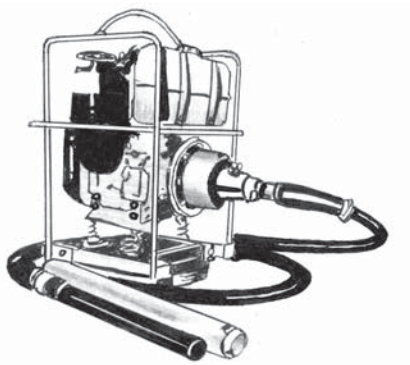
c) **Tamping:** Tamping means beating the surface of concrete with wooden cross beams of section 15cm x 8 cm .Tamping is generally done for thin structures like slabs. Similar to ramming the tamping is also done till some laitance (cement and sand mortar) appears on the surface.

7.3 Compaction by Vibration: Internal vibrator (needle vibrator), Form work vibrator (External vibrator), Table vibrator, Platform vibrator, Surface vibrator.

a) **Needle Vibrator:** Needle vibrator is most frequently used for compaction stiff concrete. The needle vibrators are available in diameters 25, 35, 40, 50, 60, 75 and 90 mm but common needle diameters are 25mm and 40 mm. The length of vibrators varies from 30cm to 65 cm in increments of 2.5 cm. the weight of the needle varies between 1 Kg. for 25 mm dia. and 6 Kg. for 90 mm dia. The frequency and amplitude of vibration for various needle vibrators is as under.

Diameter of Needle (mm)	Frequency (RPM)	Amplitude in mm.	
		Eccentric drive	Pendulum drive
25-35	12000-16200	0.85 - 0.55	0.65 - 0.40
40-60	9000-12000	1.10 - 0.75	0.85- 0.55
75-90	6000- 9000	1.60 - 1.30	1.20 -0.95

The range of vibration of a needle vibrator depends on the diameter of needle. For 25 mm needle, on concrete made with 20 mm nominal aggregate size, with slump of up to 50 mm, a needle vibrator should



NEEDLE VIBRATOR

vibrate an area 100 times the area of needle i.e. about 0.4 sq. m. and a 40 mm needle can act on 1.2 sq. m. Thus, depending on the diameter of the needle, the distance between the places for poking is decided. For 40 mm needle, it is about 35 cm. which will increase to 55 cm. for 60 mm needle. The needles are normally inserted vertically; however certain inclination up to 10 degrees is accepted. Normally, the needle should be inserted in the concrete from 2/3 'L' to 'L', 'L' being length of needle. The concrete therefore should not be deposited more than the length of needle, but not more than 600 mm. Further concrete less than 100 mm thick should not be vibrated by needle vibrator. The full length of needle must be immersed in the concrete and this depth can be increased to even more than the length of needle when required, mainly to vibrate the previous laid layer, to avoid cold joints. For better results, the needle is moved up and down while vibrating, to avoid too much vibration at one location and also to allow the released air to find a vent out.

The use of different diameter needle vibrators is normally as under,

S.No.	Size of needle	Applications
1	25-35 mm	For good workable concrete in thin sections or congested areas with cables and reinf. And is used in conjunction with other vibrators. Also used near form work.
2	40-50 mm	Good workable concrete in thin members like walls, columns, beams and deck slabs and expansion joints. Also used in conjunction with others near forms.
3	60 mm	Good workable concrete in heavy slabs, beams, columns, walls, bridges, pavements etc. Also used near forms of mass concrete piers etc.
4	75 mm	Workable concrete in mass concrete, thick pavements where the forms are of open type like power houses, bridge foundations and as ancillary near the forms in dams etc.
5	90 mm	Are used for concrete up to 150 mm size aggregate in dams etc. This can vibrate up to 4 cum concrete pour in one pour.

b) External/ Form vibrators:- For columns, thin walls and thin pre cast units, form work vibrators are used. There are three types of form vibrators namely, a) Fixed directly coupled, or FDC b) Manual directly coupled or MDC and c) Manual, flexible shaft driven. The fixed directly coupled (FDC) are compact units containing the power unit

and the vibrating unit in one body and are clamped to the form work. The manual vibrators (MDC and MF) are however held in hand and brought in contact with form work manually. The FDC, form vibrator is clamped to the external wall surface of the form work and are more commonly used. The FDC are available with power units varying from 0.2 KW to 0.75 KW and they are designated as FDC200, FDC 250 etc. depending on the wattage. The frequency of form vibrators, in unloaded condition, should be 2800 RPM and more. The force or acceleration imparted to the form work is given by equation,

Acceleration of vibration = $11.18 * n^2 * a * g * 10^{-7}$ mm/sec^2,

where 'n', is frequency in loaded condition, 'a' is amplitude in loaded condition and 'g' is acceleration due to gravity in (mm/sec^2).

Thus, if the frequency is increased the force of vibration is increased in square of that but only linearly with amplitude.

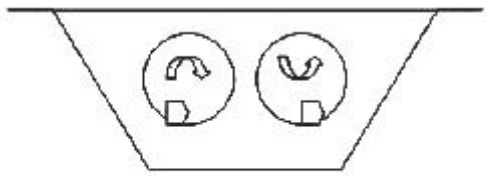
The amplitude, weight etc are given in table below,

Designation	Power (KW)	Weight (Kg) of vibrating unit	Amplitude (mm)
FDC 200	0.20	10-25	1.0
FDC 400	0.40	25-40	1.5
FDC 550	0.55	30-50	1.5
FDC 750	0.75	60-80	1.5

The amplitude imparted and the weight of the manual form vibrators(MDC and MFs) is approximately 1/3rd of FDC's and impart much less force to the form work and are used only for very light but intricate sections. The FDC's are installed on the form work at 1000-1500 mm apart depending on the type of concrete section and the designation of vibrator. However, the concrete sections thicker than 250 mm may not be fully vibrated by the form vibrators and normally form vibrators are used in conjunction with needle vibrators.

c) **Table vibrators:** Table vibrators are special type of external vibrator, used mostly in laboratories for making small but precise prefabricated RCC members. These are also used in pre-casting factories, where rich and stiff mix is used. Normally stiff concretes with slump of less than 25 mm are compacted on table vibrators.

The table vibrators are in length 1 to 3 m and width 1 m. The table is normally not higher than 0.75 m. The small table may have only one eccentric motor, but 2 and 3 m tables normally have two eccentric motors rotating in opposite direction.



Principle of
directional vibration

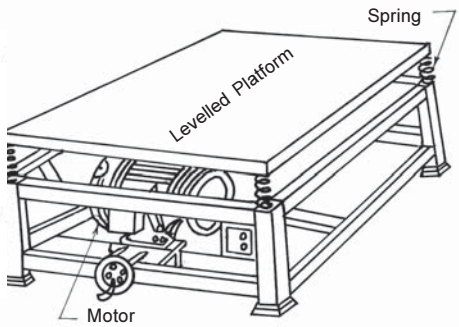
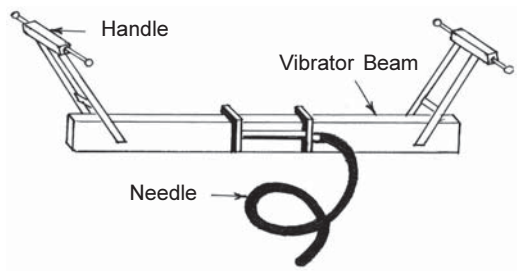


TABLE VIBRATOR

The vibrations from 3000-6000 RPM under loaded condition is imparted by these vibrators, which produce an acceleration of 4 'g'. Various properties of different table vibrators are as under:

Size (LXW)	Capacity(tonnes)		Output rating (kW)	
	(a)	(b)	(a)	(b)
1 X 1 m	0.25	1.0	0.75	1.5
2 X 1 m	0.50	1.00	0.75	1.5
3 X 1 m.	-	1.5	-	2.2

d) Surface/ Screed Vibrators:- Surface vibrators are also known as screed board vibrators. A small vibrator placed on the screed board is effective during compaction and leveling of thin concrete members like flooring, pavements etc. Generally these vibrators are not used beyond 15 cm thick concrete or are used in conjunction with needle vibrators for finishing the top surface. The common size of screed boards are 3m, 4m, or 5m. The board should be made of seasoned hard wood of cross section not less than 75X150 mm and an M.S. plate of 1.6 mm thick fixed to the board. The screed board has one or two vibrating units mounted symmetrically, on it. The steel tube handles on either end of the board need to have a dampening system so that the vibrations do not directly affect the worker holding the vibrator.



SCREED VIBRATOR

The vibrators of various types are small machines driven by portable engines and break downs are not uncommon. It is essential that during concreting at least 30% of standby arrangement is available. The frequency and amplitude for the vibrating units are given below,

S.No.	Frequency (RPM)	Amplitude (mm)	Suitable for conc. thickness
1.	3000-3200	1.5 mm	150 mm conc.
2.	3000-3200	2.0 mm	150-250 mm
3.	3500-3700	1.5 mm	> 250 mm

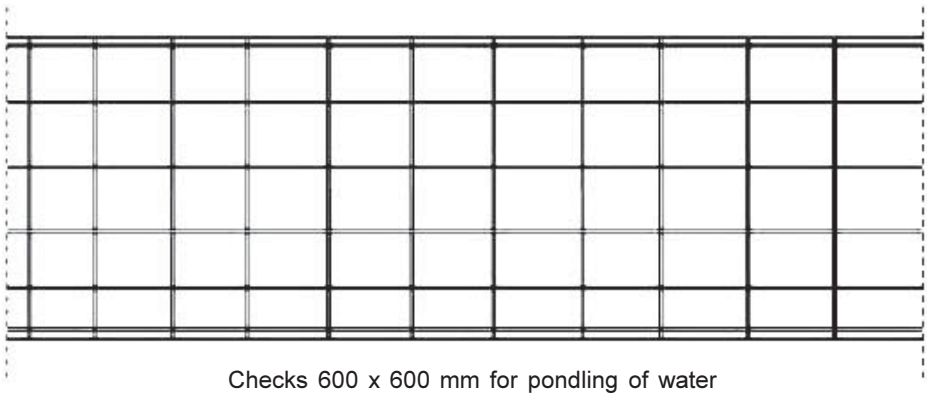
8.0 Curing of Concrete

The hydration of cement in the concrete takes a long time and it is therefore necessary that the mixed water inside concrete is not allowed to escape for as long as possible, else the gain of strength will not take place. Further, significant heat is generated in the chemical reaction of cement with water which dries the concrete and causes shrinkage of concrete. As the drying starts at the surface, the shrinkage cracks appear on surface, but with drying of moisture from inside, the cracks will occur inside also. When concrete is laid its water content is rapidly lost if, sufficient precautions are not taken, by evaporation caused by the action of sun and wind and the heat generated during hydration of cement. The prevention of such loss of water from concrete during its early life is known as curing. If curing is neglected in the early period of hydration, the quality of concrete experiences irreparable losses. For preparing good concrete, curing is as important as other processes, like mixing, vibrating and placing of concrete. After about a fortnight the curing can be stopped as changes afterwards are very slow, concrete has gained significant strength to be cracked and the shrinkage that occurs is small.

8.1 Water curing

a) **Immersion**:-The pre-cast concrete items are normally immersed in curing tanks for the required duration. This is the most effective method but feasible in small pre-cast items only.

b) **Ponding**:- This is second best method of curing. Here the exposed surface of concrete, which is most easily dried is submerged in water. Floorings, roof slabs, road slabs etc. are covered by water by making small ponds of water. This is achieved by creating small berms with



Checks 600 x 600 mm for pondling of water

cement mortar of 1:12 proportion, about 50 mm high, so as to create checks of 600x600 mm on the surface. These are filled with water, and replenished from time to time ensuring the water remains ponded, for at least 15 days.

c) **Spraying and wet covering**: Vertical retaining walls, beams and concrete columns are cured by spraying water. This is normally done using a water hose or by buckets. In some cases, wet coverings such as wet gunny bags, hessian cloth etc. are wrapped around the vertical surfaces for keeping concrete wet. The spraying water must be done at least 4 times a day, and in summer months may have to be increased.

8.2 Membrane curing: During shortage of water, or in some inaccessible locations of structure, it is not possible to cure the concrete with ample quantity of water. In such cases membrane curing is done. This is achieved by applying curing compound on the concrete surface. This can also be achieved by wrapping thin film like polyethylene film closely around the concrete structure. The basic concept behind membrane curing is that the water used to mix the concrete is not allowed to go out form the body of concrete. This water helps in uninterrupted and progressive hydration. There are several curing compound products available in market, all of them do not behave as claimed, and should be tested before applying on the structure. A simple test is, coat the curing compound on a sample of concrete cubes, instead submerging in water as is to be done in case of test of compressive strength of concrete, and check the compressive strength. A good product will give, comparable results. However, wherever possible, the water curing should only be done.

8.3 Steam curing: When concrete is subjected to higher temperatures along with moisture, it accelerates the hydration process, resulting in the development of strength much faster and 7 days strength can be achieved in a matter of few hours of steam curing. This is normally done on pre-cast elements in the casting yard, to release the form work early. However, after steam curing and de-shuttering water curing is still done for 7-15 days for gain of design strength of concrete.

8.4 Curing should be begun as soon as possible after concrete is placed and when final set has occurred(In concrete without the use of retarders/ accelerators, final set of cement takes about 6 Hrs.) and before it has hardened, and should be continued for a minimum period of 7 to 15 days.

9.0 Properties of Hardened Concrete

9.1 Concrete Crushing Strength:

Compressive strength of concrete is tested by casting 15x15x15 cm cubes at 28 days. Compressive strength of concrete is assessed by the crushing to destruction of the test cubes which require the use of

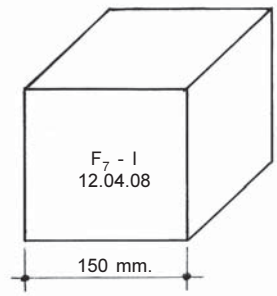
compression testing machine and is usually carried out in the field laboratory. Strength of concrete increases with age. For ordinary Portland cement concrete strength at 3 days is about 1/3rd of the strength at 28 days, Strength at 7 days is 2/3rd of the strength at 28 days and strength after one year is much greater than the strength at 28 days. In all cases the 28 day compressive strength is the only criteria for acceptance or rejection of concrete. Often, cubes are cast and tested at 3 days and at 7 days also, to check the strength at de-shuttering as also getting timely warning in case poor concrete has been manufactured. The specified frequency of sampling, for each grade of concreting done in each shift of work is as under,

Quantity of Concrete (m3)	No. of Samples*
1-5	1
6-15	2
16-30	3
31-50	4
51 and above	4+1addl. For each 50m^3 or part thereof

* Sample contains 3 cubes, the average of which is taken as the crushing load.

9.2 Casting of cubes:

1) Clean the standard cube moulds, adequate nos., as per the sampling requirement, thoroughly and tighten all the nut bolts properly.
2) Apply shuttering oil to all contact surfaces of moulds.
3) Size of mould is 150mm x 150mm x150mm
4) Take random samples, proportionately distributed over the quantity of concrete in one shift of working, from the mix in a *ghamela* while concreting.
5) Pour concrete in the cubes in 3 layers.
6) Compact each layer with 35 nos. of strokes with the tamping rod.
7) Finish the top surface by *thapi*/ trowel.
8) Cover the mould by a damp Hessian cloth.
9) After 24 hour remove the specimen from the mould, by loosening the nuts bolts. Mark a designated code on the cubes with paint or marker along with date of casting. For example, F7-I 12.4.08 could denote, foundation no.7, cast in first shift on 12.4.08.
10) Submerge the specimen in clean, fresh water until the time of testing.



IDENTIFICATION OF CONCRETE CUBES

11) Test 3 specimens for 7 days and balance specimens for 28 days.

9.3 Testing of cubes

CONCRETE CUBE TESTING MACHINE

1) Place the cubes on testing machine, so that the load is applied to the opposite side of the cube as cast i.e. not on top and bottom (Opposite sides of the cube surfaces are in contact with sides of the metal mould)
2) Apply the load without interruptions and increase the load continuously, at a rate of approximately 400 kg/ min until the resistance of the specimen breaks down and no additional load can be sustained.
3) Record the maximum load applied to the specimen.
4) Calculate compressive strength=Maximum load at failure/Contact area of the cube.
5) Take average strength of 3 specimen cubes.
6) This average strength represents the strength of concrete used in a particular portion of the structure.

9.4 Acceptance Criteria for concrete The concrete shall be said to have passed the test when both the following conditions have been met with,

Specified Grade	Average of group of 4 consecutive test results in MPa (N/mm^2)	Individual test result in MPa (N/mm^2)
M15	$\geq$ fck+0.825x Actual Std. deviation or Fck+3 N/mm^2, which ever is greater	$\geq$fck-3 N/mm^2
M20 and above	$\geq$fck+0.825x Actual std. deviation or fck+ 4 N/mm^2, whichever is greater	$\geq$fck -4 N/mm^2

$\mathbf{F_{ck}}$ is the Characteristic strength of concrete in N/mm^2, and is the same as the no. appearing after M, i.e. the fck for M20 concrete is 20N/ mm^2. For nominal mix of concrete, the fck is to be picked from last column of the table below,

9.4.1 For Nominal Mix of concrete

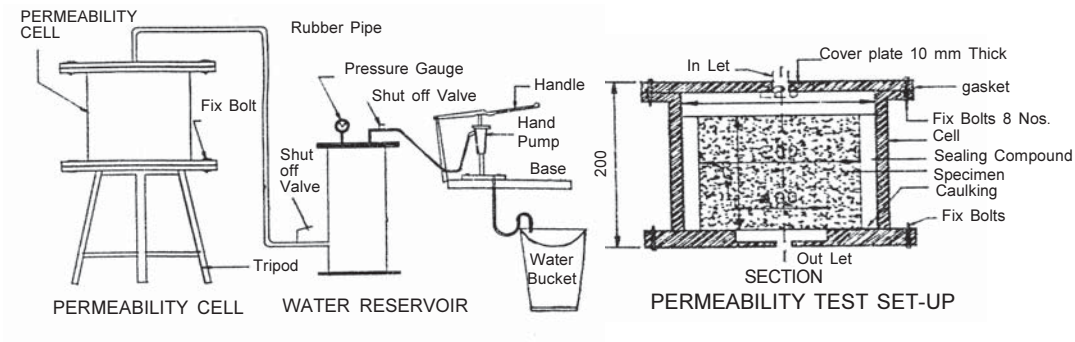
Mix (Volumetric Proportion)	Crushing compressive strength at 7 days	Crushing compressive strength at28 days	Equivalent To Mix design
1:3:6	7 N /Sq mm	10 N /Sq mm	M_{10}
1:2:4	10N/Sq mm	15N/Sq mm	M_{15}
1:1.5:3	13.5N/Sq mm	20 N/Sq mm	M_{20}
1:1:2	17 N /Sq mm	25 N/Sq mm	M_{25}

9.4.2 Concrete shall be rejected if it is porous, honeycombed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been disturbed beyond permissible limits or dimensional tolerances have not been met.

10.0 Water Permeability of concrete

In water/liquid retaining structures as well as important structures in coastal areas where penetration of chloride ions through permeation of moist air or direct attack of saline water may be a concern, water permeability test on concrete samples is also to be conducted. The test should be carried out as per IRS concrete Bridge code (Appendix-G)

The test is devised based on the premise that depth of penetration of water under a pressure head into concrete is a qualitative measure of permeability of concrete. In this test a hydraulic head is applied by pressure which ranges between 0.1MPa to 0.7 MPa for 3 days gradually increasing in steps every day and on the 8th day the sample is split to check the penetration of water. A depth of less than 50mm classifies the concrete as 'impermeable' and less than 30mm 'Impermeable under aggressive conditions'.



11.0 Construction Joints and Cold Joints

Construction joints are designed joints kept in the structure, since the whole structure can be cast and completed in one pour only in rare cases. The construction joints should be minimized if not possible to eliminate. Construction joints should be so located that they are accessible for cleaning all laitance, loose concrete, cement slurry etc. and create rough concrete surface with the coarse aggregate exposed. It is normally found that soon after the set of concrete, a high speed water jet if sprayed on the surface cleans up all the slurry, loose concrete and laitance. It also bares the coarse aggregate to provide a good bond between old and new concrete. Location of construction joints has to be worked out and advised by the design office. In some locations designers provide shear keys to resist the shear at the location.

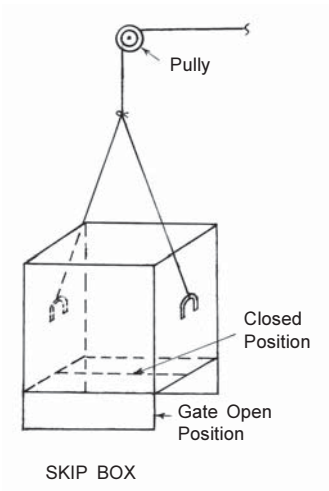
No cold joints should be allowed in a structure. Cold joint is an unplanned, unprepared construction joint. Concrete should be continuously carried out up to the construction joint without any stoppage. While pouring fresh concrete over previously laid concrete, it should be ensured that the old concrete is vibrated along with fresh concrete. This will prevent occurrence of a cold joint. If there is apprehension of delay to pour the concrete in next layer, within the setting time of previously poured and vibrated concrete, provision of retarder should be done in the design of concrete, so that the new and old concretes can be vibrated together.

12.0 Under water Concrete

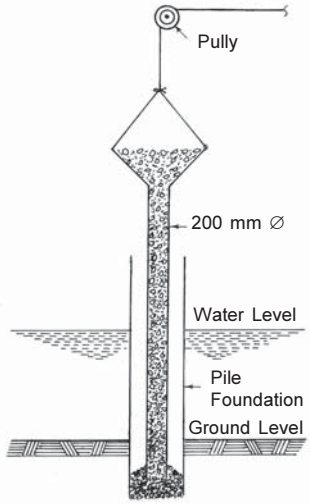
Many times concrete is to be placed under water, when the pit excavation can not be dewatered, such as in case of deep foundations etc. All such concrete is to be done by skip boxes or tremies.

12.1 Skip box is a bottom opening box, which is lowered to the place of concreting by means of a tripod and winch. When the box reaches the place of concreting, the bottom hatch is opened by a lever operated from the winch, for discharge of concrete. The concrete is tamped by means of the empty box by raising and lowering it several times under water or by a tamper lowered by the winch. The water in the pit becomes opaque due to mixing of cement and sand and the location of the placed concrete can not be visually ascertained. It is therefore necessary to make a complete plan, of location of lowering of skip box along with the quantity of concrete to be consumed and the work is to be carried out in proper sequence. The under water concrete is prepared of high workability and an additional 10% cement is added to make up for the loss of cement in water.

12.2 In important structures like pile foundations etc the under water concrete is done using tremie pipes and funnel. The principle of tremie concrete is that poured concrete does not directly come in contact with water, in spite of being under water during concreting operation. Here a pipe of 200mm diameter is lowered to the bottom of pit (about 150 mm higher than bottom). On the ground level, a funnel is attached to the other end of tremie pipe. Concrete of high workability (Slump$\geq$150mm) and water cement ratio of 0.40 -0.45, is poured into the funnel, which discharges at the bottom of pit. The first pour will only come in contact with water as subsequent charges of concrete are discharged in the heap of concrete deposited at the bottom of pit. For this to be achieved, the tremie is raised with every new charge, lesser than the height of concrete built up at the bottom. Thus the bottom end of tremie pipe is always buried in the concrete. It is also to be ensured that the tremie pipe is always full of concrete or else, the water may flood the pipe under hydrostatic pressure. The concrete rises from bottom toward the top carrying with it scum of the concrete in direct contact with water. This scum or laitance at the top can be broken and removed when it reaches the ground level or above the water level, as the case may be.



SKIP BOX



TREMIE PIPE CONCRETING

12.3 Care has to be exercised that the tremie pipe is lowered and raised continuously during the operation, to avoid clogging of the pipe and also it gives a compacting action on the concrete. Care also has to be taken that at no time during the operation the bottom end of tremie pipe is raised above the level of good concrete i.e. it should always be buried below the laitance/ scum level. Further the tremie pipe should always be full with concrete.

12.4 10% extra cement is added to concrete to compensate the loss of cement under water.

12.5 The whole operation is delicate and only experienced personnel can be relied upon to carry out the work.

13.0 Guniting or Shotcrete

Guiniting or shotcrete is very useful for rehabilitation or reconditioning of old concrete brick or masonry works which have deteriorated either due to climatic condition or inferior work. It is also used for stabilizing rock slopes, tunnel lining as also used for water proofing exposed concrete surface or for resisting water pressure on pipes, cisterns, etc. There are two basic processes by which shotcrete is applied v.i.z. a) Dry mix process and b) Wet mix process.

a) In the dry mix process cement and damp aggregate are intimately mixed and fed into a mechanical feeder or gun. The mixture is then transferred by a feed wheel into a stream of compressed air in a hose, and carried up to delivery nozzle. The nozzle is fitted inside with a perforated manifold through which water is introduced under pressure and intimately mixed with dry mortar mix. This mixture is then projected at high velocity onto the surface to be shotcreted.

b) In the wet mix process all the ingredients including water are mixed together. The mixture is then introduced into the chamber of delivery equipment and from there conveyed pneumatically by means of compressor. Additional compressed air is injected at the nozzle, and the material is projected at the surface to be shotcreted.

13.1 Normally the wet process is used for large volume operations. The usual proportions of cement and fine aggregate are 1:3 or 1:4. The fine aggregate should be well graded up to a maximum size of 10mm usual size is 4.75mm downwards. Hard stone sand should be used. The usual w/c ratio for dry mix is between 0.30 to 0.45 and 0.40 to 0.55 for wet mix process.

A very wet mixture will not stick. While shooting a nozzle under normal conditions is held at a distance of about 75 to 90 cm from the working face. The surface to be treated must be thoroughly cleaned of any dirt, grease or loose particles and should be fully wetted. The correct no, of gun should be obtained for the maximum size of aggregate or sand to be used. Reinforcement usually of 80mm sq. mesh may be incorporated to withstand structural or temperature stress.

Because of high velocity of impacting jet, not all the material projected sticks to the surface. The material which doesn't stay on the surface is called 'Rebound'. The normal rebound are as under,

Location	For dry Mix	For wet Mix
In floors and slabs	5-15%	0-5%
On sloping or vertical surfaces	15-30%	5-10%
On ceiling /soffit	25-50%	10-20%

Apart from wastage of material the rebound particles may accumulate at locations where they will get incorporated in subsequent layers of shotcrete, such as at the inside corners, at the base of walls, behind reinforcement or embedded pipes, or on horizontal surfaces. Great care there fore has to be exercised in placing of shotcrete and large diameter bars are not to be used. This also has danger of unfilled pockets behind the obstructing reinforcement bars.

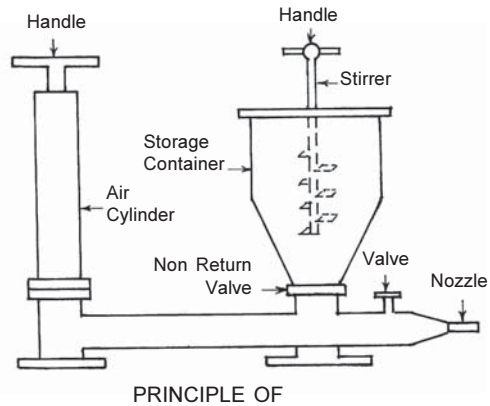
13.2 The recommended aggregate grading for shotcrete is as below,

Sieve size	Cumulative percentage Passing		
	Grading 1	Grading 2	Grading 3
10mm	100	90-100	70-90
4.75mm	95-100	70-85	50-70
2.4mm	80-100	50-70	35-55
1.2mm	50-85	35-55	20-40
600 micron	25-60	20-35	10-30
300 micron	10-30	8-20	5-17
150 micron	2-10	2-10	2-10

14.0 Pressure Grouting

Cementation is injecting under pressure cement grout in to cracks., voids or fissures in structures or ground (Road , sub grades etc) This process is useful for repairing structures, consolidating ground and forming water cut offs etc. This normally restores stability in a structure which has otherwise become unstable due to cracks or voids. Holes are drilled at selected points and cement grout, which is sufficiently fluid to ensure complete penetration, is pumped in.

Holes may be drilled about 40mm dia and about 3m horizontal and 1m vertical distance apart. Cracks, joints and voids should be tapped by such holes. Holes must not be drilled right through the thickness of the mass under repair. Cracks should be cleaned by forcing water under pressure through the grout holes.



PRINCIPLE OF
HAND GROUT PUMP

15.0 Design mix Concrete

Mix design not only requires the knowledge of properties of concrete but also sufficient experience of handling concrete. Often the design of mix carried out by laboratories has to be adjusted by field Engineers, to improve the consistency, handling and placing of concrete at site etc. Usually, a proper mix is obtained only after the mix has been used at site a couple of times and Site engineer should not be very rigid on the adopting the design initially given by the laboratory. Owner's engineer should note the following items for ensuring quality of concrete,

i) The mix design is to be prepared by the contractor and the mix so prepared will be approved by the Engineer, within the limitations of parameter and other stipulations of specifications. (The Engineer of the owner is not to approve the method of design)

ii) The characteristic strength of concrete is the compressive strength of cube of concrete tested at 28 days, and is the same figure as given after, M. i.e. for M25 concrete the characteristic strength is 25N/mm^2.

iii) The Standard deviation of mix depends on the level of control exercised in regard to uniformity of quality and gradation of aggregates, cement, mixer etc as also standardization of procedures etc. This has to be established based on actual tests of 30 different cubes. Till the time this is done, values be adopted from table below,

Grade of Concrete	Assumed Std. deviation
M10 M15	3.5
M20 M25	4.0
M30 and above	5.0

15.1 In case of change of either the source of aggregate, cement, mixing plant, or technical control a fresh standard deviation is to be established.

15.2 Periodic adjustments to the mix design are necessary to account for amount of surface water off aggregates, different grading of aggregates and even due to temperature of the raw aggregates. For the purpose, all the records of the materials going in concrete have to be meticulously kept and action to revise the mix design if required should be taken. Minor variations normally are taken care of by the standard deviation and should not unnecessarily concern the Engineer.

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CHAPTER 8

WATER PROOFING OF ROOFS

1.0 General

For any structure or building to be leak proof, due care needs to be given right from the stage of planning, design and construction.
Some essential measures to be adopted for structures are as under,

a) R.C.C. Roof Slabs:- Flat roofs of reinforced concrete should normally not require any waterproofing course or treatment if properly designed and constructed . The following should be ensured to make structures in R.C.C like slabs, leak resistant.

i) Water should not be allowed to stagnate on the concrete surface. This is achieved by providing a cross slope of not flatter than 1 in 100 and preventing any local depressions. It is best to provide the slope on the terrace roof in the shuttering for slab only, as any subsequent methods to provide slope in the water proof course etc. will unnecessarily increase the dead load on the slab.

ii) The concrete for roof slabs is normally done in concrete M15 with 330 Kg/m3 cement content. It is necessary that controlled concrete with water/ cement ratio of 0.4 to 0.45 should be used. If required, super plasticizer to increase workability be added to concrete. It needs to be ensured that the sand has minimum silt, not exceeding 8% by volume and water used for concreting is potable.

In water retaining structures, Water proofing compound like CICO etc @ 1 kg to a 50 kg of cement be added in the concrete. This also increases the workability of concrete and gives a denser concrete matrix, thereby reducing the permeability of concrete.

iii) The design for roof slabs should use reinforcement bars of smaller diameter, preferably not exceeding 16 mm ϕ to control the width of cracks. Disturbance in the reinforcement due to walking of the labour over the same during casting should be prevented by providing timber board walkways, *machans* over the steel reinforcement chairs.

iv) The reinforcement used should be free of rust, oil, paint, grease etc. to allow proper bond with concrete.

v) The concrete should be well compacted using screed vibrators. For very small works, where screed vibrators are not available, compaction may be done using screed boards under strict

supervision of a competent supervisor. Care should be exercised to see that workmen do not walk over the finished surface at least for 6 hours after concreting.

vi) The concrete in the slab should be done in one pour only to avoid any cold joints. All cold joints are a potential weak points for seepage of water. If inescapable, proper designed construction joints should be provided and sealed against any water leakage.

vii) The curing should be started immediately after 6 hours of concreting. Best form of curing is by ponding water over the slab or by covering the surface with wet Hessian cloth. This should be continued for minimum 15 days.

b) Brick walls:- Similarly the brick masonry work in the walls should be done using proper quality of bricks and ensure that all the brick bonds are filled with cement mortar by buttering the sides of the bricks while laying. It is also desirable that the rain water should be prevented from lashing directly on to the brick work by providing adequate projection of eaves.

i) Use of water proofing compounds:- There are several branded water proofing compounds available in market, which when added to cement mortar provide reduction in porosity of mortar. These are used in the external plaster or pointing mortar, in case of thin walls or walls subjected to excess exposure to water flow or rains, such as in heavy rainfall areas or side drains running close to the brick wall etc.

The joints are to be properly raked before plastering or pointing. In high rainfall areas (above 1800 mm annually), it is recommended that the outer walls should be plastered and, water proofing compound like CICO, should be added @ 1kg per 50 kg of cement.

Apart from use of branded water proofing compounds addition of crude oil upto 5% by weight of cement also reduces the porosity in the cement mortar and is used for filling gaps in brick joints, brick pavements and tiles on roofs etc.

ii) Application of silicon based water repellent:- Application of water repellants on crack free surface (width $\geq$ 0.1 mm) of masonry, with or without plaster provides protection against absorption of water, salts and dirt. Primer coats used for oil based paints serve the purpose. Silicon water repellant as per I.S.12027-1987, Class A is normally used for coating brickwork and cement based materials. The silicon material is diluted in mineral spirit or Xylene (Preferably they should have 5% solid content) and a single generous or flooding coat(should flow for 15 cm, downward) by brush or spray is applied. This can be used over

cement based painted surface also, and it preserves the colour avoids spalling or blistering of paint and sheen of the paint. Normally it does not change the appearance of the paint.

c) **Junctions and Joints:-** Care should be taken to provide all junctions and joints with properly designed water seals. The critical locations are,

i) Interfaces of brick work and R.C.C. Columns, beams, slabs, under side of lintels, under side of beams. As the expansion of brickwork and concrete is different it requires special attention to avoid cracking along the junctions of beam faces and columnfaces joining the brick work. Fixing the chicken mesh on the joints of RCC and masonry wall with half width of chicken mesh will be on masonry wall and half will be on RCC members and by fixing this chicken mesh with plumbing nails before plastering will arrest the cracking on the jointing faces. Another method can be used that the jointing faces must be properly filled with mortar by packing with 6-10mm aggregate in the jointing faces.

ii) Construction joints

iii) Crevises, holes in brick work, R.C.C. members for services like water supply, sewage pipes, down take pipes or electric cables etc.

2.0 Water proofing the RCC flat roof:

The terrace of flat roofs even if made as per good design and construction practices are normally provided separate treatment to make them fully water proof, to isolate the structural roof from the changes that may develop in the surface due to weathering, temperature variations, rough use of the surface, it may be subjected to. The water proofing of new building can be ensured by meeting the basic requirements of waterproofing during design and construction.

Provision of adequate slope, provision of adequate openings are the basic requirements of any water proofing works.

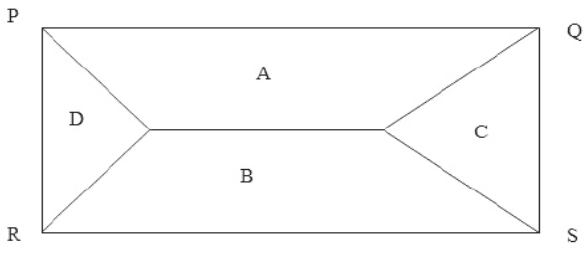
i) **Provision of Adequate slopes:-** It is absolutely essential that roofs are provided with adequate slope to ensure effective drainage. The slope of roof should be such that the water gets drained off quickly by achieving adequate velocity under influence of gravity. A slope of not flatter than 1 in 100 depending upon the type of water-proofing and the average rainfall. It is a good practice to provide steeper slopes (1 in 80 and steeper) in the form work only while casting the slabs. In longer span roofs it is preferable that ridge lines are formed at the terrace and the water should be provided the shortest passage for escape away from roof, into to the outlet openings.

ii) **Provision of adequate openings:** Adequate openings in numbers and size are necessary to allow the water to get drained off quickly. The number and size of openings depends upon the area of roof and intensity of rain fall of the region in which building is situated. Rain water pipes having bell mouth inlet at roof surface, gives better drainage effect.

The spacing in between outlet pipes should not be more than 6M. The size of rain water pipes depending upon the average rate of rain fall and roof area should be as given in Table. Average rainfall intensity may be obtained from the local office of Indian Meteorological department or the record of rain gauge at any other office.

Dia of pipes in mm	Average rate of Rainfall in mm/h (Roof area, Sq.M)					
	50 sq m	75 Sq m	100 Sq m	125 sq m	150 sq m	200 sq m
50	13.4	8.7	6.6	5.3	4.4	3.3
65	24.1	16.0	12	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7

While using the above given values, it must be ensured that the roof surface area, which will drain on a specified direction, due to slope is only considered for working out the requirement of outlet pipes. In the sketch below, if the terrace is divided in 4 parts



A,B,C and D by providing high ridges, the area A shall discharge on side PQ, area B on side RS and area C on QS side etc. The outlet pipes on each side should accordingly be provided.

2.1 The commonly used types of water proofing treatments for flat R.C.C. slabs soon after construction, are as under,

i) Lime concrete Terracing.

ii) Integrated cement based water proofing treatment with composite layer of brick bats and mortar

iii) Polymer modified cementitious slurry coating.

iv) Glazed China mosaic

2.1.1 Lime concrete Terracing : This is the most commonly adopted and oldest technique for providing water proofing of flat slabs newly constructed or old slabs.

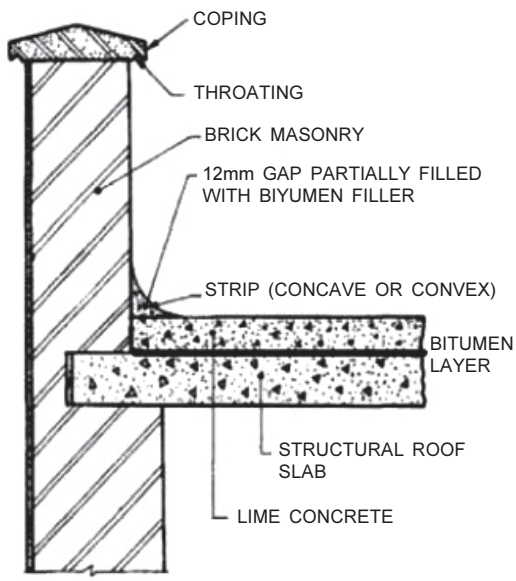
a) Preparation of lime concrete:-The lime concrete is prepared using brickbat koba (size 25 mm) and lime, brick surkhi mortar. The lime mortar is prepared separately in the ratio of 1 part slaked lime and 2 parts surkhi (brick pozolana) by volume (No sand is added). The surkhi can be replaced by burnt clay pozolana material. They are thoroughly mixed with required quantity of water, till a creamy consistency is achieved. The mortar should be grounded in a mortar mill or mechanical grinder. If for small quantity, grinder is not available, the mortar should be pounded to achieve a creamy consistency.

Brick bat (size 25 mm) aggregate, duly soaked in water for at least 6 hours, 2.5 times the volume of lime, is then spread on the level clean surface and the lime mortar prepared above is poured over the aggregate and the mixture turned till all the aggregate is coated with mortar. It is preferable to mix the concrete in mechanical mixer. In which case, the aggregate is fed first and mortar later. Many experienced masons add 12kg of bar soap and 4 kg of alum per cubic meter of concrete, after mixing in water, to decrease its permeability.

b) Surface preparation:-After cleaning the surface of concrete slab, all junctions with parapets or walls should be provided with fillets in lime concrete, all outlet pipes fixed, with fillets with their top level matching the final level of lime terrace concrete. The concrete surface is then painted with hot bitumen 80/100 @1.7 kg/m^2. Coarse sand is sprinkled over it, while the paint is wet. In case of old slab, where some cracks might be there, the cracks are grouted with cement slurry prior to application of bitumen coat. On drying of the bitumen paint the extra sand is swept away.

c) Placing of concrete :- Laying of the lime concrete should be done within 36 hours of mixing of mortar. The laying should start from the corner/edges towards the centre considering the slope required to be provided. In lime terrace minimum 1 in 60 slope should be provided. The thickness of the lime concrete should be average 100 mm. The concrete is initially rammed with wooden rammers and brought to a even and level surface. Then workers sit close together in a line, over the surface and tamp with wooden *thapis*, quite near each other. Normally, lateral clear space between two workers is maximum 500 mm. The tamping and laying of lime concrete should go on once started and sufficient labour is to be organized accordingly. During the

tamping operation lime water mixed with jaggery and *Bael* fruit (1.75 kg of *gur*(jaggery) + 1kg of bael fruit in 60 liter water) is liberally sprinkled over the surface. The tamping goes on till there is no impression of *thapis* on the concrete and the *thapi* rebounds from the surface. It takes about seven days of tamping to reach this stage. After continuous beating and consolidation, the mortar comes to top, which is finished smooth by trowel.



d) Curing and finishing: The surface is cured for 10 days by spreading straw over the surface which is kept wet by sprinkling water time to time. In case the terrace is accessible and is to be used by residents/ occupants, a layer of clay tiles set in lime mortar is fixed on the lime concrete.

The success of this procedure and system of treatment primarily depends on the quality of workmanship and the patience required for proper tamping and consolidating the lime concrete. Lately it is observed that due to improper workmanship and contractor and workers not exercising Q.C. measures, the lime concrete terraces remain permeable at some places, and this method should be adopted under strict quality control.

2.1.2 Water proofing with integrated cement based water proofing treatment with composite layer of brick bats and mortar

This method is a variation of Lime terracing as described above. The major difference is that instead of lime mortar, cement mortar with water proofing compound is used. This does not require tamping for 7 days etc. as in case of Lime concrete.

a) Surface preparation:- The surface shall be prepared by removing all old treatments like IPS/tar felt/plaster etc. and original slab surface shall be exposed. The cleaning of surface shall be done with wire brush or with pressure pipe to ensure that no loose particle /dust is left on the surface. Then after drying of surface the surface shall be then examined for cracks. In case of new slab, the surface should be

cleaned and any loose mortar or sprinkles of concrete should be removed by scraping or by wire brush.

b) Treatment of Cracks: - The identified cracks shall be marked and a V-groove 25mm wide at the top shall be made. and again cleaning the surface the cracks shall be then filled with cement mortar 1:3 with approved water proofing compound like CICO, as per manufacturer's specification.

c) Water proofing treatment:- A layer of cement mortar 1:3 mixed with water proofing compounds as per manufacturers specification shall then be laid. The cement mortar layer shall be average 20mm thick. A layer of brick bats shall then be laid with proper slope 1 in 100 towards down take pipes.

The brick bats to be laid for the purpose shall be well burnt bricks and properly soaked for a period of minimum 6 hours before laying. The brick bats (size 50-60mm) shall be laid when the bottom layer of mortar is still in wet condition and shall be firmly embedded in the mortar. The mortar is allowed to set for about 12 hours.

The slab is cured with water for a period of minimum 4 days. Then the brick bats shall be covered by filling the joints with cement mortar 1:3 with water proofing compound and with neat cement finishing at top. A false marking of 30 cm square on finished surface is made with masons line *dori* while the neat cement layer is wet.The average thickness of the water proofing layer is about 100mm.

d) Treatment of slab and parapet junction:- The junction of parapet and slab is treated along with the water proofing treatment up to a height of 30 cm.

For the treatment of junction construction of fillet and by making groove of size 75mm x 50mm at level of 300mm above slab and this should be finished at the time of finishing of slab itself.

A drip course in the form of offset shall be provided to avoid penetration of water at the junction.

e) Steps involved may be listed as below,

i) PREPARATION FOR TERRACE WATER PROOFING;-

1. Chisel the extra mortar accumulated on the terrace using a chisel and hammer.
2. Clean the terrace thoroughly with water jet.
3. Inspect entire slab for any crack if observed widen the crack in V shape and fill it with cement and sand proportion 1:3 with approved water proofing compound.
4. If there are some porous then it should be filled by grouting.

   Add one bag of cement to hundred liters of water. Stir the

mixture to get consistent cement slurry. Spread this slurry on the terrace and allow it to penetrate uniformly over the cleaned surface or apply cement water and approved water proofing compound slurry as like paint as per manufacturer's instructions.

5. Check the terrace door level and ensure that enough margin of approx. 150 mm for water proofing is left from the bottom side.
6. Check the level marked with red chalk on the parapet wall, all round.
7. Ensure that the rain water pipe outlet is bent in the correct position.

ii) Brick bat coba coat for terrace water proofing:-

1. Fix line *dori* in slope 1:100 starting from the lowest point of rainwater down take and by keeping a minimum thickness of 65mm below the rainwater outlet.
2. Fix brick bat in cement mortar layer of 1:5 proportion in a slope of 1:100 with the water proofing compound. Cured for 3 days
3. Fill the cement mortar 1:4 with water proofing compound in the brick bat joints.
4. Fix small pieces of brick bats along with 20mm metal for covering of 'watta' at the bottom of the parapet wall.
5. Special care should be taken for achieving the round shape near the rain water pipe.
6. Block the rain water outlet with gunny bags to avoid cement slurry from entering it.
7. Cure the brick bat coba for at least seven days.

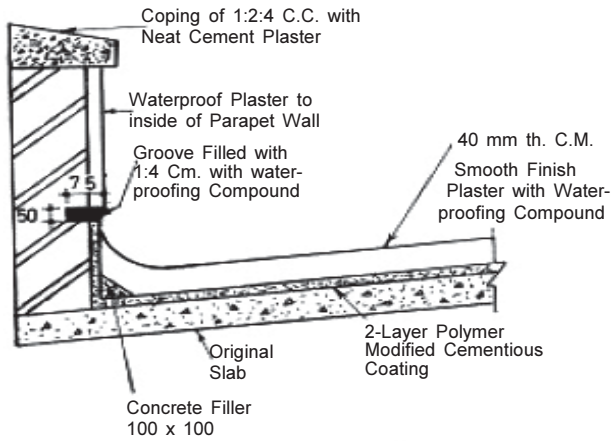
iii) Final coat for terrace water proofing:-

1. Spread cement –mortar in 1:4 proportion along with the water proofing compound over the brick bat coba.
2. Press the cement mortar with a ruler of length 2m
3. Level the surface with a wodden float, keeping 25mm thickness.
4. Polish the surface with metal float.
5. Make vertical and horizontal lines at an interval of 30cm x 30 cm using a cotton dori of minimum 3mm thickness. So as to avoid cracking of the top layer.
6. Make the projected edge between the parapet plaster and the watta on the second day

7. Clean and cure the final coat for 21 days with at least 6" water standing on the water proofing.

2.1.3 Water proofing with polymer modified cementitious slurry coating

Application of modified cementitious slurry coatings is the latest development in the field of water proofing. There are several branded formulations available in the market of cementatious polymer compounds. Polymer imparts significant improvement in impermeability of cement. Polymer modified cementitious slurry have coefficient of expansion very similar to concrete thereby it does not get cracked due to thermal variation of temperature of concrete. This treatment is used for both new slab or for old slab.



DETAILS OF WATERPROOFING TREATMENT ON TERRACE

a) Surface preparation: The preparation of surface and filling of crack is as per same discussed above under para 2.1.2.

b) Application of polymer modified cementatious slurry coating:

i) After surface preparation and filling of cracks complete, the surface should be pre-wetted for one hour.

ii) Dry blend and liquid blend as supplied are then mixed into the desired ratio as per recommendation of manufacturer/supplier. The mix shall be stirred thoroughly until no bubble remains in the mix. Any lump found in the mix shall be removed.

iiii) First coat of polymer modified cementitious slurry shall be applied by brush on wet cleaned surface. The normal thickness being about 3-4 mm.

iv) Subsequently, fiber glass cloth is laid over first coat of polymer modified cementitious slurry.

v) Second coat of polymer modified cementitious slurry is applied over fiber glass cloth, with brush.

vi) 1 more coat of Polymer modified cementitious brush topping shall be applied over second coat of polymer modified coating.

vii) Plane cement concrete, 1:2:4 (the nominal size of coarse aggregate being 10 mm and water/ cement ratio = 0.45) of

thickness 40mm, admixed with suitable water proofing compound is laid to a minimum slope of 1 in 100, like IPS . This can also be replaced by brick bat koba and mortar mixed with water proof compound as in method given under 2.1.2, instead of I.P.S.

viii) The surface should be cured with water ponding for 15 days.

Above system may slightly differ depending upon the instruction of manufacturer of water proofing system. There is no relevant Indian standard / other codes of practice for this system. Therefore work should be carried out as per manufacturer's specifications.

2.1.4 Water proofing by Glazed China mosaic

Various types of colour combinations and patterns can be obtained in this type of water proofing work so it is some expensive than other treatments and preferred when the terrace is to be used as sit out etc. Technical advantage of this type of water proofing is that china mosaic pieces offer a impermeable and smooth surface, so by fixing china mosaic 80% area becomes impermeable and possibility of development of hair-line cracks due to temperature variation is minimised.

a) Treatment:- This is same type of treatment as discussed above in para **2.1.3** but at the time of finishing of top of surface with I.P.S. or brick bat koba in water proof mortar, pieces of broken glazed tiles are pressed and fixed in the top mortar layer in various patterns.

b) Procedure for fixing tile pieces:- The brick bat coba or I.P.S. is done as discussed above except for the final coat of finishing. Instead of finishing the final coat with neat cement slurry it is roughened to receive the china mosaic treatment.

i) The roughened top of brick bat coba is cleaned.

ii) Over top surface cement mortar made in proportion 1:3 is spread uniformly on the surface with a thickness of 20 to 25mm. This is allowed to harden for one day.

iii) Design pattern if any is marked on the bed with the line dori then water is sprinkled on the work area for 15 minutes and cement slurry of creamy consistency of thickness 2-3 mm is spread on this area and pieces of broken glazed tiles are then pressed and fitted in position. The joints between the two pieces of tile pieces should not be more than 3-4mm.

iv) The joints are grouted with cement mixed with water proofing compound @ 1kg per bag of cement or as per recommendation of manufacturer. If colour joints are required then grey cement is raked and white cement with desired pigment is filled in joints and surface is cleaned with saw dust.

2.2 Water proofing the old slabs: The procedure for treating new roofs for making them water proof has been explained above, and the same method is also used for old roofs if the leakage is significant, after removing all the old treatment existing on the roof. However, if the leakage is only minor, or at few locations complete renewal of w.p. treatment need not be done and membrane based water proofing treatment is given over the existing system only.The membrane system may be based on bituminous coats or various other products of elastomers like vinyl, polyurethane or epoxies. Commonly bitumen products are used in normal buildings and some of the methods are as under,

i) Painting roof slab with hot bitumen.
ii) water proofing with bitumen felts.

2.2.1 Painting roof slab with Hot bitumen:-

This is very basic and old type of treatment to roof by painting it with hot bitumen.

Details of procedure as follows,

a) Surface preparation:- The surface should be completely dry and it should be cleaned with wire brushes and cotton or gunny cloth. After removing all loose material and scales the surface shall be further cleaned with piece of cloth lightly soaked in Kerosene oil.

b) Painting with bitumen:- The surface prepared and treated shall be painted uniformly with bitumen of approved quality such as residual type petroleum bitumen of penetration 80/100,hot cut back bitumen or equivalent as per specifications of the manufacturer. The coat of bitumen shall be continued 15 cm along the vertical surfaces joining the roof. In case of parapet walls it shall be continued up to the drip courses.

Petroleum bitumen of penetration 80/100 shall be heated to a temperature of not less than 180 degree C and not more than 190 degree C and shall be applied on the roof surface at not less than 180 degree C .Similarly hot cut back bitumen shall be heated to a temp.165 degree -170 degree and shall be applied on the surface at not less than 165 degree C.

Due care shall be taken to see that no blank patches are left. The quantity of bitumen to be applied for 10 Square m of roof surface shall be 17 Kg. It is to be ensured that the bitumen layer does not peel off or leaves the parapet or the edge of the roof at the ends and to avoid this, a rebate is created horizontally all along the length of parapet and a key of bitumen is fixed in it along with applying bitumen on the surface and the parapet.

c) Spreading Sand:- Immediately after painting ,dry clean sharp coarse

sand at the rate of 60 cubic decimeter per 10 sqm shall be evenly spread and leveled over the surface when the bitumen is still hot.

2.2.2 Water proofing with Bitumen Felts:

a) Materials required for this type of treatment are as follows.

Self finished felt: The self finished felt shall be of brand and manufacture conforming to the type and grade given in the description of the item. This shall be one of the following types.

i) Type 2 grade 1 a glass fiber base bitumen felt conforming to IS-7193

ii) Type 2 grade 2 is a fiber(vegetable or animal) base felt conforming to IS:1322

iii) Type 3 grade 1 is a Hessian base felt conforming to IS;1322

Normally, glass fiber base bitumen felt conforming to IS-7193 is used.

Bonding Material: This shall consist of blown type petroleum bitumen confirming to IS:702 or residual petroleum bitumen conforming to IS:703 or mixture thereof.

Generally blown type petroleum bitumen of S-90 shall be used for the base and intermediate layer of bonding material and residual type petroleum bitumen with higher penetration and low softening point shall be used for the finishing layer. Suitable blown type petroleum bitumen of IS grade 85/25 of approved quality.

Stone grit: Stone grit shall be as specified and shall be of 6mm and down size but free of fine sand.

b) Preparation of Surface:-The surface to be treated shall have a minimum slope of 1 in 100. This grading shall be carried out with cement concrete or cement plaster with coarse sand. Junctions of roof and vertical faces of parapet walls shall be caused by running triangular fillets 7.5 cm x 7.5cm size in cement concrete.

While grading of roof surface is being done it shall be ensured that the outlet drain pipe have been fixed and mouth at the entrance have been eased and round off properly for easy flow of water.

The graded surface of the roof and concrete fillets and the faces of walls shall be thoroughly cleaned with wire brushes and all loose scales etc to be removed. Any crack in the roof shall be cut to V section, cleaned and filled up flush with cement mortar slurry 1:4 or blown type petroleum bitumen of IS grade 85/25,

c) Priming coat:- Where so specified, or required by the Engineer-In – Charge for example under slightly damp conditions a priming coat consisting of a bitumen primer applied with brush on the roof and wall surface at 0.24 liter per sq m to assist adhesion of the bonding

material.

d) Treatment:- The choice of a four or six course treatment will depend on the climatic condition, the importance of the building , the durability required, cost and other conditions. Four stage treatment is given for normal use and six stage treatment for heavy duty usage. For Extra heavy usage another layer of felt and bonding agent is applied, resulting in 8 stage treatment.

- **Four course treatment** shall consist of the following layers.
  1. Initial layer of bonding materials, normally bitumen applied hot at specified weight per unit area.
  2. Second layer of self finished glass bitumen felt of specified brand and manufacture conforming to the type and grade.
  3. Third layer of hot bitumen or any other specified bonding material.
  4. Final layer of stone grit of pea sized gravel spread at specified volume of material per unit area.
- **In a six coarse treatment**, the first, second and third layer shall be of the same as in the four course treatment. The fourth and fifth layer shall consist of self finished felt and bonding material respectively. The sixth layer shall consist of stone grit or pea sized gravel.

e) Laying

Bitumen bonding material shall be heated to the following temperature.

- Blown type petroleum bitumen of IS grade 85/25 to 180 deg. C.
- Residual type petroleum bitumen of penetration 30/40, 180 to 190 degree C.

The heated bitumen shall be sprayed in specified quantities over the roof slab to be treated.

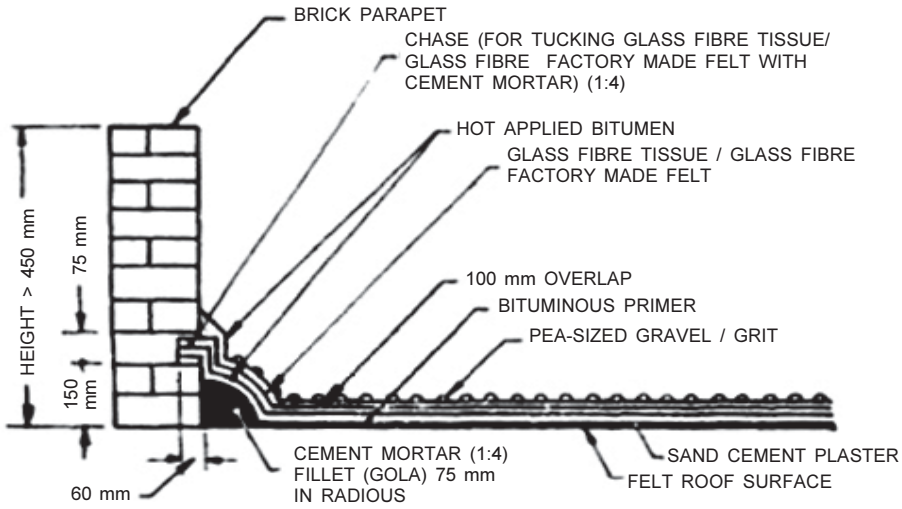
Water proofing treatment shall be carried into the drain pipe or outlets by at least 10 cm. The water proofing treatment laid on the roof surface shall over lap the upper edge of the water proofing treatment in the drain outlets by at least 10 cm.

The self finished felt shall be cut the required length, brushed clean of dusting material and laid out flat on the roof to eliminate curls and subsequent stretching. The felt shall normally be laid in length at right angles to the direction of the slope and laying shall be commenced at the lowest level and worked up to crest. The felt shall not be laid in single piece of very long lengths as they are likely to shrink, 6 to 8m are suitable lengths for laying.

Hot bonding material shall be poured on the roof over the felt in specified and uniform quantity while the felt is steadily rolled out. This process will continue strip by strip. Each strip shall overlap the preceding one

by at least 7.5 cm at the longitudinal edges and 10 cm at the ends. All overlaps shall be firmly bonded with hot bitumen. Unevenness if formed shall be leveled by heating with a blow lamp. The process shall continue till the required numbers of layers are laid.

In six course treatment the third and fourth layers of bonding material and self finished felt shall be laid in the manner described above taking care that laps in the felt are stagger from those in the second layer.



WATERPROOFING ON A FLAT ROOF WITH BRICK PARAPET OVER 450 mm IN HEIGHT - TYPICAL DETAILS

3.0 Water proofing for Water closet where sunk is provided.

a) Preparatory work-Generally Sunk is proved for Indian WC pan and before water proofing this unit it is better to complete the concealed pipe line and electrical work if any in this area. and holes in external walls be done for P- trap, floor trap , etc.

b) Steps of procedure:

i) After cleaning the base of sunk slab base coat of 25mm thick is provided with cement and sand mortar 1:4 with water proofing compound after application of polymer modified slurry as discussed above. Slope of 1:100 should be provided in base coat mortar only and this base coat should be continued on the walls up to height 45 cm above floor finish level.

ii) After proper curing of this base coat provide 25mm G.I. pipe for water escape outlet just above the base coat as shown in fig.

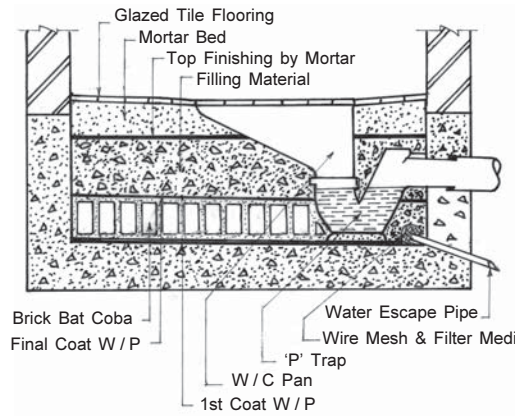
iii) Over the base coat fixing of P trap should be done by plumber and then brick bat koba is done by placing well burnt bricks in the edges and the joints filled with cement mortar in 1:6 proportion. And cure the surface for four days, care should be taken that the joints filled at this time are only half filled joints minimum 25mm below the top surface of bricks .

iv) After curing of Brick bat koba top surface is applied with Cement mortar 1:4 mixed with water proofing compound and finish the top surface properly with neat cement slurry by metal float roughening of the surface should be done by wire brush this course should be continued on sidewalls up to 45 cms.

v) Fix the W.C. pan at the required level considering the minimum 15mm sunk from the floor finish level of room .Then block the P-trap outlet hole with gunny bags and fill the WC pan with sand.

Fill the extra gap around WC pan over the topping coat with brick bat and mortar in layer up to 7.5 cm below top of Indian WC.

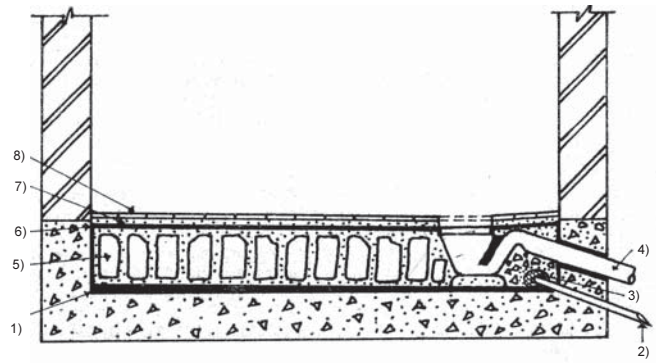
vi) Final topping coat should be done up to 50mm below top of Indian WC and roughen the surface for receiving tiled floor.



DETAILS OF W.C. WATER-PROOFING

4.0 Water proofing of Bathrooms

Same procedure is adopted for bathrooms and places where European style WC pot to be fixed only margin of brick bat coba may not be available due to less depth of sunk in such case with same procedure small pieces of bricks should be fixed on the base coat



1) 1st Coat W/P
2) Water Escape Pipe
3) Wire Mesh and Water Filter Media
4) Nahani Trap
5) Brick Bal Coba
6) Final W/P (I.P.S. Finish)
7) Mortar Bed
8) Flooring

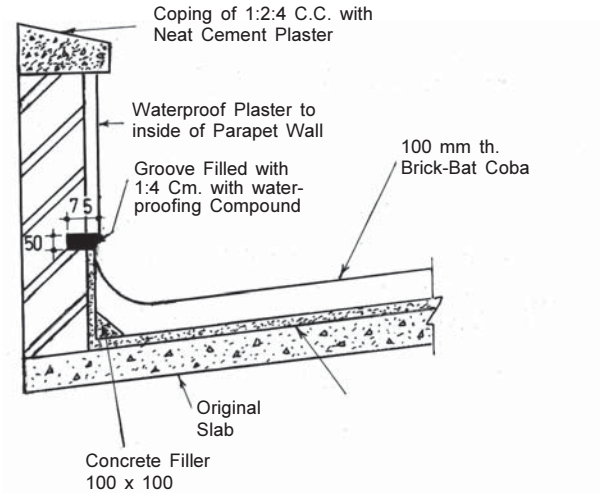
and should be finished as per brick bat coba. If sufficient margin is available for placing the brick on edge then same procedure should be followed after base coat by fixing Nahani trap and escape pipe properly as shown in fig.

5.0 Junction of roof with parapet wall: Junction of roof with parapet wall is vulnerable location for leakage. To do it as leak proof following work should be ensured.

i) The fillet (angular or concave not convex) 75mm should be provided all along the junction of parapet wall with roof.

ii) Coping on top of the parapet wall should also be provided with adequate slope along with the provision of drip course on either side.

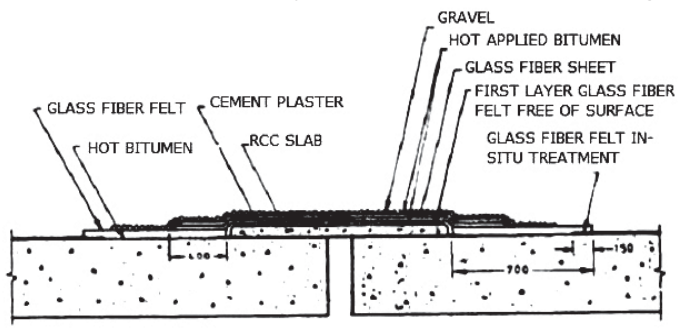
iii) Water proofing system should be extended from roof to parapet wall for minimum height of 150mm with a chase.



DETAILS OF WATERPROOFING THE JUNCTION OF PARAPET AND ROOF

6.0 Expansion Joint: The treatment to make the expansion joints water proof are explained in sketches, below, which are self explanatory. Expansion joints must be treated with suitable non-absorbent, compressible, non-brittle and water tight sealants so that they are capable of taking the expansion and contraction of the slab due to temperature variations and stay integral with the slab and prevent any leakage. Brief details of some of the common methods used are given below,

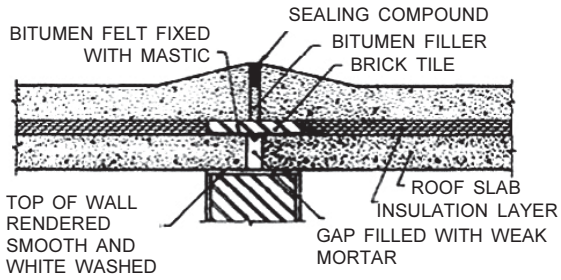
a) Water proofing of expansion joint in RCC slab using Bitumen with glass fiber felt, is used normally when the water proofing of RCC slab is done by application of hot bitumen on the concrete surface. A precast RCC slab is used to bridge the gap between the



WATER PROOFING OF EXPANSION JOINT WITH GLASS FIBER FELT ON RCC ROOF

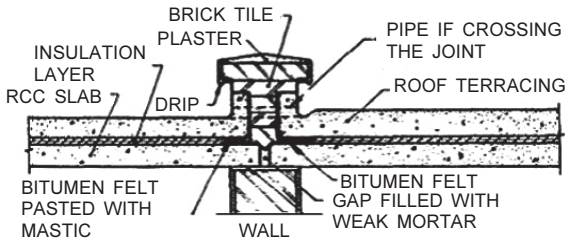
joint and two layers of glass fiber felt is used following the procedure of water proofing using bitumen felt a explained in para 2.2.2.

b) Lip type joint in slab:- when the joint is supported on a wall and the RCC slab is provided with Lime concrete terracing or equivalent Lip type joint is provided. At the time of doing the lime concrete for terrace, a bitumen felt is fixed bridging the gap keeping an extra length folded to allow for expansion of slabs due to temperature, and brick tiles are placed over the felt and the water proofing treatment is done as explained by sketch.



LIP TYPE JOINT IN SLAB OVER WALL

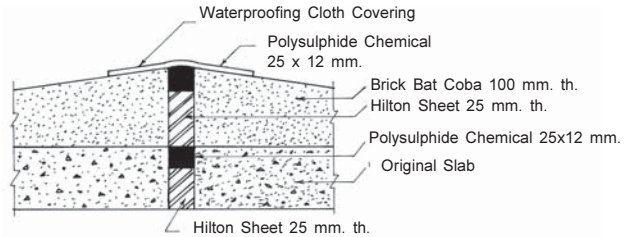
c) Parapet joint at terrace: A variation of the above treatment is as detailed in sketch below. This is adopted normally when a parapet is required for other reasons, at a location where wall may or may not be supporting the joint, such as for supporting any pipe line etc.



PARAPET JOINT AT TERRACE WITH OR WITHOUT WALL

d) Treatment using polysulpide: This is very common way of treating an expansion joint in roof slab. The joint between slab is filled with polysulphide chemical which provides a good seal against seepage of water and also compresses and extends to accommodate the expansion contraction of RCC slab due to temperature variations. PIDISEAL PS42P is a branded product from M/S Pidilite Industries, which is two pack Polysulphide sealant. There are other makes also available in the market.

Polysulphide forms a tough permanent rubber like seal, grey in colour which is resistant to bio-degradation and U.V.rays effect of sun light.



TREATMENT TO EXPANSION JOINT

Procedure for laying:

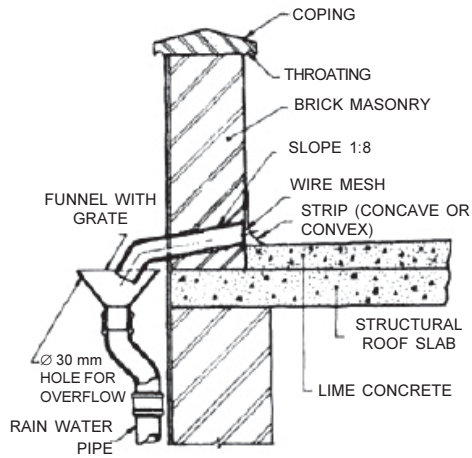
1) The laying starts soon

after casting and curing the slab is completed. This treatment is done in two layers, one at slab top level and another at terrace level after the water proofing of slab has been completed.

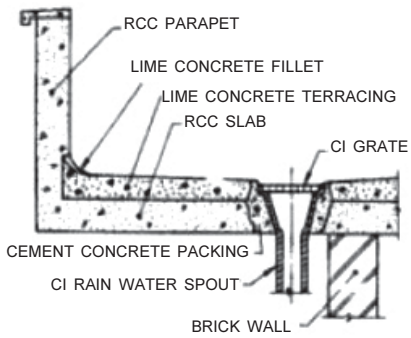
2) Clean the joint surfaces with wire brush and remove all loose particles. Repair the damaged edges of the joint, if any, with 1:2 cement plaster.
3) The expansion gap is normally kept as 25 mm wide. While treating the first layer i.e. the RCC slab, fill the gap with Hilton sheet or Shalitex board to leave a depth of 12 mm to be filled with Polysulphide chemical.
4) Apply a coat of primer (PIDIPRIMER in case of PIDISEAL is being used) with brush, it cleans any dust particles and also provides proper bond of concrete with Polysulphide.
5) Fill the gap with polysulphide sealant with the help of trowel or polish *patra* matching the top surface with the slab top.
6) Complete the laying of Lime concrete terrace or othe water proofing treatment over slab leaving a gap of 25 mm over the joint.
7) Repeat the process as detailed in items 1) to 5) above for second layer of treatment.
8) The joint so prepared is covered by pasting a plastic sheet/ felt on top of the joint.

7.0 Outlets for rain water pipes: The junction of the roof slab with the parapet is another weak spot from where leakage takes place.

The outlet pipes for rain water should be provided as shown above, either from the fillet/strip joining the parapet wall to the the water proofing layer or in case of overhung parapet from near the wall. The bell mouth is



ARRANGEMENT OF DOWN TAKE PIPE

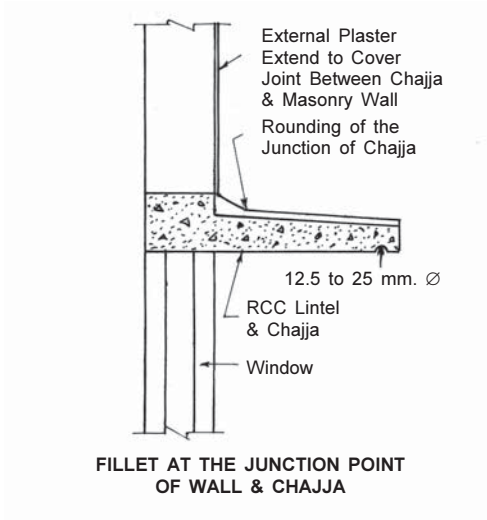


DETAILS OF RAIN WATER PIPE ON A OVERHANG PARAPET

provided in both cases and the concrete is packed in the gap beyond the outlet pipe. A layer of chicken wire mesh in the opening, prior to concrete packing gives much better bond between old and new concrete surfaces.

8.0 Water proofing of Chajjas

The junctions of lintel and chajjas beams are the sources of leakage of water if not given proper care. While doing water proofing treatment to chajjas first clean the top surface of chajjas including joint with beam and apply thick cement slurry over the top of chajjas including joint of lintel beam and brick masonry .Then spread metal screed coat of 1:1.5:3 of concrete with water proofing compound taking due care of slope generally 1:100 and making fillet of 50mm x 50mm at the junction with wall and then after curing for at least one day then apply smooth finish plaster with 1:4 cement mortar with water proofing compound and make a drip mould or groove of size 12.5mm dia at the bottom edge as shown in fig.



FILLET AT THE JUNCTION POINT OF WALL & CHAJJA

CHAPTER 9

STAIRCASE, LINTELS AND CHAJJAS

1.0 Stair-case

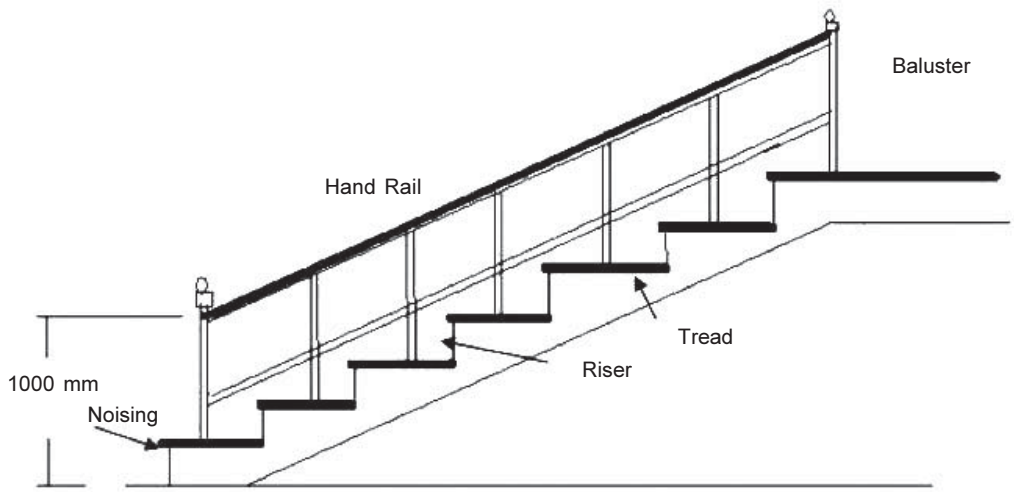
A stair is defined as a sequence of steps and it is provided to afford the means of ascent and descent between the floors or landings. The apartment or room of a building in which the stair is located is known as **staircase**.

Riser - The vertical or front member of the step which is connected to the treads is known as riser.

Treads - The horizontal upper portion of a step is known as tread.

1.1 Requirement of a good stair

1.1.1 The staircase in a residential building should not have a **riser** of more than 190 mm and a **tread** of less than 250mm, without nosing. For public buildings it is desirable to have a riser of not more than 150mm and a tread of not less than 300 mm.



1.1.2 Minimum Width: The width of stair should be sufficient for two persons to pass on it simultaneously and for furniture, etc to be carried up and down the stair . The minimum width of a stair is taken as about 750mm for row housing of two storeys. The minimum recommended width of staircase shall be as follows

S.No.	Use of Building	Width (meter)
1	Residential bldg.	1.0
2	Residential hotel (Guest House)	1.5
3	Public gathering like auditorium etc.	2.0
4	Educational bldg	1.5
5	Institutional bldg.	2.0
6	All others	1.5

1.1.3 Pitch: The inclination of a stair to the horizontal should be close to 30 degree.

1.1.4 Flight: It is not desirable to provide a flight with more than 12 steps and not less than 3 steps. Suitable landing should be provided to give comfort and safety to the users for the stair after every flight.

1.1.5 Head room: The minimum clear head room should be 2.2m, measured from the top of riser to the ceiling

1.1.6 Hand Rail: Hand rails shall be provided at a height of 1.0m from middle of the treads to the top of the rail. Balusters and hand rails shall be so provided that the width of the staircase does not reduce.

1.1.7 If the height of the building is more than 5 storeys, and any building used as educational, public assembly, Institutional etc with area of 500 sqm on each floor, there shall be minimum 2 staircases, for Fire Safety Regulations.

2.0 Lintels and Chajjas

2.1 A lintel is a horizontal member used to span openings in walls for doors, windows, passages etc.

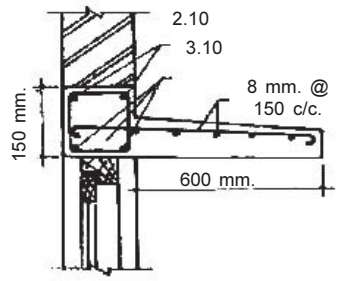
Lintels can be classified according to the material it is made as follows

a) Timber lintels
b) Stone lintels
c) Brick lintels
d) Steel lintels
e) Reinforced concrete lintels

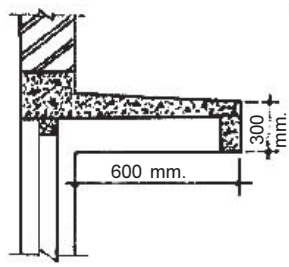
Lintels work as a beam to support the dead and live load over an opening. In old buildings stone lintels were commonly used for door ways and openings. Nowadays stone lintels are used only for small openings and in low cost houses. As stones are weak in tension there are limitations for use of stone as lintels. Other type of lintels such as timber lintel, brick lintel and steel lintels have their own limitations and may not offer a very aesthetic solution.

2.1.2 Reinforced concrete lintels are the most commonly used type as other type of lintels such as timber lintel, brick lintel and steel lintels have their own limitations. Usually lintels are combined with Chajjas. To protect the building from the sun and rain, chajjas are required for windows facing the east, west and south. Chajjas also help in making the elevation more attractive. Chajjas should not be provided normally for north facing windows as they reduce day light illumination to some extent.

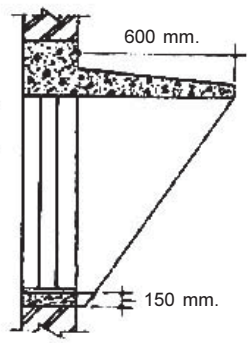
2.1.3 The figure shows a typical detail for reinforcement for chajja and lintels. According to varing length of spans and thickness of walls details tabulated in Table no. 1 and 2 may be used as guide lines for reinforcement for load bearing structures.



SECTIONAL VIEW OF
RCC LINTEL WITH CHAJJA



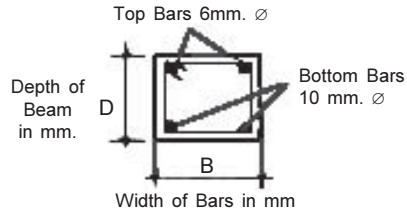
CHAJJA WITH
SUN BREAKING



CHAJJA WITH
RAIN BREAKING

2.1.4 According to varying length of spans and thickness of walls details tabulated in Table may be used as guide lines for reinforcement for lintel with or without chajja (Type I),

a) Details of reinforcement for Lintel without chajja upto 1.1m span of opening

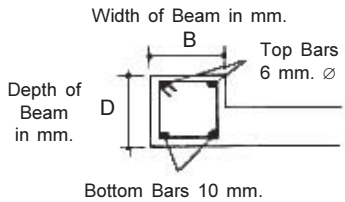


SECTION OF LENTEL W/O CHAJJA

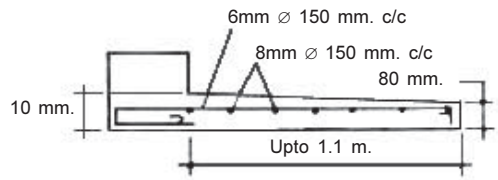
Thick ness of wall (A)	Width of beam (B)	Depth of beam (D)	No of 10 mm ⌀ bars at bottoms of Lintel		
			Up to span 700mm	Span of 700-900	Span of 900-1100
230 mm	230mm	100mm	2	2	2
345mm	340mm	100mm	3	3	3
460mm	460mm	100mm	3	3	3

Note: For top reinforcement 2 bars of 6mm ⌀ to be provided for all spans. Stirrups should be provided at 140mm c/c of 6mm dia.

b) Details of reinforcement for Lintel without chajja up to 1.1M



SECTION OF LINTEL WITH CHAJJA



SECTION OFCHAJJA

Thickness of wall (A)	Width of beam (B)	Depth of beam (D)	No of 10 mm ⌀ bars at bottoms of Lintel		
			Up to span 700mm	Span of 700-900	Span of 900-1100
200 mm	200mm	200mm	2	2	2
300mm	300mm	200mm	3	3	3
400mm	400mm	200mm	3	3	3

Note: For top reinforcement 2 bars of 6mm ⌀ to be provided for all spans. Stirrups should be provided at 80mm c/c of 6mm dia.

3.0 Sunbreakers/Rainbreakers

3.1 Orientation of a building is fixed by studying the sun diagram indicating the path of the sun at a particular place during the day and during the year. The atmosphere inside the house is made comfortable by choosing proper materials and methods of construction.

Wall facing the east, south and west are protected by chajjas, sun shades or vertical louvers to cut off rays of the sun whenever not required and to regulate the flow of light and heat through openings in the wall .These projections cast shadows on the opening of the window area and also protect the walls from the rain.

3.2 The following suggestions will be helpful in fixing the orientation of a building.

Long walls of the building should be placed towards the north and south and short wall towards the east and west to minimize the area of the walls exposed to the sun, thus keeping the temperature inside the building comfortable.

If the front wall of a structure is facing the south, sun-breakers should be provided on the windows on that side.

3.3 Sun breaker is an element of construction projecting on the external face of the wall. It is provided on the west and south face of the building to protect from sun and rain. Sometimes a combination of vertical and horizontal louvered is made.

The maximum permissible projection for chajjas and louvers is 750mm according to bye-laws.

3.4 General consideration in planning of sunshades are that the sunshades should project for a length not less than that required to protect the window or door leaf that may open out, from rains. As a shading device, it is taken as a minimum of 60 cm for the main windows of residence and up to one meter in the front side of the entrance door.
Side drops are sometimes provided on the north side for the sunshades of windows but never for the doors. Similarly facia for sunshades can be provided generally in the front side and vertical drops can be provided on western side windows, if necessary as a shading device.

Thus the whole layout of sunshades will depend on the shading required from the sun as well as the protection of the window leaves opening form the rains. A typical rain breaker is shown in sketch.

Ventilators and openings in bathrooms or kitchen usually do not require sunshades but can be given on outside border.

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