

A.P.HOUSING BOARD

DRAFT

QUALITY MANUAL

NOTE:- The Manual is under preparation and finalization subject to changes. This is for the guidance of the engineers of the A.P.H.B for execution of works.

QUALITY POLICY

To ensure continual improvements by adopting innovative methods of construction with quality and transparency to reach the beneficiary to his expectations and satisfaction.

Vice Chairman and Housing Commissioner
A.P. Housing Board, Hyderabad

I N D E X

S.NO.	PARTICULARS	PAGE NOS.
1)	GUIDE LINES TO START WITH	3-4
2)	CIVIL WORKS: Materials and construction practice	5-91
	TESTS	92-140
3)	AMENITIES AND INFRASTRUCTURE	141-174
4)	EARTH QUAKE TIPS	176-181

GUIDE LINES TO START WITH

1. As soon as the possession of the land is taken over from the revenue/ others, the boundary pillars shall be fixed and the land shall be protected from encroachments.
2. A detailed contour survey shall be carried out to know the topography of the terrain. The contour plans shall be forwarded to planning wing for formulation of layouts.
3. The estimates shall be prepared with accuracy to avoid enhancement of unit cost at the end.
4. Before grounding the scheme, ensure the following are completed.
 - a) Zonal conversion if required to be taken care of.
 - b) Layout approval along with building plans.
 - c) The soil exploration (S.B.C).
 - d) The structural designs shall be kept ready.

During the Execution:-

1. Pre levels should be recorded for the respective blocks/units before starting the earth work excavation.
2. Centre line pillars shall be fixed for reference points to columns / footings. The diagonals shall be verified at each level.
3. The foundations shall be carried out according to the designs duly ensuring the required depths and soil strata.

4. Any deviation in the soil profile the same has to be brought to the notice of the design wing and superior officers.
5. Ensure that the contractor established Quality Control lab for material testing etc.
6. The required check list, OK cards have to be followed strictly during execution.

7. The site Engineers should be thorough with the specification and other contents of the Agreement.
8. Any deviation shall be carried out with the prior permission of the Competent Authority.
9. Quality of the construction material shall be tested before using at site.
10. Site order books along with the quality control lab records etc. shall be maintained at site.
11. I) Ensure that minors are not employed by the contractor.
II) Ensure that contractor follows safety precautions while carrying out the works.
12. Project monitoring shall be done by CPM/PERT.
13. One model flat/House have to be completed for inspection of the allottees.
14. Road formation levels and basement levels are to be finalized before starting the foundation work.
15. Allottees are a part of our organization and activities.
Hence address their grievances quickly and amicably.
16. Rainwater harvesting shall be provided for recharging the ground.
17. Plantation of trees invariably be taken up to encourage the green environment.

REQUIREMENTS OF PARTS OR BUILDINGS: (As Per National Buildings Codes)

Plinth:

Main Buildings: The plinth or any part of a building or outhouse shall be so located with respect to the surrounding ground level that adequate drainage of the site is assured. The height of the plinth shall be not less than 450 mm from the surrounding ground level.

Interior Courtyards and Covered Parking:

Every interior courtyard shall be raised at least 150 mm above the determining ground level shall be satisfactory drained.

Habitable Rooms.

Height.

The height of all rooms for human habitation shall not be less than 2.75 m measured from the surface of the floor to the lowest point of the ceiling (bottom of slab). In the case of pitched roof, the average height of rooms shall not be less than 2.75 m. The minimum clear headroom under a beam, folded plates or eaves shall be 2.4 m. In the case of air-conditioned rooms, a height of not less than 2.4 m measured from the surface of the floor to the lowest point of air-conditioning duct or the false ceiling shall be provided.

The requirements of height apply to residential, business and mercantile buildings. For educational and industrial buildings, the following minimum requirements apply:

- a) Educational Ceiling height 3.6 m for all regions; in cold

Buildings	regions, 3 m
(b) Industrial Buildings	Ceiling height 3.6 m for except when air-conditioned, 3 m (Factory Act 1948 and Rules therein shall govern such heights, where applicable).

Size:

The area of habitable room shall not be less 9.5 m², where there is only one room with a minimum width of 2.4 m. Where there are two rooms, one of these shall not be less than 9.5 m² and other not less than 7.5 m², with a minimum width of 2.1 m.

Kitchen

Height:

The height of a kitchen measured from the surface of the floor to the lowest point in the ceiling (bottom slab) shall not be less than 2.75 m, except for the portion to accommodate floor trap of the upper floor.

Size:

The area of a kitchen where separate dining area is provided, shall be not less than 5.0 m² with a minimum width of 1.8 m. where there is a separate store, the are of the kitchen may be reduced to 4.5 m². A kitchen, which is intended for use as a dining area also, shall have a floor area of not less than 7.5 m² with a minimum width of 2.1 m.

Other Requirements:

Every room to be used as kitchen shall have:

- (a) Unless separately provided in a pantry, means for the washing of kitchen utensils which shall lead directly or through a sink to a grated and trapped connection to the waste pipe;
- (b) An impermeable floor;
- (c) A flue, if found necessary; and
- (d) A window or ventilator or opening of size not less than as specified

Bathrooms and Water Closets:**Height:**

The height of a bathroom or water closet measured from the surface of the floor to the lowest point in the ceiling (bottom slab) shall not be less than 2.1 m.

Size:

The area of a bathroom shall not be less than 1.8 m² with a minimum width of 1.2 m. The floor area of water closet shall be 1.1m² with a minimum width of 0.9 m. If bath and water closet are combined, its floor area shall be 2.8 m² with a minimum width of 1.2 m.

Other Requirements:

Every bathroom or water closet shall:

- a) be so situated that at least one of its walls shall open to external air;
- b) not be directly over or under any room other than another water closet, washing place, bath or terrace, unless it has a water tight floor;
- c) Have the platform or seat made of water tight non-absorbent material;
- d) Be enclosed by walls or partitions and the surface of every such wall or partition shall be finished with a smooth impervious material to a height of less than 1 m above the floor of such a room;
- e) Be provided with an impervious floor covering, sloping towards the drain with a suitable grade and not towards VERANDAH or any other room; and
- f) Have a window or ventilator, opening to a shaft or open space, of area not less than 0.3 m² with side not less than 0.3 m.

No room containing water closet shall be used for any purpose except, as a lavatory and no such room shall open directly into any kitchen or cooking space by a door, window or other opening. Every room containing water closet shall have a door completely closing the entrance to it.

Ledge or TAND/Loft**Height:**

The minimum headroom of ledge or TANDA/Loft shall be 2.2 m. The maximum height of loft shall be 1.5 m.

Size:

A ledge or TANDA/Loft in a habitable room shall not cover more than 25 percentage of the area of the floor on which it is constructed and shall not interfere with the ventilation of the room under any circumstances.

Mezzanine floor:

It shall have a minimum height of 2.2 m

Size:

The minimum size of the mezzanine floor, if it is to be used as a living room, shall not be less than 9.5 m². The aggregate area of such mezzanine floor in a building shall in no case exceed one-third the plinth area of the building.

Other Requirements:

A mezzanine floor may be permitted over a room or a compartment provided:

- a) it conform to the standard of living rooms as regards lighting and ventilation in case the size of mezzanine floor is 9.5 m² or more;
- b) it is so constructed as not to interfere under any circumstances with the ventilation of the space over and under it;
- c) such mezzanine floor is not sub-divided into smaller compartments;
- d) such mezzanine floor or any part of it shall not be used as a kitchen; and
- e) in no case shall a mezzanine floor be closed so as to make it liable to be converted into unventilated compartments.

Store Room:

The height of a storeroom shall be not less than 2.2 m.

Size:

The size of a storeroom, where provided in a residential building, shall be not less than 3 m².

Garage:**Height:**

The height of a garage shall be not less than 2.4 m.

Size:

The size of garages shall be as below:

- a) Private Garage: 3.0 m x 6.0 m, minimum; and
- b) Public Garage: Based on the number of vehicle parked, etc.

Basement:

The basement shall not be used for residential purposes.

The construction of the basement shall be allowed by the Authority in accordance with the land use and other provisions specified under the Development Control Rules.

The basement to be constructed within the building envelope and subject to maximum coverage on floor 1 (entrance floor) may be put to only the following uses:

- a) Storage of household or other goods of ordinary non-combustible material;
- b) Strong rooms, bank cellars, etc;
- c) Air-conditioning equipment and other machines used for services and utilities of the building; and
- d) Parking spaces.

The basement shall have the following requirements:

- a) Every basement shall be in every part at least 2.4 m in height from the floor to the underside of the roof slab or ceiling;
- b) Adequate ventilation shall be provided for the basement. The ventilation requirements shall be the same as required by the

particular occupancy according to bylaws. Any deficiency may be met by providing adequate mechanical ventilation in the form of blowers, exhaust fans, air-conditioning systems, etc;

- c) The minimum height of the ceiling of any basement shall be 0.9 m and the maximum, 1.2 m above the average surrounding ground level;
- d) Adequate arrangements shall be made such that surface drainage does not enter the basement.
- e) The walls and floors of the basement shall be watertight and be so designed that the effects of the surrounding soil and moisture, if any, are taken into account in design and adequate damp proofing treatment is given; and
- f) The access to the basement shall be separate from the main and alternative staircase providing access and exit from higher floors. Where the staircase is continuous in the case of buildings served by more than one staircase, the same shall be of enclosed type serving as a fire separation from the basement floor and higher floors. Open ramps shall be permitted if they are constructed within the building line.

The exit requirements in basements shall comply with the provisions of 'Fire and Life safety'.

Chimneys:

The chimneys shall be built at least 0.9 m above flat roofs, provided the top of the chimneys is not below the top of the adjacent parapet wall. In the case of sloping roofs, the chimney top shall not be less than 0.6 m above the ridge of the roof in which the chimney penetrates.

Parapet:

Parapet walls and handrails provided on the edges of roof terraces, balcony, VARANDAH, etc shall not be less than 1.0 m and not more than 1.2 m in height from the finished floor level.

Cabin:

The size of cabins shall not be less than 3.0 m² with a minimum width of 1.0 m. The clear passages within the divided space of any floor shall not be less than 0.75 m and the distance from the farthest space in a cabin to any exit shall not be more than 18.5 m. In case the sub-divided cabin does not derive direct lighting and ventilation from any open spaces/ mechanical means, the maximum height of the cabin shall be 2.2 m.

Boundary Wall:

The requirements of the boundary wall are given below:

- a) Except with the special permission of the Authority, the maximum height of the compound wall shall be 1.5 m above the centre line of the front street, compound wall up to 2.4 m height may be permitted

if the top 0.9 m is of open type construction of a design to be approved by the Authority.

- b) In the case of a corner plot, the height of the boundary wall shall be restricted to 0.75 m for a length of 10 m on the front and side of the inter-sections and the balance height of 0.75 m if required in accordance with (a) may be made up of open type construction (through railings) and of design to be approved by the Authority.

- c) However, the provisions of (a) and (b) are not applicable to boundary walls of jails. In industrial buildings electric sub-stations, transformer stations, institutional buildings like sanatoria, hospitals, industrial buildings like work shops, factories and educational buildings like schools, colleges, including hostels, and other uses of public utility undertakings and strategically sensitive buildings a height up to 2.4 m may be permitted by the Authority.

Septic Tanks:

Where a septic tank is used for sewage disposal, the location, designed and construction of the septic tank shall conform to requirements of 'Plumbing

Services, section 1 water supply, Drainage and sanitation (including solid waste management)'.

Location of the Septic Tanks and Subsurface Absorption Systems:

A sub soil dispersion system shall not be closer than 18 m from any source of drinking water, such as well, to mitigate the possibility of bacterial pollution of water supply. It shall also be as far removed from the nearest habitable building as economically feasible but not closer than 6 m, to avoid damage to the structures.

Requirements:

- a) Dimensions of septic tanks – Septic tanks shall have a minimum width of 750 mm, a minimum depth of 1 m below the water level and minimum liquid capacity of 1 m³. The length of tanks shall be 2 to 4 times the width;
- b) Septic Tanks may be constructed of brickwork, stone masonry, concrete or other suitable materials as approved by the Authority.
- c) Under no circumstances shall effluent from a septic tank be allowed into an open channel drain or body of water without adequate treatment.
- d) The Minimum nominal diameter of the pipe shall be 100 mm. Further, at junctions of pipes in manholes, direction of flow from a branch connection shall not make an angle exceeding 45° with the direction of flow in the main pipe;
- e) The gradients of land drains, under-drainage as well as the bottom of dispersion trenches and soak ways shall be between 1:300 and 1:400;
- f) Every septic tank shall be provided with ventilating pipe of at least 50 mm diameter. The top of the pipe shall be provided with a suitable cage of mosquito-proof wire mesh. The ventilating pipe shall extend to a height, which would cause no smell nuisance to any building in the area. Generally, the ventilating pipe may extend to a height of about 2

m, when the septic tank is at least 15 m away from the nearest building and to a height of 2 m above the top of the building when it is located closer than 15 m;

- g) When the disposal of septic tank effluent is to a seepage pit, the seepage pit may be of any suitable shape with the least cross-sectional dimension of 0.90 m and not less than 1.00 m in depth below the invert level of the inlet pipe. The pit may be lined with stone, brick or concrete blocks with dry open joints, which should be backed with at least 75 mm of clean coarse aggregate. The lining
- h) above the inlet level should be finished with mortar. In the case of pits of large dimensions, the top portion may be narrowed to reduce the size of the RCC cover slabs. Where no lining is used, specially near trees, the entire pit is should be filled with loose stones. A masonry ring may be constructed at the top of the pit to prevent damage by flooding of the pit by surface runoff. The inlet pipe may be taken down a depth of 0.90 m from the top as an anti-mosquito measure; and
- i) When the disposal of the septic tank effluent is to a dispersion trench, the dispersion trench shall be 0.50 m to 1.00 m wide

REQUIREMENTS OF BUILDING CONSTRUCTION:

1. Selection of Site : The selection of site for construction of housing projects mainly depends on the following.

- 1) Demand for housing
- 2) Easy connectivity to local transport system
- 3) Accessible to Hospitals, Educational Institutions, shopping center & Government Offices and Banks.
- 4) Last but not least the cost of land.

2. Site Reconnaissance : It includes the topography of the land, types of structures constructed in the surrounding area and the soundness in the structures, appearance, water level in the nearby rivers/ streams, water courses, flood marks, drainage systems available ground water table etc. Site reconnaissance will help on getting the important preliminary information for taking up any project.

3. Site Exploration : It is necessary to find out the soil strata available beneath the proposed construction and assess those properties of sub soil that may affect the performance of building. Certain tests are required to be conducted to determine the character sited of the sub soil.

Bearing Capacity : It is the capacity of the soil mass which is going to support the weight of the structure. The ultimate bearing capacity is defined as the minimum gross pressure intensity at the base of the foundation at which the soil fails in shear. The following tests are conducted to determine the bearing capacity.

- 1 Drilling of Bores
- 2 Standard Penetration test I.S 2131 – 1981
- 3 In-situ vane shear tests (IS 4434 – 1978)
- 4 Plate load test (I.S 1888– 1982)

Safe Bearing Capacity: The maximum pressure which the soil can carry safely without risk of shear failure is called the safe bearing capacity.

$$\text{SBC} = \frac{\text{Ultimate bearing capacity}}{\text{Factor of safety}}$$

Base on the SBC the type of foundation will be decided.

Soil Investigations : The soil investigation is done to determine:

The type of soil / rock available in the foundation and its engineering properties to be considered for designing the foundations. It is also useful in finding the depth of ground water table.

Undisturbed samples give exact picture of the soil strata. Generally the soil samples will be collected by following means.

1. Trail pits
2. Bores

The No. of trails pits and bore holes depends on the area of the site and also to find out the changes of soil profile. Where soil profile is uniform, less no. of trail pits are enough. Normally for smaller areas one sample each at corner and 1 at the middle area to be taken. The depth of exploration should be one and half times the width of footing.

Ground water table : Indication of water table is most important for the designing the foundations. The waterlogged soils are generally weak for resting the foundations. Besides that the water will exert uplift pressure on the base of the footing. Hence it is desirable to assess the water table before designing the structure. Find it leads rectification during earthquake hazards.

Foundations:

Generally there are foundations are classified in to

1. Shallow foundations.
2. Deep foundations.

Shallow foundations (IS 1080-81): According to Teraghi a foundation is a shallow foundation if its depth is equal to less than its width. The load is distributed into a larger area without settlement. These are the following types.

1. Spread footing
2. Strip footing
3. Combined footing
4. Raft footing

Shallow foundations: (IS: 13063 – 1991) In rocky terrain:

When ever foundation is rests partially or fully in rock mass, the foundation concrete shall be laid from surface to surface of rock mass on sides. This will prevent any rock mass movement due to loosening effect on the sides of foundation.

The surface drains in the building should be planned in such a way that water is drained away from the building.

If the foundations are laid on the water bearing strata, suitable drainage arrangements shall be provided around the building foundation and uplift pressure shall be accounted for in design of foundations.

Foundations adjacent to sloping ground:

The base rock under the footing with sides, which make 60° with horizontal, shall remain within the sloping surface of rock. And bearing of 60 cm horizontal to be maintained. The depth of foundation should be increased in case of loose rock profiles. Anchor bars have to be provided with grouting in cm (1:1 1/2) proportion to avoid slipping of foundation and also to have proper bonding.

Foundation at different levels:

The minimum horizontal distance between the adjacent foundations shall be such that the loads from the foundations at higher level are not transferred to the foundations at lower level so as to keep the lower foundations outside the bearing frustum of higher foundation ie; it should be outside the 60° angle to the base of the foundation at higher level.

If this condition is not maintained the lower level foundation is to be designed considering additional loads.

Deep Foundations : In the case of deep foundations the depth is equal to greater than the width. These are the following types.

1. Pile foundation
2. Well foundation etc.

Pile Foundation

(a). Bearing Piles: Bearing piles are used to transfer load through water or soft soil to a suitable bearing stratum.

(b) Under reamed pile: It is a bored pile having an increased diameter or bulb at same point in its length to anchor at the foundation in expansive soil subjected to alternative

expansion and contraction. The diameter shall not be less than 200 mm.

The capping beams shall be kept a minimum of 80 mm clear of the ground.

Deep foundations are meant for transferring the loads to deeper bearing strata.

The base rock under the footing with sides, which make 60° with horizontal, shall remain within the sloping surface of rock. And bearing of 60 cm horizontal to be maintained. The depth of foundation should be increased in case of loose rock profiles.

EARTH WORK EXCAVATION:

Classification of soils:

Ordinary Soils:-

- Soil, sand, gravel, loamy, clay, black cotton, moorum, shale etc.
- **Ordinary rock**: Rock, which can be excavated by splitting with crow, bars or picks, wedging without blasting.
- **Hard rock**: a) rock or boulders require blasting
b) Hard rock excavation with chiseling (without blasting)

Excavation in firm soils, the sides of the excavation shall be kept vertical up to depth of 2 mts and for greater depth steps should be given.

- **Blasting**: Prior permission should be obtained from the competent Authority before under taking blasting. All precautionary measures like signboards showing time of blasting etc. should be displayed at the site. The ground levels should be recorded before commencement of the work. *** is also one kind of application.

IMPORTANT NOTE:

Before start of excavation pre levels shall be taken duly recording in L.F books.

Ref: A P D S S No. 308.

Filling in Foundations and Basement:

Earth used for back filling shall be free from salts, organic or other deleterious matter. All clods of earth shall be either well powdered or removed.

As soon as the construction of the foundation has been completed and measured, the space all around the foundation shall be cleared of all debris and filled with earth in layers not exceeding 150

mm, each layer being watered and well compacted before the succeeding layer is laid, care being taken not to disturb the constructed foundation. The backfill shall be brought to the original ground surface.

Similarly the basements shall be filled with earth / morrum in layers not exceeding 150 mm thick, each layer is well compacted with watering etc., expansive soils and sea sand shall not be used.

Ref: A P D S S No. 309 & 310.

AGGREGATES

Aggregates, crushed or uncrushed, derived from natural sources, such as river terrains and river beds, glacial deposits, rocks, boulders and gravels are used in the production of concrete for normal structural purposes including mass concrete works and as a road material. General classification of aggregates may be (1) Coarse aggregate, and (2) Fine aggregate.

TRADE GROUPS OF ROCKS USED AS CONCRETE AGGREGATES:

Granite, Aplite, Dolerite, Basalt, Sand stone, Lime stone, Granulites and Marble are commonly used rocks for concrete aggregate.

SPECIFIC GRAVITY:

It is defined as ratio of weight of the solids to the weight of a gas free distilled water of equal volume. Specific gravity indicates the strength of aggregate. The more the specific gravity the more the strength, the lesser the specific gravity the lesser the strength. The specific gravity of natural aggregates is between 2.6 and 2.7.

BULK DENSITY:

It is weight of material in a given volume, for a large aggregate of given specific gravity, the higher bulk density means that there are fewer voids to be filled by sand and cement.

POROSITY AND WATER ABSORPTION:

The porosity of aggregate, its permeability and absorption affect the bond between the aggregate and cement paste, the resistance of concrete to freezing and thawing, chemical stability and resistance to abrasion offered by the aggregate and specific gravity of the aggregate.

MOISTURE CONTENT :

The surface moisture is expressed as a percentage of the weight of the saturated and surface dry aggregate.

CHARACTERISTICS:

The following are the characteristics of the aggregates for concrete work.

AGGREGATES:

IS : 383-1970 covers the specification for coarse and fine aggregates from natural sources such as river terrains and river beds, glacial deposits, rocks, boulders and gravels, for using in the production of concrete for normal structural purposes including mass concrete works.

QUALITY OF AGGREGATES:

Aggregates shall consist of naturally occurring stones, gravel and sand or combination thereof. They shall hard, strong, dense, clear and free from injurious amounts of disintegrated pieces, alkali vegetable matter and other deleterious substances. As far as possible, flaky and elongated pieces should be avoided.

Other type of aggregates such as slag & crushed over-burnt brick or tile, which may be found suitable with regard to strength, durability of concrete and freedom from harmful effects may be used for plain concrete members but such aggregates should not contain more than 0.5 percent of sulphate as SO₃ and should not absorb more than 10 percent of their own mass of water.

Aggregates shall not contain any harmful material such as Coal, Lignite, Mica or Laminated material, Clay Alkali, soft fragments, seashells

and organic impurities in such quantity as to affect the strength or durability of the concrete. Aggregate to be used for reinforced concrete, shall not contain any material liable to attack the steel reinforcement. Aggregates, which are chemically reactive with Alkalies of cement, are harmful as cracking of concrete may take place.

AGGREGATE CRUSHING VALUE:

The aggregate crushing value when determined in accordance with IS:2386 (Part-IV)-1963 shall not exceed 45% for aggregate used for

concrete other than for wearing surfaces, and 30% for concrete for wearing surfaces such as runways, roads and pavements.

AGGREGATE IMPACT VALUE:

As an alternative to the aggregate crushing value, the aggregate impact value may be determined in accordance with the methods specified in IS: 2386 (Part-IV)-1963. The aggregate impact shall not exceed 45% by weight for aggregates used for concrete other than for wearing surfaces and 30% by weight for concrete for wearing surfaces such as runways, roads and pavements.

AGGREGATE ABRASION VALUE:

The abrasion value of aggregates, unless otherwise agreed to between the purchaser and the supplier, the abrasion value of aggregates, when tested in accordance with the method specified is IS: 2386(Part-IV) – 1963 using Los Angeles Machine, shall not exceed the following values.

- a) For aggregates to be used in concrete for wearing surfaces 30%.
- b) For aggregates to be used in other concrete – 50%.

SOUNDNESS OF AGGREGATES:

For concrete liable to be exposed the action of frost, coarse and fine aggregates shall pass a Sodium or Magnesium sulphate accelerated soundness test specified in IS: 2386(Part-IV)-1963, the limits being set by agreement between the purchaser and supplier, except that aggregates failing in the accelerate soundness test may be used if they pass a specified freezing and thawing test.

Note:- As a general guide, it may be taken that the average loss of weight after five cycles shall not exceed the following:

- a) For fine aggregate: 10% when tested with sodium sulphate and 15% when tested with Magnesium sulphate.
- b) For coarse aggregate: 12% when tested with sodium sulphate and 15% when tested with Magnesium sulphate.

PARTICLE SHAPE AND SURFACE TEXTURE:

The classification of particle shape is made into four ways :

- 1) Rounded 2) Irregular or partly rounded 3) Angular and 4) flaky.

Surface characteristics have been classified under five headings or groups: 1) Glassy 2) Smooth 3) Granular, 4) Crystalline 5) Honey combed or porous.

Aggregate most of which is retained on 4.75 mm IS sieve. It may be described as:

- a) Uncrushed gravel or stone which results from natural disintegration of rock.
- b) Crushed gravel or stone when it results from crushing of gravel or hard stone, and
- c) Partially crushed gravel or stone. When it is a product of the blending of (a) & (b).

1. **Nominal Size Coarse Aggregate:-** A small specified size of aggregate is larger than the nominal size.

2. **Single Sized Coarse Aggregate:-** Aggregate most of which is close to the nominal size aggregate.

3. **Graded Aggregate:-** Aggregate with sizes well distributed between the nominal size and lower limit for coarse aggregate.

GENERAL:

Stones absorbing more than 10% of their weight after 24 hours immersion in water are considered porous. Porous materials contribute to corrode reinforcement.

Angular pieces have more voids than rounded aggregates. Rounded aggregates require 1 cft. of less cement and 2 cft of less sand for 100 cft. of concrete. Further, rounded aggregates require 1/3 of a gallon less water per bag of cement than angular pieces to produce the same workability. Hence, it is preferred to use rounded aggregates than angular pieces.

The permissible limits for slit, clay and fine dust put together are as follows:

(B.S.S.882).

In natural or crushed gravel sand 4% by weight.

In crushed stone sand 10% by weight.

Aggregates should not contain more than 2% of sulphates.

Hand broken stone is usually flaky and doesn't conform to upper and lower limits in sizes too angular and hence not suitable for concrete making.

Machine crushed aggregate is more cubical in shape, less angular and well graded, hence it is preferred for concrete making.

The specific gravity of an aggregate is considered to be a measure of strength of quality of aggregates. Stones having low specific gravity test is the indication of the strength of a stone.

I.S. 383 / 1970 Table - I
COARSE AGGREGATES

I.S.Sieve Designstion	Percent passing for single-sized aggregate of nominal size					Percent passing for graded aggregate of nominal size				
	63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
1	2	3	4	5	6	7	8	9	10	11
80 mm	100	-	-	-	-	-	100	-	-	-
63 mm	85-100	-	-	-	-	-	-	-	-	-
40 mm	00-30	85-100	100	-	-	-	95-100	100	-	-
20 mm	0-5	0-20	85-100	100	-	-	30-70	95-100	100	100

16 mm	-	-	-	85-100	100	-	-	-	90-100	-
12.5 mm	-	-	-	-	85-100	100	-	-	-	90-100
10 mm	0-5	0-5	0-20	0-30	0-45	85-100	10-35	15-55	30-70	40-85
4.75 mm	-	-	0-5	0-5	0-10	0-20	0-5	0-10	0-10	0-10
2.36 mm	-	-	-	-	-	0-5	-	-	-	-

METHOD OF TESTS:

Every test of material required shall be carried out in accordance with a standard method of test issued by the Indian Standards Institution. In the absence of methods of tests where Indian Standards are not available, the same shall conform to the methods of tests issued by the recognized authority. Laboratory tests shall be conducted by recognized laboratories the authority acceptable.

LABORATORY TESTS:

The following are the references of the tests which are conducted in the Lab, for assessing the quality of the aggregates.

1. Sieve analysis, Coarse and fine aggregates: For testing procedure refer IS: 2386 (Part I) –1963.
2. Specific Gravity and water absorption of coarse and fore aggregate: Refer IS: 2386 (Part III) 1963.
3. Determination of flakiness index value: Refer IS: 2386 (Part I) –1963 for testing procedure.
4. Determination of aggregate impact value: Refer IS: 2386 (Part IV)- 1963 for testing procedure.
5. Determination of aggregate crushing value is given in IS: 2386 (Part IV) – 1963 in detail.
6. Determination of Los Angeles machine abrasion value IS: 2386 (Part IV) – 1963 for detailed procedure.

7. determination of bulking of sand: Refer IS: 2386 (Part III) – 1963.

SAND:-

Sand is a granular material passing through 4.75 mm to 150 micron sieve and predominantly retained in 75 -micron sieve.

Sand to be used shall be composed of hard siliceous material. It shall clean, sharp and angular type. The sand shall be durable and free from organic matter and clay balls sand shall not be contain any harmful impurities suah as cement is harmful and adversely affects the sand shall be screened before use.

The object of grading is to minimize the voids.

Grading of sand for concrete (IS: 383 –1970) based on the particle size distribution the grading is divided in to 4 zones. Zone 1 to zone IV indicates the courser to finer combination of particles. Natural of crushed stone sands percentage passing for

Different grading of sand

The grading of sand is classified into four grading zones in which sand becomes progressively finer from grading zone I to grading Zone IV as in Table.

I.S.Sieve Designation	Percent Passing for			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10.00 mm	100	100	100	100
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
600.00 microns	15-34	35-59	60-79	80-100
300.00 microns	5-20	8-30	12-40	15-50
150.00 microns	0-10	0-10	0-10	0-10

Requirements of grading for sands for Masonry work.

IS: Sieve Designation	Percentage by weight passing IS: Sieve
(1)	(2)
4.75 mm	100
2.36 mm	90-100
1.18 mm	70-100
600 microns	40-100
300 microns	5-70
150 microns	0-15

Requirements of grading for sands for external plastering and renderings.

IS: Sieve Designation	Percentage by weight passing IS: Sieve.	
	Class A.	Class B.
(1)	(2)	(3)
4.75 mm	100	100
2.36 mm	90-100	90-100
1.18 mm	70-100	70-100
600 microns	40-85	40-95
300 microns	5-50	10-65
150 microns	0-10	0-15

Requirements of grading for sands for internal wall and ceiling plastering.

IS: Sieve Designation	Percentage by weight passing Class A	IS: Sieve Class B
(1)	(2)	(3)
2.36 mm	98-100 for under coats 100 for finishing coats	98-100 for under coats 100 for finishing coats

1.18 mm	80-95 for under coats 85-100 for finishing coats	80-100 for under coats 95-100 for finishing coats
600 microns	30-85	30-95
300 microns	5-50	5-65
150 microns	0-10	0-15

Water:

Water is used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete.

The pH value of water shall be not less than 6.

Permissible Limits for Solids(as per IS:456)

S.No	Tested as per	Permissible Limits, (Max)
I)	Organic IS 3025 (Part 18)	200 mg/l
ii)	Inorganic Sulphates (as SO ₃) IS 3025 (Part 18)	3000 mg/l 400 mg/l
iv)	Chlorides (as Cl) IS 3025 (Part 18)	2000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforcement concrete work 2000 mg/l
v)	Suspended matter IS 3025 (Part 17)	2000 mg/l

Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface. The presence of tannic acid or iron compounds is objectionable.

CEMENT

The common ingredients of concrete are cement, coarse and fine aggregates and water. Among the four ingredients, cement is far by the most important constituent of concrete, in that it forms the binding medium for this discrete ingredients. Made out of naturally occurring raw materials and some times, blended or inter ground with industrial wastes. Cements come in various typed and chemical compositions. Depending upon the wide variety of raw material used in manufacturing of cements, the typical ranges of those elements in ordinary Portland cement may be expressed in percent as follows:

Ca O (Lime)	59.64
SiO ₂ (Silica)	19.24
Al ₂ O ₃ (Alumina)	3.6
Fe ₂ O ₃ (Iron Oxide)	1.4
Mg O(Magnesia)	0.5-4 (max. limit is 6%)

The role of four major components on the properties of cement can be summarized by the kinetics of reaction, development of strength and evaluation of heat of Hydration of individual components.

CLASSIFICATION

The cement used shall be any of the following and the type selected should be appropriate for the intended use:

- a) 33 Grade ordinary Portland cement conforming to IS: 269.
- b) 43 Grade ordinary Portland cement conforming to IS: 8112.

- c) 53 Grade ordinary Portland cement conforming to IS: 12269.
- d) Rapid hardening Portland cement conforming to IS: 8041.
- e) Portland slag cement conforming to IS: 455.
- f) Portland pozzolana cement (fly ash based) conforming to IS: 1489 (Part 1).
- g) Portland pozzolana cement (calcined clay based) conforming to IS: 1489 (Part 2).
- h) Hydrophobic cement conforming to IS: 8043.
- i) Low heat Portland cement conforming to IS: 12600.
- j) Sulphate resisting Portland cement conforming to IS: 12330.

Note: 53 grade cement requires curing after the initial setting time completed since the fineness is more than 43 grade cement.

CHARACTERISTICS & PROPERTIES OF CEMENT:

The following are the main characteristic of the cement to assess the strength and durability.

1. Rate of setting
2. Rate of hardening
3. Heat evaluation
4. Resistance to chemical action

FINENESS:

The fineness of cement is a measure of the size of particles of cement. For a given weight of cement the surface area is more for finer cement than for coarser cement. Finer the cement, the rate of chemical reaction is more since more surface area is available which results in greater strength development. As per Indian standards, the residue should not exceed 10% when the cement is sieved on IS Sieve No.9 (IS: 4031 – 1968).

SETTING TIME:

When Portland cement is mixed with water to make a soft paste, it becomes gradually less plastic and finally becomes a hard mass. The time at which cement paste loses its plasticity after addition of water is known as initial setting time. The time corresponding to the paste becoming a hard mass is known as final setting time. It is essential for proper concreting that the initial setting time should not be too less to allow time for mixing, transporting and placing of the concrete. The setting process is accompanied by temperature changes at the time of initial set, the temperature rises

rapidly and at final setting it reaches a peak value. Setting time decreases with rise in temperature. Low temperature increases the setting time.

SOUNDNESS:

Un-soundness is caused by undue expansion of some of the constituents and expansion will result in disintegration and cracks. After the cement has set it should undergo large change in volume. Unsoundness is due to the presence of lime and magnesia in the cement. The cement contains some free lime even after final grinding. This lime hydrates very slowly. The free lime covered by thin film of cement which also prevents direct contact between lime and water. After the paste has set, moisture penetrates into the free lime and hydration starts and the slaked lime occupies large volume. Hence, expansion takes place. As per IS: 4031 -1968 the expansion should not be more than 10mm.

COMPRESSIVE & TENSILE STRENGTH:

The strength of concrete depends on the cohesion of cement, adhesion to the aggregate. Pure cement is tested for compressive strength. Cement mortar (1:3) cubes having an area of 50 sq.cm are prepared in cement block casting machine. For ordinary Portland cement the compressive strength at 3 & 7 days should not be less than 160 kgs/sq.cm and 220 kgs./sq.cm respectively as per IS: 4031 – 1968. Tensile strength at 3 and 7 days should not be less than 21 kgs/sq.cm. and 26 kgs/sq.cm respectively.

The following values are the various grades of cement

Code	Grade	Compressive Strength Kg/sq.cm		
		3 Days	7 Days	28 Days
269-1976	33	160	220	330
8112-1989	43	230	330	430
12269-1987	53	270	370	530

PRECAUTIONS:

While handling the cement, the following precautions are to be taken:

STORAGE OF CEMENT:

Cement in bags should be stored in a dry room on a raised wooden platform 15 to 23 cm. above the floor level and 30 cm. away from walls. Bags to be stacked in not more than 10 bags high (maximum 4.5 mts) to prevent bursting of bags in bottom layers. The bags should be placed close together to reduce circulation of air and all openings in the room should also be well closed. If the piles are to be more the bag should be placed in header and stretchers is alternatively length-wise and cross-wise.

4.2 DETERIORATION OF CEMENT WITH STORAGE:

Ordinary Portland cement which has been stored for over six months and rapid hardening cement which has been stored over two months from the time of leaving the factory should always be tested before use.

Cement in bulk storage of the mill, prior to shipment, for more than six months, or cement in bags in local storage in the hands of a vender for more than three months after completion of tests, may be rejected before usage and may be rejected if it fails to conform to any of the requirements of this specification.

QUALITY CONTROL MEASURES:

To ensure the quality of cement, the following tests are necessary.

- a) Fineness test specified in the IS: 5516-1969.
- b) Test on standard consistency & setting time is specified in IS: 5513-1969.
- c) Soundness test is given in the IS: 5514-1969
- d) Compressive strength of cement is specified in the IS: 4031-1968.
- e) Test on specific gravity is given in the IS: 4031-1968.

STEEL FOR REINFORCEMENT

CLASSIFICATION:

The reinforcement shall be any of the following as per IS: 456

- a) Mild steel & Medium tensile steel bars confirming to IS: 432 (Part-I)
- b) High strength deformed steel bars conforming to IS: 1786.
- c) Hard drawn steel wire fabric confirming to IS: 1566
- d) Structural steel confirming to Grade A of IS: 2062.

Plain bars may be either round or square. Mild steel rods for reinforcement should be obtained from standard manufacturer. Re-rolled rods manufactured by small mills are not generally of full strength.

Though deformed and twisted bars have higher initial cost than those of plain bars, it is advantageous since lesser steel is required as these bars

have higher tensile strength and yield point. Deformed bars increase the bond between steel and concrete and hooks can be eliminated.

PROPERTIES:

The steel should be tough and ductile. It shall be neither brittle nor shall it break under shock. Its tensile and compressive strengths are much higher. It shall have a hard surface and resists wear and tear. It can be tempered melted or welded. It shall be very elastic and shall retain magnetism.

Any structure carrying axial forces, loads, bending moments, torsional moments, shear forces shall be analysed first and then the members are designed. Reinforcement will be provided where tensile stresses occur since concrete is weak in tension. The positioning of reinforcement bars will be across the crack or along the line of action of tensile force.

Reinforcement shall be bent & fixed in accordance with procedures specified in IS: 2502. Bar bending schedule shall be prepared for all reinforcement work.

Steel and Iron Reinforcement Bars (CDT,TMT)

	Test	Frequency	Ref. Codes	Acceptance Standards
1	Chemical Tests			
(a)	Carbon	Once for every source approval Once for every lot Once every 3 months	IS: 1786:1985	0.30 max.
(b)	Sulphur			0.06 max.
(c)	Phosphorus			0.11 max.
(d)	Sulphar+Phosphorus			
	22.Physical Test			
(a)	Ultimate Tensile Strength	Once for every source approval Once for every lot Once every 3 months		10% more than the actual 0.2% proof stress but not less 485 Mpa.
(b)	0.02% proof stress			415 MPa Min.
(c)	% Elongation			14.5 min.
(d)	Bend Test			To be satisfactory
(e)	Rebend Test			To be satisfactory
(f)	Mass per meter run(Kg)			6.31 \pm 3% for 32 mm dia, 4.830 \pm 3% for mm dia, 3% for 25mm dia, 2.470 \pm for 20 mm dia, 1.580 +5% for 16 mm dia, 0.88 \pm 5% for 12 mm dia.

GENERAL DETAILING REQUIREMENTS:

The following are the most important points in detailing of reinforcement steel.

- 1) Main reinforcement to be provided at the extreme possible tensile fibres with adequate minimum cover in case of flexured members, especially slab elements. The cover requirements are specified in IS: 456-1978.
- 2) Secondary reinforcement is to be provided on compression side of main reinforcement.
- 3) Closed stirrups have to be provided when members are subjected to torsional moment.
- 4) Open stirrups may be provided when members are subjected to flexural, shear only.

DEVELOPMENT OF STRESS IN REINFORCEMENT:

The calculated tension or compression in any bar at any section shall be developed on each side of the section by an appropriate development length or end anchorage or by a combination thereof.

Development length of bars in tension or compression is to be calculated so as to ensure proper transfer of stresses in the composite system.

The development length L_d is given by:

$$L_d = \frac{\sigma_s}{4 T} \phi$$

Where ϕ = Nominal diameter of the bar.

σ_s = Stress in bar at the section considered at design load (i.e., $0.87 f_y$)

T = Design bond stress for bars in tension. (Ref. IS:456-2000)

The development length of each bar of bundled bars shall be that for the individual bars, increased by 10 percent for two bars in contact, 20 percent for three bars in contact and 33 percent for four bars in contact.

ANCHORING BARS IN TENSION:

Deformed bars may be anchored in straight lengths provided the development length requirements are satisfied. Plain bars shall not be normally anchored through straight lengths and should be provided with hooks.

BENDS AND HOOKS:

These should conform to IS: 2502.

- a) Bends: The anchorage value of a standard bend shall be taken as 4 times the diameter of the bar for each 45 degrees bend subject to a maximum of 16 times the diameter of the bar.
- b) Hooks: The anchorage value of standard 'U' type hook shall be equal to 16 times diameter of the bar.

ANCHORING BARS IN COMPRESSION:

The anchorage values of standard hooks & bends for different diameters are given in SP 34 (S&T) – 1987/IS: 456-2000. The anchorage length of a straight bar in compression shall be equal to the development length. The projected length of hooks, bends and straight length beyond bends, if provided for a bar in compression, should be considered for development length.

REINFORCEMENT SPLICING:

Splicing is required to transfer force from one bar to another. Where splices are provided for continuity in the reinforcing bars, they will be away from the section of maximum stress and be staggered. Not more than half the bars shall be spliced at a section and where the bending moment is more than 50% of moment of resistance, the splicing is not allowed in flexural members.

LAP SPLICES:

Lap splices shall not be used for bars larger than 36 mm. In these cases welding may be resorted to. Where welding is not practicable, additional spirals should be provided around the lapped bars.

- A) Lap Length in Tension: Lap Length including anchorage value of hooks shall be as follows:
 - i) In case of flexural tension: L_d or 30 dia whichever is greater.
 - ii) For direct tension: $2L_d$ or 30 dia which ever is greater. The straight length of the lap shall not be less than 15 dia or 200 mm. which ever is greater. Where L_d = development length.
- B) Lap Length in compression: The Lap Length in compression shall not be less than 24 dia.
- C) Splice in Column: In columns where longitudinal bars are offset at a splice, the slope of the inclined portion of the bar with the axis of the column shall not exceed 1 in 6 and the portions of the bars above and below the offset shall be parallel to the axis of the column.

D) Lap splices shall be considered as if the centre to centre distance of the slices is not less than 1.3 times the lap length;

SHEAR REINFORCEMENT:

A stirrup in a beam shall pass around or adequately secured to the outer most tension and compression reinforcement, and such stirrup should have both its ends anchored properly.

MAXIMUM SPACING:

The maximum spacing of shear reinforcement measured along the axis of the members shall not exceed $0.75d$ (effective depth of the section) for vertical stirrups and for inclined stirrups, where d = effective depth of section under consideration. In no case shall it exceed 300 mm.

SIMPLY SUPPORTED SLABS:

ONE WAY SLABS:-

If the effective length of the slab exceeds two times its effective width, the slab is considered to be spanning in one direction. The bars in the shorter direction (main bars) are placed in the bottom layer. At least 50% of main reinforcement provided at mid span should extend to the supports and the remaining 50% should extend to within 0.11. of the support.

TWO WAY SLABS:-

If L_y/L_x is less than 2 is considered to be slab spanning in two directions. Where, L_y and L_x are the effective spans in longer and shorter directions. The bars in the shorter direction are generally placed in the bottom layer and tied with the bars in the longer direction placed above it. At least 50% of the tension reinforcement provided at mid span should extend to supports and remaining 50% should extend to within $0.1L_x$ or $0.1L_y$ of the support. This is specified in IS: 456– 1978.

CONTINUOUS SLABS:-

CANTILEVER SLABS:

The main reinforcement shall be placed in the top of cantilever slab extending to sufficient length over the support and back into the normal span. The bending of main bars should be such that they contribute to the supporting of

steel i.e., bars that extend to the end should have vertical bends with a fixing bar at the end. Secondary steel at right angles to the support may be provided.

TORSIONAL REINFORCEMENT:

Torsional reinforcement shall be provided at such corners, where the slab is simply supported in both directions. This torsion reinforcement is helpful to hold the corner and is prevented from lifting and possible cracking. It shall consist of top and bottom reinforcement each with a layer of bars placed parallel to the sides of the slab and extending from the edges to a minimum distance of one fifth of the shorter span. The area of reinforcement per unit width in each of these layers shall be three quarters of the area required for the maximum mid span moment per unit width in the slab.

FABRICATION:

In general tolerances are not fixed on bending angles, on the other hand, it is important that the overall dimensions of the fabricated reinforcement conform to the plan.

Bending of bars may be done either by improvised means or by hand operated machines and by power operated bender. For bars of 12 mm diameter and under mechanical contrivances may be employed. The hand machine could be employed for bending bars upto 16 mm diameter and for larger diameters geared bar bender is required. Bending of bars of 36 mm diameter and larger require special equipment, such as power operated benders. Special roller spindles may be necessary for bending deformed and twisted bars.

TYING:

Tying may, in order of increasing resistance of slipping, be by means of a:

- Single or snap tie
- Saddle ties and
- Figure of eight tie.

PLACING OF REINFORCEMENT:

Correct placing of reinforcement requires proper maintenance of the distance between the two bars and concrete cover that is the exact placing the reinforcement in accordance with the drawings. This is generally, achieved by using spacers to ensure that the reinforcement is kept in position allocated in the design.

DISTANCE BETWEEN HORIZONTAL LAYERS:

The distance between these layers is often ensured by means of a bar (say 12mm) known as chairs. This high chair, which is easy to make on site, is fixed to the main reinforcement and is never in direct contact with the shuttering.

BETWEEN VERTICAL LAYERS:

The distance between vertical layers of reinforcement is usually ensured by means of straight bars, hooked bars or bent into a 'U' tied to the main reinforcement. Bars bent into a 'U' may be easily and correctly tied to the main reinforcement.

IN BEAMS AND COLUMNS:

In beams, columns and other elements the main bars, which are parallel, are connected by tying to the stirrups in order to form a rigid cage.

CHECK LIST:

The following observations are to be made while placing reinforcement.

1. Steel bars reinforcement overlaps, anchorage is to be verified for footings and plinth beams.
2. Details of column reinforcement such as overlaps position is to be verified.
3. Lintel reinforcement is placed in correct location with chairs.
4. Verify the sections, reinforcement of column with respect to structural drawing.
5. Verify the sections, reinforcement of slab with respect to structural drawing.
6. Check the overlaps anchorage lengths and column extension overlaps.
7. Verify the extra or additional reinforcement bars.
8. Verify the chairs below crank and top bars.

TESTS ON STEEL:

1. Tensile. Test of steel.
2. Impact test of steel.
3. Cold bend test of steel.
4. Chemical analysis of Steel.

It is important to note that the reinforcement steel plays an important and crucial role in the effective functioning of a RCC element. Hence, proper care and precaution of the reinforcement steel is inescapable for any structural Engineer. Meticulous care has to be taken to fabricate, place in position before and during the concreting.

REFERENCE I.S. CODES:

1. I.S. : 1521-1972 – Method of tensile testing of steel wire.

2. I.S. : 1499-1959 – Method for charpy impact test for steel.
3. I.S. : 1586-1968 – Method for rock well hardness test for steel.
4. I.S. : 1599-1960 – Method for bend test of steel.
5. S.P.-34.
6. I.S. : 456-1978 & I.S.:456-2000 – Code of practice for Plain & reinforced concrete.
7. National Building Code.

CONCRETE

CONSTITUENTS OF CEMENT:-

Concrete is no longer a mere four component system. Concrete can be combination of far more number of ingredients.

Apart from cement, coarse, fine aggregates and water, modern concrete contains chemical and mineral admixtures.

Chemical and mineral admixtures improve strength and durability of concrete.

Grades:

The minimum grade of concrete for plain and reinforcement concrete shall be as per Table.

Concrete of grades lower than those given in Table may be used for plain concrete constructions, lean concrete, simple foundations, foundation for masonry walls and other simple or temporary reinforced concrete construction.

Tensile Strength of Concrete:

The flexural and splitting tensile strengths shall be obtained as described in IS 516 and IS 5816 respectively. When the designer wishes to

use an estimate of the tensile strength from the compressive strength, the following formula may be used.

$$\text{Flexural strength } f_{cr} = 0.7 \sqrt{f_{ck}} \text{ N/mm}^2$$

Where f_{ck} is the characteristic cube compressive strength of concrete in N/mm^2

The modulus of elasticity of concrete can be assumed as follows:

$$\text{Where } E_c = 5000 \sqrt{f_{ck}}$$

E_c is the short term static modulus of elasticity in N/mm^2 .

Actual measured values may differ by ± 20 percent from the values obtained from the above expression.

Shrinkage:

The total shrinkage of concrete depends upon the constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and, to a lesser extent, by the cement content.

In the absence of test data, the approximate value of the total shrinkage strain for design may be taken as 0.0003.

Nominal Cover to reinforcement

The Protection of the steel in concrete against corrosion depends upon inadequate thickness of good quality concrete. Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. It shall be not less than the diameter of the bar. For concrete members exposed directly along the seacoast shall be provided with adequate cover to protect the steel from corrosion.

Nominal Cover:

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. It is the dimension used in design and indicated in the drawings. It shall be not less the diameter of the bar.

Nominal cover to meet Durability Requirement:

Minimum values for the nominal cover of normal weight aggregate concrete which should be provided to all reinforcement, including links depending on the condition of exposure described shall be as shown in the Table.

However for a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12mm, a nominal cover of 25mm may be used. For footings minimum cover shall be 50mm.

Nominal cover to meet specified period of Fire Resistance :

Minimum values of nominal cover of nominal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance shall be given in Table.

Fire Resistance	Nominal Cover						
	Beams		Slabs		Ribs		Columns
	Simply supported	Continuous	Simply supported	Continuous	Simply supported	Continuous	
h	mm	mm	mm	mm	mm	mm	mm
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	<u>35</u>	20	40
2	<u>40</u>	30	<u>35</u>	25	45	<u>35</u>	40
3	60	<u>40</u>	45	<u>35</u>	55	45	40
4	70	50	55	45	65	55	40

NOTES:

1. The nominal covers given relate specifically to the minimum dimensions given in the table.
2. Cases that lie below the bold line require attentional measures necessary to reduce the risks of spalling

WORKABILITY OF CONCRETE:

The concrete mix proportions chosen should be such that the concrete is of

adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below:

Placing Conditions 1	Degree of Workability 2	Slump (mm) 3
Blinding Concrete; Shallow sections; Pavements using pavers	Very low	
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining	Low	25-75
Strip footings Heavily reinforced sections in slabs, beams, walls, columns; Slip form work;	Medium	50-100 75-100
Pumped concrete Trench fill; In-situ Tremie concrete	High Very High	100-150

NOTE- For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used.

DURABILITY OF CONCRETE:

General:

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The

materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, Sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. With normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, and by adequate curing.

The factors influencing durability include:

- (a) the environment;
- (b) the cover to embedded steel;
- (c) the type and quality of constituent materials;
- (d) the cement content and water/cement ratio of the concrete;
- (e) workmanship, to obtain full compaction and efficient curing; and
- (f) the shape and size of the member.

Chlorides in concrete:

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion.

Sulphates in concrete:

Sulphates are present in most cement and in some aggregates; excessive amounts of water-soluble sulphate from these or mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO_3 , should not exceed 4 percent by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix.

Limits of Chloride Content of Concrete

Sl. No.	Type or Use Concrete	Maximum Total Acid Soluble Chloride Content
----------------	-----------------------------	--

(1)	(2)	Expressed as kg/m ³ of Concrete (3)
i)	Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete	0.4
ii)	Reinforced concrete or plain concrete containing embedded metal	0.6
iii)	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

CONCRETE MIX PROPORTIONING

Mix Proportion:

The mix proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

The determination of the proportions of cement, aggregates and water to attain the required strengths shall be made as follows:

- a) By designing the concrete mix, such concrete shall be called '**Design mix concrete**'. or
- b) By adopting nominal concrete mix, such concrete shall be called '**Nominal mix concrete**'.

Design mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason on the work for grades of M 20 or lower, nominal mixes may be used with the permission of engineer-in-charge, which, however, is likely to involve higher cement content.

MIX DESIGN PROCEDURE:

DIFFERENT STEPS FOR MIX PROPORTIONING

Step:-1: Selection of maximum size of aggregate.

Step:-2: Calculation of Target mean strength

Step:-3: Selection of water cement ratio

Step:-4: Selection of water content

Step:-5: Calculation of cementitious material content

Step:-6: Estimation of coarse aggregate proportion

Step:-7: Estimation of fine aggregate proportion

Step:-8: Combination of different coarse aggregate fractions

Step:-9: Trial mixes.

Step:-10: Admixtures.

DATA FOR MIX PROPORTIONING

Grade designation

Type of cement

Maximum cement content

Maximum water cement ratio

Workability

Exposure condition as per IS 456

Maximum temperature of concrete at the time of placing

Method of transporting and placing

Early age strength requirements, if required

Type of aggregates

Maximum cement content, and

Whether an admixture shall or shall not be used and the type of admixture and the condition of use

MIX DESIGN PROCEDURE (IS : 10262)

STEP – 1 TARGET MEAN STRENGTH

The 28 – day target mean strength Is _____

Calculated using following formula:

Target strength = $F_{ck} + 1.65\sigma$

f_{ck} = 28 - day characteristics compressive strength of concrete

σ = standard deviation of compressive strength of concrete samples

σ (Standard deviation) can be calculated using the method given in IS: 456 – 2000

- The standard deviation shall be calculated taking the strength of 30 samples out of one mix.
- Where the sufficient test result for a particular grade of concrete are not available, the value of σ may be assumed as given in IS: 456 – 2000.

Assumed Standard Deviation.

(Table – 8 of IS : 456– 2000)

Grade of concrete	Assumed Standard Deviation, N/mm ²
M10, M15	3.5
M20, M25	4.0
M30, M35, M40, M45 M50, M55	5.0

STEP: 2 SELECTION OF WATER CEMENT RATIO

- To be selected from established relationship if available
- Table 5 of IS: 456 – 2000 may be used as a starting point for respective exposure condition.

Table: 5 (IS: 456–2000)

REQUIREMENTS FOR DIFFERENT EXPOSURE CONDITIONS

S.No	Exposure	Plain Concrete		Reinforced Concrete		Minimum Grade	
		Minimum Cement	Maximum free	Minimum Cement	Maximum free	Plain concrete	Reinforced concrete

		Kg/m ³	w/c	Kg/m ³			
i)	Mild	220	0.60	300	0.55	--	M 20
ii)	Moderate	240	0.60	300	0.50	M15	M 25
iii)	Severe	250	0.50	320	0.45	M20	M 30
iv)	Very severe	260	0.45	340	0.45	M20	M 35
v)	Extreme	280	0.40	360	0.40	M25	M 40

Note: Minimum cement prescribed in the Table is irrespective of grades of cement and it is inclusive of mineral admixtures.

The addition such as flyash or ggbs may be taken into account in the concrete composition with respect to the cement and water-cement ratio as long as maximum amounts taken into account do not exceed the limits of respective codes.

EXPOSURE CONDITIONS

ENVIRONMENT	EXPOSURE CONDITIONS
Mild	Condition surfaces protected against weather or aggressive conditions
Moderate	Concrete exposed to condensation and rain Concrete continuously under water Concrete surfaces sheltered from rain or freezing whilst wet Concrete in contact or buried under non-aggressive soil / groundwater
Severe	Concrete surfaces exposed to severe rain, alternate wetting and Drying or occasional freezing whilst wet or severe condensation Concrete completely immersed in sea water Concrete exposed to coastal environment
Very Severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete in contact with or buried under aggressive sub soil / groundwater
Extreme	Surface of members in tidal zone, Members in direct contact With liquid/solid aggressive chemicals.

**SELECTION OF WATER CONTENT
MAXIMUM WATER CONTENT PER CUBIC METRE OF CONCRETE FOR
NOMINAL MAXIMUM SIZE OF AGGREGATE**

Nominal Maximum Size Of Aggregate Mm	Maximum Water Content Kg
10	208
20	186
40	165

Water content corresponding to saturated surface dry aggregate

Note: These quantities of mixing water are for use in computing cementitious material contents for trial batches.

SELECTION OF WATER CONTENT

- The water content in Table 2 is for angular aggregate and for 25-50 mm slump range
- The water estimate in Table 2 can be reduced approximately 10 Kg for sub angular aggregates, 20 Kg for gravel with some crushed particles and 25 Kg for rounded gravel.
- The required water content may be established by trials or an increased by about 3% for every additional 50 mm slump
- Water reducing admixtures or super plasticizers usually decrease water content by 5 -10% and 10-30% respectively at appropriate dosages.

CALCULATION OF CEMENTITIOUS MATERIAL CONTENT

- The cement and supplementary cementitious material content per unit volume of concrete may be calculated from the free water cement ratio and the quantity of water per unit volume of concrete

- The cementitious material content so calculated shall be checked against the minimum cementitious content for the requirements of durability and greater of the two values adopted

ESTIMATION OF COARSE AGGREGATE PROPORTION

TABLE 3 VOLUME OF COARSE AGGREGATE PER UNIT VOLUME OF CONCRETE FOR DIFFERENT ZONES OF FINE AGGREGATE

Nominal Maximum of Aggregate MM	Volume of coarse aggregate per unit Volume of concrete for different zones of fine aggregate			
	Zone IV	Zone III	Zone II	Zone I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

- Volume are based on aggregates in saturated surface dry condition
- For pumpable concrete it may be desirable to reduce the estimated coarse aggregate content determine using Table 3 up to 10%

ESTIMATION OF FINE AGGREGATE PROPORTION

- Now all the ingredients have been estimated except the coarse and fine aggregate content.
- These quantities are determined by finding out the absolute volume of cementitious material, water and their respective specific gravity, multiplying by 1/1000 and subtracting the result of their summation from unit volume
- The value so obtained are divided into coarse in accordance with coarse aggregate proportions already determined
- The coarse and fine aggregate contents are then determined by multiplying with their respective specific gravities and multiplying by 1000

- Coarse aggregates of different size fractions shall be combined in suitable proportions so as to result in an overall grading conforming to IS : 383 for particular nominal maximum size of aggregate.

TRIAL MIXES

- The calculated mix proportions shall be checked by means of trail batches
- If the measured workability of trail mix no. 1 IS different from the stipulated value, the water and/or admixture content shall be adjusted suitably.
- Recalculate the mix proportions keeping the free water cement ratio at the pre-selected value for trail mix no. 2.
- In addition two more trail mixes shall be made with the same water content as in trail mix no. 2 required for desired workability and varying the water cement ratio by $\pm 10\%$ of the pre selected value.

Frequency of Sampling:

Sampling Procedure:

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

Frequency:

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of concrete in the Work, m ³	Number of Samples
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 and above	4 plus one additional sample for each additional 50 m ³ or part thereof
Sample means six cubes	3 cubes for 7 days.

3 cubes for 28 days.

NOTE- At least one sample shall be taken from each shift.

Where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by suppliers and purchasers.

Test Specimen:

Three-test specimen shall be made for each sample for testing at 28 days. Additional sample may be required for various purposes such as to determine the strength of concrete at 7 days or at time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional samples may also be required for testing samples cured by accelerated shall be tested as described in IS 9103. The specimen shall be tested as described in IS 516.

Test Results of Sample:

The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ± 15 percent of the average. If more, the test results of the sample are invalid.

ACCEPTANCE CRITERIA.

Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

- a) The mean strength determined from any group of four consecutive test results complies with the appropriate limits .
- b) Any individual test result complies with the appropriate limits.

Flexural Strength:

When both the following conditions are met, the concrete complies with the specified flexural strength.

- a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by least 0.3 N/mm^2 .
- b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2 .

Quantity of Concrete Represented by Strength Test Results:

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and the last samples were taken together with all intervening batches.

For the individual test result requirements given in Table, only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3 .

If the concrete is deemed not to comply pursuant to, the structural adequacy of the parts affected shall be investigated and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

Concrete is liable to be rejected if is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been met. However, the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the engineer-in-charge.

MIXING:

Machine mixing: Concrete shall normally be mixed in a mechanical mixer. Mixing shall be continued until there is a uniform distribution of materials and the mass is uniform in colour and consistency, but in no case shall the mixing be done for less than 2 minutes after all the materials are in the drum.

PLACING AND COMPACTING:

Transporting: The concrete shall be handled from the place of mixing to the place of final deposit as rapidly as practicable by methods which will prevent the

segregation or loss of any of the ingredients. If segregation does occur during transportation the concrete shall be mixed before being placed.

Placing: The concrete shall normally be placed and compacted within half an hour of mixing and shall not be subsequently disturbed. Method of placing shall be such as to preclude segregation. All concrete, which has set before placement, shall be rejected and immediately removed from site.

Compaction: Concrete shall be thoroughly compacted during the operation of placing and thoroughly worked around the reinforcement, around embedded fixtures and into corners of formwork. Wherever possible vibrators of the surface, form or immersion type shall be used. Over vibration or vibration of very wet mixes shall be avoided.

Admixtures:

Admixtures are added to the concrete mix before or during mixing, in order to modify one or more of the properties of concrete. Use of admixtures should be correlated to the type of cement and aggregates to be used and to the conditions expected at the site.

Admixtures should be used only on the basis of approval by the Authority.

Types of Admixtures

- (a) Accelerating admixtures: These are added to hasten the rate of early strength development, which would facilitate early removal

of formwork; or reduce the required period of curing or concreting in cold weather or in emergency repairs.

Common accelerates are calcium chlorides, fluorosilicates and triethanolamine; but chloride content in concrete shall be carefully checked.

- (b) Retarding admixtures: These admixtures tend to slow down the rate of setting of cement. They are useful in hot weather concreting; for avoiding cold joints in mass concrete works and for special treatment of concrete surfaces.

Common retarders are starches, cellulose products sugars and hydroxyl-carboxylic acids and their salts.

- (c) Water-reducing or plasticizing admixtures: These admixtures allow greater workability to be achieved for a given water-cement ratio; or for the same workability reduces water content. When used in sufficient quantities, these admixtures function as set-retarders. The basic ingredients of water-reducing admixture are either lingo-sulphonate or polyhydroxy compounds.

All admixtures should be used taking into account manufacturer's instructions. Use of two or more admixtures may be considered after ascertaining their compatibility.

All admixtures shall be tested as per IS: 9103-1979.

Construction joints: Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be predetermined by the Executive Engineer. When the work has to be resumed on a surface which has hardened such surface shall be roughened by chiseling,

swept clean, thoroughly wetted and covered with a 12 mm layer of freshly mixed mortar composed of cement and sand (in the same ratio as the cement and sand in the concrete), immediately before the placing of the concrete. When the concrete has not fully hardened all laitance shall be removed by scrubbing.

LOCATION OF CONSTRUCTION JOINTS:

Construction joints when necessary shall be located as follows:

In the main beams over the center of supports.

No vertical joints shall be permitted in case of main beams. In other cases they shall be provided if necessary in the following locations:

- a) in subsidiary beams at mid span.
- b) In the case of slabs, the joints wherever possible shall be parallel to the main reinforcement in the case of one way reinforced slabs and over the center of supporting beams or walls in other cases.

In general the joints shall not be provided in locations of considerable shear or under concentrated loads.

Suitable water stops as specified shall be provided in the case of water retaining structures.

EXPANSION JOINTS:

Expansion joints shall be provided in the case of very long structures at locations of large variation in the height or width of the structure or where different in foundation condition are involved. As per IS 456 the structures more than 45 m length shall be provided with one or more expansion joints to avoid cracking due to stresses developed. However expansion joints may be provide at a distance of 15 to 20 meters to be on safer side.

CONCRETE IN SEA WATER:-

Concrete in sea- water or exposed directly along the sea-coast shall be at least M 20 Grade in case of plain concrete and M30 in case of reinforced concrete; The use of slag or pozzolana cement is advantageous under such conditions.

In reinforced concrete structures, care shall be taken to protect the reinforcement from exposure to saline atmosphere during storage, fabrication and use. It may be achieved by treating the surface of reinforcement with cement wash or by suitable methods and also by providing more cover.

INSPECTION AND TESTING OF STRUCTURES:

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards. Where applicable, use should be made of suitable quantity assurance schemes.

Care should be taken to see that:

- a) design and detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;
- b) there are clear instructions on inspection standards.
- c) there are clear instructions on permissible deviations;
- d) elements critical to workmanship, structural performance, durability and appearance are identified; and
- e) there is a system to verify that the quantity is satisfactory in individual parts of the structure, especially the critical ones.

Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

Testing:

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of core test/ load test may be carried out.

Core Test:

The points from which cores are to taken and the number of cores required shall be discretion of the engineer-in-charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

Cores shall be prepared and tested as described in IS 516.

Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75 percent.

Load Tests for Flexural Member:

Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24 h and then the imposed load shall be removed.

NOTE - Dead load include self weight of the structural member plus weight of finishes and walls or partitions, if any, as considered in the design.

The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load the structure does not recover at least 75 percent of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If shall be deemed to be unacceptable.

If the maximum deflection in mm, shown during 24 h under load is less than $40 l^2/D$, where l is the effective span in m; and D , the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions shall not apply.

Members Other Than Flexural Members:

Members other than flexural members should be preferably investigated by analysis.

Non-destructive Tests:

Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. The methods adopted include ultrasonic pulse velocity and rebound hammer [IS 13311 (part 2)], probe penetration, pullout and maturity. Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

GENERAL REQUIREMENTS OF READY MIXED CONCRETE

(IS: 4926-2003)

Basis of Supply:

Ready-mixed concrete shall be supplied having the quantity in accordance with the requirements agreed with the purchaser or his agent. Notwithstanding this, the concrete supplied shall generally comply with the requirements of IS 456.

All concrete will be supplied and invoiced in terms of cubic metres (full or part) of compacted fresh concrete. All proportioning is to be carried out by mass except water and admixture, which may be measured by volume.

Transport of Concrete:**General:**

Ready-mixed concrete shall be transported from the mixer to the point of placing as rapidly as practicable by methods that will maintain the required workability and will prevent segregation, loss of any constituents or ingress of foreign matter or water. The concrete shall be placed as soon as possible after delivery, as close as it practicable to its final position to avoid rehandling or moving the concrete horizontally by vibration. If required by the purchaser the producer can utilize admixtures to slow down the rate of workability loss, however this does not remove the need for the purchaser to place the concrete as rapidly as possible. The purchaser should plan his arrangements so as to enable a full load of concrete to be discharged within 30 min of arrival on site.

Concrete shall be transported in a truck-mixer unless the purchaser agrees to the use of non-agitating vehicles are used, the mixed concrete shall be protected from gain or loss of water.

Time in Transport:

The general requirement is that concrete shall be discharged from the truck-mixer within 2 h of the time of loading. However, a longer period may be permitted if retarding admixtures are used or in cool humid weather or chilled concrete is produced.

SAMPLING AND TESTING OF READY-MIXED CONCRETE.**Point and Time of Sampling:**

For the assessment of compliance of ready-mixed concrete, the point and time of sampling shall be at discharged from the producer's delivery vehicle or from the mixer to the site or when delivered into the purchaser's vehicle. It is critical that the sampling producer and equipment used enables as representative a sample as possible to be taken of the quantity of concrete delivered.

The sampling may be carried out jointly by the purchaser and the supplier with its frequency mutually agreed upon. However, it will not absolve the

supplier of his responsibility from supplying concrete as per the requirements given in this standard or otherwise agreed to where so permitted in the standard.

Workability:

The test for acceptance is to be performed upon the producer's delivery vehicle discharge on site or upon discharge into the purchaser's vehicle. If discharge from the producer's vehicle is delayed on site due to lack of preparedness on behalf of the purchaser then the responsibility passes to the purchaser after a delay of more than 30 min.

The workability shall be within the following limits on the specified value as appropriate:

Slump	:	+ 25 mm or + 1/3 of the specified value, whichever is less.
Compacting factor	:	± 0.03 , where the specified value is 0.90 or greater, ± 0.04 , where the specified value is less than 0.90 but more than 0.80, and ± 0.50 , where the specified value is 0.80 or less.

Flow table test may be specified for concrete, for very high workability. Acceptance criteria for speed (flow) are to be established between the supplier and the purchaser.

Specified Strength:

Compliance shall be assessed against the requirements of IS: 456 or other agreed Indian Standard. The purchaser may perform his own sampling and testing or may enter in to arrangement with the producer to provide his testing requirements.

Unless otherwise agreed between the parties involved, the minimum testing frequency to be applied by the producer in the absence of a recognized ready-mixed concrete industry method of production control, should be one sample for every 50 m³ of production or every 50 batches, whichever is the greater frequency. Three test specimens shall be made up for each sample for

testing at 28 days. In all cases 28 days compressive strength shall alone be the criteria for acceptance or rejection of the concrete.

INFORMATION TO BE SUPPLIED BY THE PURCHASER:

The purchaser shall provide to the producer the details of the concrete mix or mixes required by him and all pertinent information on the use of the concrete and the specified requirements. Prior to supply taking place, it is recommended that a meeting is held between the purchaser and the producer. Its objective to clarify operational matters, such as notice to be given prior to delivery, delivery rate, the name of the purchaser's authorized representative who will coordinate deliveries, any requirements who will coordinate deliveries, and requirements for additional services such as pumping, on site testing or training etc.

INFORMATION TO BE SUPPLIED BY THE PRODUCER:

When requested, the producer shall provide the purchaser with the following information before any concrete is supplied:

- a) Nature and source of each constituent material,
- b) Source of supply of cement, and proposed proportions of quantity of each constituent/m³ of fresh concrete.(mix design)
- c) A component contains when requested, the producer shall provide the purchaser the following information on admixtures:
 - a) Generic type(s) of the main active constituent(s) in the admixture;
 - b) Whether or not the admixture contains chlorides and if so, the chloride content of the admixture expressed as a percentage of chloride ion by mass of admixture;
 - c) Whether or not the admixture leads to the entrainment of air when used at the adopted dosage;
 - d) Where more than one admixture is used, confirmation of their compatibility: and
 - e) Initial and final setting time of concrete when admixture is used at adopted dosage (tested as per IS: 8142).

Check Slip for Footings:

1. Check the depth of foundation in as per design. The base should be hard. All loose pockets must be removed. An irregular faces of rocks and undulation should be coursed in PCC bed concrete.
2. De-watering should be done if seepage water is accumulated. As far as possible the seepage water should be trained up and care should be taken to avoid seepage water to enter foundation trenches.
3. As far as possible all the footings should be at one level. Each footing should not fall with in the line footing in a slop of 60° to horizontal.
4. If depth of footing is more than 45 cm nominal reinforcement in the shape of mat is to be provided.
5. The surface of earth must be made wet so that water is not absorbed from concrete.

6. Check the level of P.C.C then mark the center of footing in cement mortar on P.C.C with the help of centerline pillars.
7. Place the footing formwork box; check the size and diagonals of formwork box.
8. Footing mesh should be prepared by cutting the bars considering the allowance for L and cover on all the sides and the bars with binding wire. Care should be taken to tie each and every junction with binding wire.
9. Cut the column bars and also pedestal bars to the required length not be less than development length. The 'L' should be min 30 cm.
10. Footing jail should be kept in the footing shuttering with column base tied to its center with binding wire. The center of footing should be matched with jail of footing.
11. Proper cover should be maintained from sides as well as from bottom by providing over bricks.
12. Proper supports should be given to footing box so as to prevent any

possible displacement.

13. Before concentrating, clean interior of box and PCC, with the help of water jet.
14. The column reinforcement should be supported to the plumb for maintaining proper alignment.
15. Proper compaction should be done.
16. Minimum cover shall be 50 mm thick.

CHECK SLIP FOR COLUMNS:

1. Plot grid lines for center of column above plinth/floor slab.
2. Locate and mark the centers of columns duly checking size of column as per drawing.
3. Proper cover and verticality should be maintained throughout. Any eccentricity increases the bending movement and weakness the member.
4. Care should be taken to tie the main bars of the lower floor columns firmly to the upper floor columns.
5. Check the quality of shuttering before placing. There should not be any curvature in the shuttering planks.
6. Allow curtailment of rods in multistoried buildings should be staggered. Care should be taken to maintain development length below the floor level.
7. The starter should be laid with rich grade of concrete and should be cured sufficiently before putting of centering for column. If the starter is weak, it will be crushed once the designed load transfers.
8. As per IS: 456, the longitudinal reinforcement shall not be less than 0.8 percent nor more than 8% of gross cross sectional area.
9. The bars shall not be less than 12 mm in diameter.
10. The eccentricity should not be more than 20 mm.

11. The laps should be as far as possible provided in the middle third position of the column.
12. The nominal cover shall be 40 mm to meet the norms of fire resistance.
13. Column may be considered as short, when both the slenderness ratio less than 12.

Where:

$$L/D \text{ or } B \text{ (minimum)} < 12$$

L = effective length of column

D = depth of the member

B = width of the member.

14. All the laps should not come at one place. It is advisable to stagger the laps.
15. Concreting should be done maximum of 1m at a stretch with proper compaction for every 30 cms depth.
16. The shrinkages should be bent at 135° hook to have proper grip.

CHECK SLIP FOR BEAMS:

1. Formworks, columns, beams joint should be carefully placed to ensure concrete without honeycombs. Proper compaction should be done. Care should be taken to maintain the dimensions as per designs.
2. Check the position and level of the beam bottom supports (caps) with the help of the minimum area of tension reinforcement shall not be less than the following.

$$s = bd \left(\frac{0.85}{b_y} \right)$$

b = breadth of the beam

d = effective depth

ty = Characteristic strength of reinforcement in N/mm².

3. The maximum compression and tension should not exceed $0.04 bD$.
4. Top and middle extra bars should be properly placed.
5. Where the depth of web is more than 750 mm side reinforcement should be provided along the two faces.
6. Check the centering for tightness and alignment should be straight.
7. To avoid bulging of beams during vibrations support should be given from outside.
8. Reinforcement should be checked as per drawings.
9. Ensure proper cover is maintained at two corners, sides and bottom. If cover is more discontinues ends at beam will become weak.
10. Check the level of beam bottom before providing beam sides.
11. It is better to complete basement filling and layer of base concrete before centering is erected. Access should be closed to the room after erection of shuttering.
12. Gaps in beam and slab should be filled.

PRECAUTIONS TO BE TAKEN BEFORE AND AFTER DURING CASTING OF SLAB:

1. The reinforcement in either direction shall not be less than 0.12% of cross sectional area.
2. Check the grade of concrete
3. Maintain the log register for materials used in every batching.
4. Corrections to be applied to water content if the aggregation are having moisture content.
5. The horizontal distance between parallel main reinforcement bars shall not more than three times the effective depth of solid slab or 300 mm which ever is less.

6. Check the junction and all electrical points as per electric layout, position of fan points M.S. boxes, junction boxes etc.
7. Ensure that proper cover is maintained and reinforcement is laid properly.
8. Required No. of chairs to be placed to hold the top reinforcement at a required level.
9. Ensure that the reinforcement not disturbed during casting of slab.
10. Centering should be checked before laying and during laying of concrete.
11. If 53-grade cement is used, curing should be started early to avoid shrinkage cracks.
12. Care should be taken to maintain the correct water cement ratio. Slum test to be done periodically.
13. The levels should be checked periodically to get uniform level.
14. Proper thickness of slabs and compaction to be ensured.
15. Proper slopes should be maintained on terrace slab, drain out the rain water.
16. Pond test should be conducted on slabs before making final payment.

DURING SLAB CASTING:

1. Ensure proper cover to both + ve and - ve steel by providing spacers, chairs and also bed blocks.
2. Ensure proper level of slab after vibration and finishing by the mason, by Visual inspection.
3. Ensure Presence of the carpenter below the slab shuttering during casting to tackle emergencies.
4. In case of sudden & unforeseen rain, cover the slab with big plastic sheet to protect it duly keeping sufficient stock ready.

AFTER CONCRETING:

1. Dешutter the outer beam sides after 24 hrs. (Stripping time as per clause 10.3 of IS: 456).
2. Make small ponds in sand and cement mortar (1:10) for ponding method of curing for slab. Curing for slab shall be done for 28 days.
3. Paint the date of casting of slab on front side beam.
4. Dешutter the slab after 7 days, 10 days or 15 days depending on span.
5. Hack the beam sides & bottom and slab bottom for proper adherence of plastering.
6. Check all minor honey combing surfaces and if required finish the surface with rich mortar, don't allow concrete with major honey combing.

PROCEDURE FOR CASTING OF CUBES (Clause : 14 of IS: 456)

1. Clean the standard cube moulds 6 Nos. thoroughly and tight all nuts-bolts properly.
2. Apply oil to all contract surface of mould.
3. Size of mould is normally 150 mm x 150 mm x 150 mm.
4. Take the random sample from the mixing ghamela while concentrating.
5. Fill the concrete in cubes in 3 layers.
6. Compact each layer with 35 Nos. of stroke by tamping rod.
7. Finish the top surface by trowel after completion of last layer.
8. Cover the mould by damp hesian cloth immediately to prevent loss of water.
9. Each specimen should be taken from various locations of proposed concreting.
10. After 24 hours remove specimen out of mould.
11. While removing, take care to avoid breaking of edges.
12. Put coding on cubes by paints or marker, coding should be self-explanatory showing site name, concrete location, building number and date of casting.
13. Submerge the specimen in clean fresh water till the time of testing.

14. Test 3 specimens for 7 days and 3 specimens for 28 days curing.
15. Average strength of 3 cubes represents the strengths of concrete of particular portion of the structure.

CURING: Care should be taken for proper curing for all the concrete and cement mortar works. Curing should be looked after by one Engineer/Supervisor of the contractor exclusively.

BRICK MASONRY

Bricks:

CHARACTERISTICS:

The following are the characteristics of bricks used in brick masonry work.

General Quality: The bricks shall be hand or machine molded. Allowance be made for shrinkage in drying and burning. They shall be free from cracks and flaws.

STRENGTH REQUIREMENTS OF BRICKS:

Common building bricks shall have a minimum crushing strength of 35 Kgs/cm² when tested as per IS: 1077 – 1986. The compressive strength of various classes of bricks shall be as follows (as per IS: 1077–1986).

WATER ABSORPTION:

After 24 hours immersion in cold water the maximum water absorption should be as follows:

First Class bricks	20%	By weight
Second Class bricks	22%	„
Third Class bricks	25%	„
Heavy duty bricks	10%	„

EFFLORESCENCE:

Bricks made from clay contain a relatively large proportions of soluble salts particularly calcium sulphate which are liable to become discoloured by the formation of a whitish deposits. While this salting or efflorescence is particularly common to new brick work it may also form on the faces of old external walls which are subjected to excessive dampness.

Brick shall be laid on a full bed of mortar. When laying, the bricks shall be slightly pressed so that the mortar gets into all the pores of the brick surface to

ensure proper adhesion. Cross joints and wall joints shall be properly flushed and packed with mortar so that no hollow spaces are left. Properly filled joints ensure maximum strength and resistance to penetration of moisture which takes place mainly through joints.

In the case of thick walls (two-brick thick and over), the joints shall be grouted at every course in addition to bedding and flushing with mortar.

The course at the top of the plinth and sills at the top of the wall just below the roof slab or floor slab and at the top of the parapet, shall be laid with bricks on edge (applicable only in the case of traditional bricks); and at corners and dead ends the bricks shall be properly radiated and keyed into position by using cut-bricks (also known as 'punja' bricks or 'maraconas').

Bricks with 20 mm deep frog shall be used frog-down. Bricks with 10 mm deep frog shall be used either frog up or frog-down.

The courses shall be aligned and care shall be taken to keep the perpend. The brickwork shall be built in uniform layers; corners and other advanced work shall be taken raked back. No part of a wall during its construction shall rise more than one metre above the general construction level, to avoid unequal settlement and also improper jointing.

Plasters:

These shall be set out as to avoid broken bond.

Openings:

The depth of reveals and rebates shall, where practicable, conform to standard brick sizes in order to avoid cutting of bricks and thereby weakening the work.

The arrangement of bond at quoins at jambs of openings shall be symmetrical.

Partitions:

For half-brick partitions to be keyed into main walls, indents shall be left in the latter.

Fixing of Frames:

Where door or window frames of timber are fixed in the openings, the fixing shall be done generally with hold-fasts of adequate size and strength securely embedded in the brickwork or in chases later filled up by cement mortar or concrete. Hold-fasts shall be fixed in the brickwork for a sufficient length and then turned up at end in to a cross joints, thus avoiding indiscriminate cutting of bricks iron hold-fast shall be given a work faces in contact with brickwork shall be treated with wood preservative to prevent attack from insects and termites.

Protection Against Damage:

Care shall be taken during construction that edges of jambs, sills, heads, etc are not damaged.

In inclement weather, newly built work shall be covered with gunny bags or tarpaulin so as to prevent the mortar from being washed away.

Curing:

In hot dry weather, the mortar is likely to dry up before it has attained its final set and may crumble. This shall be prevented by keeping the brickwork constantly wet for at least 14 days curing is suggested.

BONDING OF BRICKS:-

A systematic arrangement of bricks to obtain a homogenous construction and uniform dispersal of load on the wall is termed as bonding.

The bonds are briefly described below:

1. **English Bond:** This is the most commonly used bond in brick construction. The important features of this construction are:
 - (i) A header course should not start with a closer.
 - (ii) A queen closure is provided after quoin header.
 - (iii) Vertical joints should not be continuous, except at the stopped end.
 - (iv) The wall presents the same appearance on both the faces if the thickness is even number of half-bricks i.e. one brick two bricks thickness etc.
 - (v) If the wall thickness is odd number of half bricks i.e. $\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$ brick thickness the same course will present stretcher on one face and header on the other.
 - (vi) The filling consists of headers only.
 - (vii) The joints in the header course are thinner than those in the stretcher course since the number of joints in the stretcher course is half the number of joints in the header course.

2. **Flemish Bond:** The Flemish bond may be single Flemish or double Flemish. The main features of these bonds are the alternate header and stretchers in the same layer.

(a) Single Flemish Bond: The facing consists alternately of header and stretcher and filling as well as backing consists of English bond in each course. This type of construction can be adopted in 1½ brick and more thicknesses.

- (i) This bond has the strength of English Bond and the appearance of a Flemish Bond.
- (ii) Better bricks can be used for facing and comparatively inferior bricks can be used for filling and backing.
- (iii) The formation of a continuous vertical joint renders the wall weak.
- (iv) More skilled labour is required.

(b) **Double Flemish Bond:** The special features of this type of bond are:

- (i) Stretchers and headers are placed alternately in both facing as well as backing.
- (ii) The queen closer is placed next to the quoin header in alternate courses.
- (iii) A header in any course rests over the stretcher below it.

Double Flemish Bond has the following advantages:

- (i) It presents pleasing appearance in the facing.
- (ii) It is economical as a number of bats can be utilized.

The English Bond is however stronger than the Double Flemish Bond. Also it is suitable only in walls of 1½ bricks or more thickness.

Soaking of bricks

All bricks shall be thoroughly soaked in a tank filled with water prior to being laid. Soaked bricks shall be removed from the tank sufficiently in advance so that they are skin dry at the time of actual laying. Such soaked bricks shall be stacked on a clean place where they are not contaminated with dirt, earth, etc.

Jointing

The thickness of joints of both bed and shall not exceed 10mm for fly ash / cement bricks and 12 mm for clay bricks.

All Brickwork shall be laid in an English bond, unless otherwise specified even and true to line, in accordance with the drawing or as directed by the Engineer, plumb and level and all joints accurately kept.

The joints shall be raked out to a depth of 15 mm while the mortar is still green, so as to facilitate proper bonding for subsequent plastering.

QUALITY CONTROL TESTS:

IS:3495(Part-I to IV)- 1976 gives the testing methods on burnt clay bricks.

1. Compressive strength of burnt clay bricks.
2. Water absorption of burnt clay bricks.
3. Efflorescence of burnt clay bricks.

REFERENCE:

IS: 1077 – 1986 specification for common burnt clay – building bricks.

IS: 3495(Part – I to IV)- 1976 Methods of tests of burnt clay bricks.

IS: 2212 Brick Masonry.

STONE MASONRY**CLASSIFICATION:**

The various types of rocks are as follows:

- a) Principal stones from Igneous rocks: Granite, Basalt and Trap.
- b) Principal stones from Sedimentary rocks: Sand stone, Shales, Lime stone and Laterite.
- c) Principal stones from Metamorphic rocks: Quartzite, Schist, Slate, Marble and Gneiss.

CHARACTERISTICS & PROPERTIES OF GOOD BUILDING STONES:

The chief requirements of building stones are strength density and durability combined with reasonable facility of working. Stones with uniform color are generally found highly durable.

A good building stone should possess several characteristics such as high strength (crushing strength greater than 100 Kgs/sq.cm), high durability, sufficient hardness (coefficient of hardness is greater than 14), high resistance to wear, specific gravity more than 2.70, crystalline structure, high impact value (toughness index greater than 13), low water absorption after 24 hours (less than 0.60), facility for carving and dressing, weather resistance and better appearance. Generally stones from igneous and metamorphic rocks are heavier and more durable than stones from sedimentary rocks. The stone shall be sound, free from cracks and decay. It shall be of uniform colour and texture, hard, durable, tough and best quality of its respective kind.

STRENGTH:

The strength, values of different stones are given below as per SP: 23-1982.

Sl.No.	Type of Stone	Min. Crushing Strength in MN/Sq.m
1.	Granite	185
2.	Basalt	200
3.	Lime Stone	165
4.	Schist	245
5.	Quartzite	330

REFERENCE:

- 1.IS: 1597 (Part -I) – 1987 – Code of practice for stone masonry.
- 2.IS: 1567(Part -II) – 1967 - Code of practice for stone masonry (Ashlars masonry)
- 3.Andhra Pradesh Detailed standard specification.
- 4.Civil Engineer's Hand Book by Khanna.

COURSED RUBBLE FIRST SORT:-

The face stones shall be squared on all joints with beds horizontal and unless otherwise ordered by the Executive Engineer, they shall be set in regular courses of uniform thickness from bottom to top throughout. Unless

other wise ordered by the Executive Engineer, each course shall be the height of each stone in the course, i.e., different depth stones are not to be used and leveled off at certain heights of form the course for this class of masonry. No face stone shall be of less width in plan than 150 mm for walls 400 mm thick, 200 mm for walls 450 mm thick and 250 mm for walls 600 mm thick and more and half the quantity shall be not less than 1/70 cubic metre, 1/50 cubic metre and 1/35 cubic metre in volume for walls of the above thickness respectively. The face stones shall be laid headers and stretchers alternatively, so as to break joint by at least 75 mm and headers shall project at last 100 mm beyond the stretchers. Long vertical faces shall be carefully avoided. The stones shall be solidly bedded, set full in mortar with joints not exceeding 12 mm in thickness and with no pinning whatever on the face and shall extent well back into the heating. Height shall not exceed breadth at face nor length inwards. The backs shall be left rough as quarried, the bed and vertical joints being hammer dressed square with the face for a width of not less than 75 mm and 40 mm inwards from the face respectively. Bushing shall not project more than 40 mm in faces. C.R. Masonry 1st sort shall not be plastered, but it shall be pointed. Where plastering is proposed, the bushing shall not project more than 12 mm.

Height of Courses: The courses are to be not less than 150 mm in height unless otherwise specified. No course shall be deeper than any course below it and no course shall differ from that adjacent by more than than 25 mm in depth.

Through stones and Headers: In all walls upto a width of 600 mm bond stones running through the wall shall be provided at intervals of 2 metres clear in every course. For thicker than 600 mm a line of headers each header overlapping the other by 150 mm or more shall be provided from front to back at 2 metres intervals in every course shall be taken not to place the bond stones of successive courses over each other. The positions of bond stones shall be marked on both the faces for identification and verification. (Tar marking where plaster is to be applied will suffice).

No under-pinning of any kind is to be allowed and hollow bedding and flushing such gaps with mortar are to be carefully avoided.

Hearting: All stones, chips, spalls, etc., shall be wasted clean with water before use so as to ensure a clean surface for the mortar to adhere to. They shall be sprinkled with water before actually placing in work to prevent absorption of water from the mortar. This is specially necessary in the case of sand stones and other highly absorbent stones. The interior shall be filled in with good flat-bedded stones set as close as possible, well flushed in mortar. Chips and spalls of stone shall be wedged in wherever necessary so as to avoid thick beds or joints of mortar care being taken that no dry work or hollow space shall be left anywhere in the masonry. The face work and backing shall be brought up evenly but the backing shall not be leveled up at each course by the use of chips.

The quoins and the angles of the openings shall be of selected stone very carefully squared and bedded and arranged to bond alternately long and short in both directions. Exterior and interior angles and corners shall be chamfered, chisel drafted and rounded.

The work on the interior face shall be precisely the same as on the exterior face, unless the work is to be plastered in which case the sides joints need not be vertical.

Finishing of Joints: The joints shall be struck neatly at the close of the day's work. Where pointing or plastering to stone masonry is not contemplated the joints shall be rubbed smooth.

COURSED RUBBLE IN MORTAR (SECOND SORT):-

This work shall be executed similar to the specifications for C.R.Masonry First Sort, according to the mortar described in the tender schedule for the item i.e., Lime Mortar, Surki Mortar or Cement Mortar respectively with the exception that the hearting and backing shall conform to the standard specification for

Random rubble masonry and bond with the face stones being carried up continuously.

RANDOM MASONRY:- (Uncoursed and Coursed)

Dressing:-

Stone shall be hammer dressed on the face, the sides and beds to enable it to come in proximity with the neighboring stone. The bushing on the exposed face shall not be more than 40 mm and 12 mm on a face to be plastered stones with round stones shall not be used in construction.

Insertion of chips:-

Chips and spalls of stones may be used wherever necessary to avoid thick mortar beds or joints and shall be ensured that no hollow spaces are left anywhere in the masonry. The chips shall not be used below hearting stones to bring these up to the level of face stones. Use of chips shall be restricted to filling of interstices between the adjacent stones in hearting and they shall not exceed 20 per cent of the quantity of stone masonry.

Face Stones:

The width and height of stones shall not be less than 150 mm thick.

Hearting Stones:-

The hearting or interior filling of the wall face shall consists of rubble stone, carefully laid, hammered down with a wooden mallet into position and solidity bedded in mortar. The hearting should be laid nearly level with facing and backing.

Bond stones:-

Through bond stones shall be provided in masonry up to 600 mm thickness for 2 mm interval and in case of masonry above 600 mm thickness, a set of two or more bond stones overlapping each other at least by 150 mm shall be provided in a line from face to back. In case of highly absorbent types of stones

shall (porous limestone and sandstones, etc.) the bond stone shall extend only about two-third into the wall, as through stones in such cases may give rise to penetration of dampness and therefore, for all thickness of such masonry work, a set of two or more bond stones overlapping each other by at least 150 mm shall be provided. One bond stone or a set of bond stones shall be provided for every 0.50 sq. m. of the masonry surface.

Laying:-

The masonry shall be laid with or without courses as specified. The quoins shall be laid header and stretcher alternately. Every stone shall be fitted to the adjacent stone so as to form neat and close joint. Face stone shall extend and bond well in the back. These shall be arranged to break joints, as much as possible, and to avoid long vertical lines of joints.

Joints:-

The face joints shall not be more than 20 mm thick, but shall be sufficiently thick to prevent stone-to-stone contact and shall be completely filled with mortar.

FORM WORK

INTRODUCTION:-

When concrete is placed, it is in a plastic state. It requires to be supported by temporary supports and casings of the desired shape till it becomes sufficiently hardened and attains strength to support its own weight. This temporary casing is known as form work or forms or shuttering. In other

words, Form work is the temporary support given before any part of concrete or masonry is done and removed subsequently.

Page 25 *

Regarding designs, detailing etc., reference may be made to IS: 14687.

REQUIREMENTS OF FORM WORK:

The following are the requirements of good formwork.

EASY REMOVAL:

The design of formwork should be such that it can be removed easily with least amount of hammering. This will also prevent the possible injury to concrete, which has not become sufficiently hard and also can be refused.

ECONOMY:-

It is to be noted that form work does not contribute any thin to the stability of the finished structure and hence it will desirable to bring down its cost to a minimum but without compromise with safety.

LESS LEAKAGE:-

The formwork should be so arranged that there is minimum of leakage through the joints.

RIGIDITY:-

The formwork should be rigid enough so as to retain the shape turnout a good concrete surface.

SMOOTH SURFACE:-

The inside surface of formwork should be smooth so as to turnout a good concrete surface.

STRENGTH:-

The formwork should be sufficiently strong enough to bear the dead load of wet concrete as well as weights of equipments, labor etc. required for placing and compacting concrete.

MATERIALS:-

The usual materials, which are employed in the preparation of formwork, are steel and timber.

STEEL FORMWORK:

Steel is used for formwork when it is desired to re-use the formwork several times. The initial cost of steel formwork is very high. But it proves to be economical for large works requiring many repetitions of formwork. The erection and removal of steel formwork are simple and it presents a smooth surface on removal.

Timber used for scaffolding shall be of suitable quality.

FORMWORK FOR FLOORS:

Formwork for an RCC consists of a skeleton to receive the concrete. It consists of row of vertical posts which carry small wooden beams at their top. The planks for slab are placed on these beams. The boxes for beams are prepared from two sides and one bottom. The vertical posts are suitably supported by lateral supports, laterals, tapering blocks, base-beams, wooden blocks and struts are provided to make the formwork for floor strong enough to bear the load coming upon it.

Following important facts of formwork for floor should be recommended:

1. The formwork for floor should be designed for the weight of concrete plus some additional working load to the extent of about 30% to provide for labour, storage of materials, equipment etc.
2. If required, the posts should be provided with diagonal braces.
3. It is possible to use steel forms for slab, the other components being of wood.

4. Vertical supports should be firmly supported at the bottom.

Stripping Time:

Forms shall not be released until the concrete has achieved a strength of a least twice the stress to which the concrete may be subjected at the time of removal of formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportion and cured under conditions of temperature and moisture similar to those existing on the work.

While the above criteria of strength shall be the guiding factors for removal of formwork, in normal circumstances where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period may deem to satisfy the guideline given in table.

Type of Formwork	Minimum Period Before striking Formwork
a) Vertical formwork to columns, Walls, beams	15-24 h
b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
a) Props to slabs:	
1) Spanning up to 4.5 m	7 days
2) Spanning over 4.5 m	14 days
b) Props to beams and arches:	
1) Spanning up to 6 m	14 days
2) Spanning over 6 m	21 days

QUALITY CONTROL CHECKS:-

For achieving better quality the following points are to be kept in mind.

Checks are to be made for proper alignment and fixing of the following.

1. Supports
2. Planks
3. Joists
4. Cross struts
5. Alignment of beams
6. Levels of beams & slab
7. Centering slopes.

Good concreting can be possible by controlling the formwork effectively and efficiently. The line, level and plumb of all concrete members can be best achieved by providing the formwork properly.

REFERENCES:-

- a) IS 4990 –1981
- b) IS 303 –1975
- c) IS 3337 – 1978
- d) IS 4014 (Part –I) 1967

PLASTERING

PREPARATION OF SURFACE FOR PLASTERING:

- a) All the mortar joints of wall to be plastered are left rough and projecting, so to give a key to hold to the plaster. If the surface is smooth or the wall to be plastered is old one, then the mortar joints are raked out at least to a depth of 12mm to give a key to the plaster.
- b) All cavities and holes inside the surface are properly filled up with cement mortar in advance (daubing).

- c) The mortar joints and surfaces of wall are well washed, wetted with water and keep for at least 6 hrs. before plastering.

In order to obtain a true surface to a plane and uniform thickness, screeds or bands of size 15cm x 15cm and thickness 10 mm, are fixed on the wall horizontally and vertically at a distance of about 2 m. covering the entire wall surface. Mortar is then applied on the wall between ground work of screeds so prepared. Plastering shall be started from top and worked to bottom.

APPLICATION OF PLASTER OF COATS:

The first coat of plaster is applied with mason's trowel and then leveled by means of wooden floats. Finally polishing with a trowel should finish it. Site Engineers should check that all corners and junctions shall be true to line and plumb.

Second Coat or Fine Coat: Before applying the second coat, the first coat is left to set (but not to dry) and is roughened to form proper key with the second coat. This second coat is laid in a thin layer of 3 mm maximum thickness over the rough and moist surface of the first coat. Fine rendering is done with sponge block to have smooth and uniform finishing. The finished plaster whether one or two coats is kept wet by sprinkling water for at least 7 days in order to develop strength and hardness. The average thickness of plaster shall not be less than the specified thickness.

DEFECTS IN PLASTERING:

CRACKING:

Formation of cracks or fissures in the plasterwork, is a common phenomenon observed in a number of buildings. The reasons are as follows:

- a) Plastering on very wet background.
- b) Old surface not being properly prepared.
- c) Excessive shrinkage of plaster due to thick coats.
- d) Excess use of water in the mortar.

FALLING OUT OF PLASTER / PEELING:

Plaster from some portion of surface comes off and results in the formation of patches. The reasons attributable to the above are as follows:

- a) Due to lack of adhesion, a perfect key may not be formed with the background or due to bond failure between successive coats of plaster.
- b) Excessive moisture in back ground or non-uniform suction of water by back ground or non-uniform suction of water by ground material.

EFFLORESCENCE OF PLASTER SURFACE :

It is the whitish crystalline substance which appears on the surface of walls due to presence of salts in the lime, cement, sand, bricks and the sometimes even in water used in the process.

This defect can be rectified by the following process.

A solution consisting of 1 part of hydrochloric acid or sulphuric acid and 5 parts of clean water is prepared. This solution is applied using scrubbing brushes over the well wetted surface. Finally the surface should be washed by spraying with clean water. In case of brick work also, the salts can be removed with a solution of sulphate and water. The surface is brushed off when dry.

Popping defect consists of conical holes known as poses or blows in the prepared surface due to presence of a particle substance which expands on being set.

Crazing defect consists of formation of hair cracks on plastered surface.

CHECKS:

- 1) Care should be taken to complete all concealed works like electrical, water supply and sanitary lines before plastering.
- 2) Rectifications of cracks in masonry works should be done before taking up the plastering.
- 3) The quality of sand used shall be checked to confirm to the specification as indicated at para no.2.3.
- 4) It shall be seen that correct sieve to suit the type of plastering is used.
- 5) The plane and plumb of plastered surface shall be checked and preparation of screeds or bands shall be insisted.
- 6) Care should be taken to avoid irregular joints, patches in the plastering work.
- 7) Care should be taken to provide grooves exactly covering the joints between concrete and masonry components.
- 8) The size, thickness and uniformity of the ceiling borders should be checked.
- 9) Curing should be done properly.
- 10) Dead mortar from doors, windows and flooring should be removed.
- 11) Excess water should not be used in mortar;

12)Wetting of surface before plastering to be done.

13)The mixed mortar should be used before the initial setting tank.

REFERENCES:

1. IS: 712-1964 on plastering work.
2. IS:2542 (Part-1) (Sec.1 to 12)-1978 Methods of test for gypsum plaster.
3. APDSS No.903 & 904

FLOORING

Preparatory Work:

All the inside walls, ceiling and outside walls shall be plastered and door frames and windows fixed in position.

The sub-floor shall be finished to a reasonably true plane surface about 35 to 50 mm below the level of the finished floor, properly graded and free from loose earth, dirt or dust and lumps.

Before tiling work is started, all points of level for the finished tile surface shall be marked out. This is particularly necessary in the case of finished staircase landings. Wherever slopes in finished floors are desired points of level and outlets shall be correctly marked and outlet openings made before hand.

Where it is feared or suspected that dampness may percolate either from the ground floor or walls, the same shall be damp-proofed or waterproofed.

Spreading of Cement Mortar: The tiles shall be soaked in water for 12 hours before using. The base shall be well compacted and the surface shall be rough to form a suitable key. The base shall be cleaned and wetted without allowing any pools of water on the surface. Cement mortar shall be evenly spread over the base for two rows of tiles and about 3 to 5 m in length with thread level fixed at both ends to act as a guide. The top of the mortar shall be kept rough so that cement slurry can be absorbed. The thickness of bedding shall be not less than 10 mm and not more than 30 mm in any one place.

Tiles which are fixed to the floor adjoining the wall shall go above 10 mm under the plaster, skirting or dado as may be required.

The joints shall be kept as close as possible and in straight lines. The joints between the tiles shall normally be 1.5mm wide.

After fixing the tiles, the floor shall be kept moist and allow to mature for 7 days so that the bedding and joints set properly.

The following tests shall be carried out to check the quality of tiles.

1. Determination of water absorption IS: 13630 (Part 2)
2. Determination of modulus of rupture Part 6
3. Determination of linear thermal expansion Part 4
4. Determination of chemical resistance Part 8

5. Determination of resistance to surface abrasion Part 11
- 6 Determination of Scratch hardness of surface Part 13
7. Sampling and basis for acceptance of ceramic tiles.

TESTS TO BE CONDUCTED FOR FLUSH DOOR SHUTTERS.

- | | |
|--|-----------------|
| 1. Measurement of dimensions and square ness | IS: 4020 Part 2 |
| 2. Impact Test | Part 5 |
| 3. Flexure Test | Part 6 |
| 4. Shock resistance | Part 8 |
| 5. Slamming test | Part 10 |
| 6. End immersion test | Part 13 |
| 7. Knife test | Part 14 |
| 8. Glue adhesion test | Part 15 |
| 9. Screw with drawl resistance | Part 16 |

PAINTING

OBJECTIVES:

The various objectives of painting on the different surfaces are as follows:

1. To protect the surface from weathering effects of the atmosphere.
2. To protect the decay of wood and corrosion of metals.
3. To provide a decorative finish to obtain a clean colourful and pleasing surface.

CHARACTERISTICS OF A GOOD PAINT:

- 1) A paint should possess good spreading or covering power.
- 2) The paint should have such a consistency that it can be applied easily and freely on the surface with a brush or spray.
- 3) The paint should be such that it dries within 24 hrs. to a hard dry condition but not too rapidly.
- 4) The paint should not be affected by weathering agencies, i.e., rain, heat, wind etc.
- 5) The paint colour should afford a clean, attractive and pleasing appearance of the surface.
- 6) The paint colour should neither fade nor change by atmosphere influences.
- 7) It should offer a surface which is durable and strong enough to resist moisture penetration.

TYPES:

The following are some of the types of Paints

ALUMINIUM PAINT:

Aluminium paint is widely used for painting metal roofs, gas tanks, oil storage tanks, silos, electric and telegraphic poles, hot water pipes, machinery, radiators etc. It consists of finely ground aluminium suspended in either quick-drying spirit varnish or slow drying oil varnish as per the requirements. Due to silvery shining texture, it is visible even in darkness and possesses high spreading power.

EMULSION PAINT:

This paint consists of a vehicle such as polyvinyl acetate, synthetic resins (usually chlorinated rubber) as the main constituent. It has the qualities of quick drying, good workability and high durability. This paint is recommended for use on stucco, bricks and masonry surfaces which contains free alkali. The surfaces to be painted should be washed with zinc sulphate solution so as to reduce alkalinity.

ENAMEL PAINT:

The paint consists of metallic oxide ground with a small quantity of oil and mixed with petroleum spirit holding resinous matter in solutions. The

enamel paints are generally used for painting porches, stairs, decks, concrete surface etc. This paint is available in market in ready made form in variety of colours.

PAINTING IRON WORK:

Quality of paint required for primer coats and other coats is about same where red -oxide paints are used.

PAINTING CO-EFFICIENTS FOR EQUIVALENT PLAIN AREAS:

WOOD WORK (Doors)

Panelled or framed & braced	1 1/8 (for each side)
Flush	1 (for each side)
Partly panelled & partly glazed	1 (for each side)
Fully glazed	1/2 (for each side)
Fully venetianed or louvred	1 1/2 (for each side)

STEEL WORK (Doors.)

Plain sheeted steel doors	1 1/8 (for each side)
Fully glazed	1/2 (for each side)
Part panelled & part glazed	1 (for each side)
Corrugated sheeted	1 1/4 (for each side)
Rolling shutter	1 1/4 (for each side)
Collapsible gates	1 1/2 (for painting all-over)

FOR NEW WOOD WORK:

Before painting, wooden surfaces shall be well cleared with soap dissolved in water. The washing shall be done by means of large white wash

brushes. After soap and water have been used, the surface shall be well washed down with clean water, and painter's hands must on no account touch the surface. The surface must be dry before the application of paint. All projections, glue or whiting spots, all tool marks and other irregularities, shall be carefully removed with stopping knife and duster and smoothed off and all heads of screws and nails set 1/2" below the surface.

After the surface has been prepared, the primary coat shall be applied. The primary coat shall consist of one part white lead to eight of whiting, ground and mixed together with four parts of twice boiled linseed oil.

After the primary coat has dried, all nail and screw holes and cracks shall be filled with putty and irregularities reduced with sand paper and pumice stone. Priming coat is applied before the wood work is fixed in place.

FOR OLD WOOD WORK:

In case removal of the oil paint is found to be unnecessary, the old painted surface will be rubbed down with sand paper if it is rough, and then washed down with soap and water. If the old painted surface is blistered or flaked, it is necessary to remove the old paint before repainting.

Old paint shall be removed by burning with an ordinary painter's blow-lamp, or by covering the surface with kerosene oil or other paint remover and then burning afterwards scraping off the paint.

When the paint has been thoroughly removed, the surface shall be washed, rubbed down, and holes etc., sealed as specified above for new wood works.

FOR NEW IRON & STEEL WORK:

The surface shall be thoroughly scraped, well brushed and cleaned free of rust, scale and dirt. The primary coat shall consist of red lead and boiled linseed oil.

APPLICATION:

Painting wood work will only be done in dry weather, when the wood work is perfectly dry. Painting to unseasoned wood will do more harm than good and will only induce dry rot, and also result in the paint blistering. Similarly surfaces of all descriptions to be painted -iron, plaster, etc. must be thoroughly cleaned before application of the paint. Paint brushes shall be of best quality manufacture. Only skilled painters shall be employed on painting, varnishing etc.

When thinning of paint is required to produce the required consistency, it shall be done with the following mixture:

Boiled linseed oil	-	14 parts
Spirits of turpentine	-	1 part

The paint shall be laid on evenly and properly by means of crossing and laying off the later in the direction the grain for wood work and care shall be taken that the paint is of such consistency that it runs easily from the brush. The paint must not be allowed to settle in the cans. To prevent this,

each painter shall have in his paint can a small smooth stick with which the paint shall be carefully stirred before the paint is used.

Successive coats of colour shall be applied after the previous coats are thoroughly dried and inspected by the in-charge. Such coat, except the last coat, shall be slightly rubbed down with sand paper or fine pumice stone and cleaned of dust before the next coat is laid. No hair marks from the brush or clogging of paint shall be left on the work.

In painting (or varnishing) doors and windows, the putty round the glass shall also be painted but the glass must not be smeared. Stains of paint in glass panel etc. shall be carefully removed by applying a little turpentine and the whole work left in a clear condition.

REFERENCE:

APDSS No.1201 to 1212

IS: 2395 Part-I, II – 1966-67

TESTS

SIEVE ANALYSIS (COARSE AND FINE AGGREGATE) **(I.S. : 2386 (Part I) - 1963 and I.S. : 383 - 1970)**

OBJECT

To determine particle size distribution of fine, coarse and all-in-aggregate by sieving or screening.

Apparatus:

1. **I.S. Sieves :**

Type	Sieve Designations:
Square hole, perforated plate	40mm, 20mm, 16mm, 12.5mm, 10mm, 4.75mm.
Fine Mesh, Wire Cloth	10 mm, 4.75 mm, 2.36mm, 1.18mm, 600 microns, 300 microns, 150 microns.

2. Balance:

The balance or scale shall be such that it is readable and accurate to 0.1% of the weight of the test sample.

Sample:

The weight of sample available shall be not less than the weight given below. The sample for sieving (see below given table) shall be prepared from the larger sample either by quartering or by means of a sample divider.

Minimum weights for sampling

Maximum size present in substantial proportion (mm)	Minimum weight of sample dispatched for testing (Kg)
63	100
50	100
40	50
25	50
20	25
16	25
12.5	12
10	6
6.3	3

Test procedure for coarsed and fine aggregates

The sample shall be brought to an air – dry condition before weighing and sieving. This may be achieved either by drying at room temperature or by heating at a temperature of 100°C to 110°C. The air-dry sample shall be weighed and sieved successfully on the appropriate sieve starting with the largest; Care shall be taken to ensure that the sieve are clean before use.

Each sieve shall be shaken separately tray until not more than a trace passes, but in any case for a period of not less than two minutes. The shaking shall be done with a varied motion, backwards and forwards, left to right, circular, clockwise and anti- clockwise, and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions. Material shall not be forced through the sieve by hand pressure, but on sieves coarse than 20 mm, placing of particles is permitted. Lumps of fine material, if present may be broken by gentle pressure with fingers against the side of the sieve. Light brushing with a soft brush on the under side of the sieve may be used to clear the sieve openings.

Light brushing with a fine camel hairbrush may be used in the 150 microns and 75 microns IS sieves to prevent aggregation of powder and blinding of apparatus. Stiff or worn out brushes shall not be used for this purpose and pressure shall not be applied at the surface of the sieve to force particles through the mesh.

On completion of sieving, the material retained on each sieve together with any material cleaned from the mash, shall be weighed.

In order to prevent blinding of the sieve apertures by overloading, the amount of aggregate placed on each sieve shall be such that the weight of the aggregate retained on sieve at completion of the operation is not greater than the values given for that sieve in table (B). Sample weights given in table (C) will thus normally require several operations on each sieve.

Note:-

1. For many routine purposes mechanical sieving is advantageous, but if this method is used, care should be taken to ensure that the sieving is complete.

2. If sieving is carried out with a nest of sieve on a machine, not less than 10 minutes sieving will be required for each test.

SIZE OF GRADING OF AGGREGATES (I.S. : 2386 (Part-I) 1963 and I.S. : 383)

Coarse aggregate:

The grading of single-sized coarse aggregate and graded coarse aggregate, when determined as described in I.S. 2386(Part-I) 1963 shall be within limits given in Table I.

Fine aggregate:

The grading of fine aggregates, when determined as described in I.S. 2386 (Part I) 1963, shall be within limits given in Table II.

All-in-aggregates:

The grading of all-in-aggregates when determined as described in I.S. 2386 (Part) 1963 shall be in accordance with Table III.

Observation Sheet.

Sl.No	I.S. Sieve No.	Weight	% Weight Retained	Cumulative % Retained	% Passing
(1)	(2)	(3)	(4)	(5)	(6)

SPECIFIC GRAVITY AND WATER ABSORPTION

OBJECT

Determination of the specific gravity, apparent specific gravity and water absorption of aggregates of size between 40 mm and 10 mm.

Apparatus

The apparatus shall consist of following :

- a) Balance – capacity not less than 3 Kgs.
- b) Oven – a well-ventilated oven, thermostatically controlled to maintain a temperature of 100°C – 100°C .
- c) Glass vessel or jar – a wide mouthed glass vessel such as jar of about 1.5 litres capacity with a flat ground top and a plane ground disc of plate glass to cover it giving a virtually water tight fit.
- d) Clothes – two dry soft absorbent clothes each not less than 75 x 45 cms.
- e) Tray – a shallow tray of area not less than 325 cm.
- f) Container – an air tight container large enough to take the sample.

Sample

A sample of about one Kg of the aggregate shall be used. Aggregates, which have been artificially heated, shall not normally be used; if such material is used, the fact shall be stated in the report.

Two tests shall be made and it is recommended that the two samples should not be tested concurrently.

Test procedure

The sample shall be screened on a 10 mm I.S. Sieve, thoroughly washed to remove finer particles dust and immersed in distilled water in the glass vessel at a temperature of 22 to 32 °C for $24 \pm \frac{1}{2}$ hours. Soon after immersion and again at the end of the soaking period, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation; this maybe achieved by rapid clockwise and anti-clockwise rotation of the vessel between the operator's hands.

The vessel shall be over-filled by adding distilled water and the plane ground glass disc slide over the mouth so as to ensure that no air is trapped in the vessel. The vessel shall be dried on the outside and weighed.(Weight A).

The vessel shall be emptied and the aggregate allowed to drain. Refill the vessel with distilled water. Slide the glass disc in position as before. The vessel shall be dried on the outside and weighed. (Weight B)

The difference in the temperature of water in the vessel during the first and second weighing shall not exceed by 2°C.

The aggregate shall be placed on a dry cloth and gently surface dried with the cloth, transferring it to a second dry cloth when the first will remove no further moisture. It shall then be spread out more than one stone deep on the second cloth, and left exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes or until it appears to be completed by surface dry. The aggregate shall be turned over at least once during this period and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of different aggregates shall then be weighed (Weight C).

The aggregate shall be placed in the oven in the shallow tray at a temperature of 100 to 110°C for $24 \pm \frac{1}{2}$ hours. It shall then be cooled in airtight container and weighed (Weight D).

calculations:

Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

$$\text{Specific Gravity} \quad : \quad \frac{D}{C - (A - B)}$$

$$\text{App. Sp. Gravity} \quad : \quad \frac{D}{D - (A - B)}$$

$$\text{Water Absorption} \quad : \quad \frac{100 (C - D)}{D}$$

Where :

A = Weight in grams of vessel containing sample and filled with distilled water.

- B = Weight in grams of vessel filled with distilled water only.
- C = Weight in grams of saturated surface dry sample.
- D = Weight in grams of oven-dried sample.

Reporting of results:

The individual and mean results shall be reported. The size of the aggregate tested shall be indicated.

Application of test:

- (a) The specific gravity of an aggregate is considered to be a measure of strength of quality of the material. Stones having low specific gravity are generally weaker than those higher specific gravity values. The specific gravity tests the indication of the stone.

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0, with an average value of 2.68 though high specific gravity an aggregate is considered as an indication of high strength, it is not possible to judge the suitability of a sample of road aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values.

- (b) Water absorption gives an idea of strength of rock stones having more water absorption are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

Water absorption value ranges from 0.1 to about 2% for aggregates normally used in road surfacing stones with water absorption up to 4% have been used in base courses. Generally a value of less than 0.6% is considered desirable for surface course though slightly higher values are allowed in bituminous constructions. Indian Roads Congress has specified the maximum water absorption value as 1% for aggregates used in bituminous.

DETERMINATION OF FLAKINESS INDEX VALUE**OBJECT:**

To determine the flakiness index of coarse aggregate sample.

NOTE:

Flakiness index of an aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three fifths ($3/5$) of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.

Apparatus:

The following apparatus are required:

- a) A balance of enough capacity and sensitivity. It should have an accuracy of 0.1% of the weight of test sample.
- b) Metal Gauge conforming to I.S. 2336 (Part I) 1977.
- c) I.S. Sieves – 63 mm, 50 mm, 40 mm, 31.5 mm, 25 mm, 16 mm, 12.5 mm, 10 mm and 6.3 mm.

Sample:

Sufficient quality of sample is needed so that it consists of at least 200 pieces of any fraction to be tested.

Test procedure:

1. The sample has to be carefully and properly sieved.
2. Nine fractions are to be collected with the following specifications:

SIZE OF AGGREGATE		THICKNESS	LENGTH
Passing through I.S. Sieve	Retained on I.S. Sieve	GAUGE	GAUGE
(1)	(2)	(3)	(4)
		mm	mm
63 mm	50 mm	33.90	--
50 mm	40 mm	27.00	81.0
40 mm	25 mm	19.50	58.5
31.5 mm	25 mm	16.95	--
25 mm	20 mm	13.50	40.5
20 mm	16 mm	10.80	32.4
16 mm	12.5 mm	8.55	25.6
12.5 mm	10 mm	6.75	20.2

10 mm

6.3 mm

4.89

14.7

This dimension is equal to 0.6 times the mean sieve size.

This dimension is equal to 1.8 times the mean sieve size.

3. Every piece of each fractional sieve shall be gauged for the minimum thickness with the help of the ISI gauge or in bulk using a set of sieves having standard elongated slots.
4. Thus, each fraction is to be separated into two parts: One consisting of pieces which pass through the corresponding slot in the standard gauge and the other consisting of pieces which do not pass through the corresponding slot in the standard gauge.
5. Weight of each part is separately weighed. Sum of both the weights gives the total weight of each fraction.

The aggregate shall be placed in the oven in the shallow tray at a temperature of 100 to 110°C for $24 \pm \frac{1}{2}$ hours. It shall then be cooled in air tight container and weighed (Weight D).

Calculations:

The sum weight of portions of all fractions; in which pieces pass through the corresponding slots (W.1) and the sum of the weights of all fractions ((W.2) are to be calculated.

Observation Sheet.

Sl.No	Sieve size (in mm)	Weight of Passing	Weight retained	Remaining sample weight
(1)	(2)	(3)	(4)	(5)

$$\text{Percentage Flakiness Index} = \frac{\text{Weight of passing} \times 100}{\text{Total weight}}$$

Application of Flakiness Index:

In pavement construction Flaky and elongated particles are to be avoided, particularly in surface course. If flaky and elongated are present in appreciable proportions, the strength of the pavement layer would be adversely due to

possibility of breaking down under loads. In Cement Concrete the workability also reduced. However, the reduction in strength in cement concrete depends on cement content.

Free from loose mill scales, loose rust and coats of paints, oil mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement.

DETERMINATION OF AGGREGATE IMPACT VALUE

(DRY METHOD : L.S. 2386 (Part IV) 1963)

Object

This method of test covers the procedures for determining the aggregate value of coarse aggregate.

Note: The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact which in same aggregate differs from its resistance to a slow or compressive load.

Apparatus

The apparatus shall consists of the following:

- a) An impact testing machine of the general form as per L.S. 2386 (Part IV) 1963 of weight not more than 60 Kg and not less than 45 Kg.
- b) Sieves : The L.S. Sieve of size 12.5 mm, 10 mm and 2.36 mm.
- c) Measure : A cylindrical metal measure of sufficient rigidity, to retain its form under rough usage, and of the following internal dimensions :
Diameter : 75 mm
Depth : 50 mm.
- d) Tamping Road : A straight metal tamping rod of circular cross section of 10mm in diameter and 230 mm long rounded at one end.
- e) Balance : A balance of capacity not less than 500 gms; readable and accurate to 0.1 gm.
- f) Oven : A well ventilated oven, thermostatically controlled to maintain temperature of 100 C to 110 C.

Preparation of test sample

The test sample shall consist of aggregate the whole of which passes a 12.5 mm L.S. Sieve and is retained on a 10 mm L.S. Sieve. The aggregate

comprising the test sample shall be dried in an oven for a period of four hours at a temperature of 100 °C to 110 °C and cooled.

This measure shall be filled about one-third full with the aggregate and tamped with 25 strokes of the rounded end of the tamping rod. A further similar quantity of aggregate shall be added and a further tamping of 25 strokes given. The measure shall finally be filled to overflowing, tamped 25 times and the surplus aggregate struck off, using the tamping rod as a straight edge. The net weight of aggregate in the measure shall be determined to the nearest gram (Weight A) and this weight of aggregate shall be used for the duplicate test on the same material.

Test Procedure

The impact machine shall rest without wedging or packing upon the level plate block or floor, so that it is rigid and the hammer guide columns are vertical.

The cup shall be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by a single tamping of 25 strokes of the tamping rod.

The hammer shall be raised until its lower face is 380 mm above the upper surface of the aggregate in the cup, and allowed to fall freely on the aggregate. The test sample shall be subjected to a total of 15 such blows, each being delivered at an interval of not less than one second.

The crushed aggregate shall then be removed from the cup and the whole of it sieved on the 2.36 mm L.S. Sieve until no further significant amount passes in one minute. The fraction passing the sieve shall be weighed to an accuracy of 0.1 gm (Weight B). The fraction retained on the sieve shall also be weighed (Weight C) and, if the total weight (B+C) is less than the initial weight (Weight A) by more than one gram, the result shall be discarded and a fresh test made.

Calculations

The ratio of the weight of fines formed to be total sample weight in each test shall be expressed as a percentage, the result being recorded to the first decimal place :

$$\text{Aggregate impact value} = \frac{B}{A} \times 100$$

Where :

B = Weight of fraction passing 2.36 mm L.S. Sieve.

A = Weight of oven dried sample.

Reporting of results

The mean of the two results shall be reported to the nearest whole number as the aggregate impact value of the tested material.

Sl. No.	Initial Weight of material taken	Weight of material passing 2.36 mm Sieve	Weight of material retained on 2.36 mm Sieve.	Percentage passing B/A x 100	Average

WATER CONTENT OF SOIL

(L.S. : 2720 (Part II))

A) Object

To determine the water content of a soil sample using a Pycnometer.

Apparatus

- a) Pycnometer
- b) Balance

Procedure

Weigh clean and dry pycnometer with its Cap (W.1).

Place a sample of wet soil (200 grams to 500 grams) into pycnometer and weigh (W.2).

Add water to soil in pycnometer till it is about half full, mix thoroughly with glass rod and remove entrapped air, continue stirring and add more water till it is flush with the whole in the conical top. Dry the outer side and weigh (W.3). Entrapped air may be removed by vacuum pump, if available.

Empty the pycnometer, clean it and refill with clean water flush with top hole. Wipe dry the outside and weigh (W.4).

Calculations

$$\text{Water content } w = \frac{(W_2 - W_1)}{(W_3 - W_4)} \times \frac{G - 1}{G} \times 100\%$$

Where :

G = Specific gravity of soil particles can be obtained by using dry soil specimen.

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Where :

W1 = Weight of pycnometer empty.

W_2 = Weight of pycnometer + Weight of Soil.

W_3 = Weight of pycnometer + Soil + Water.

W_4 = Weight of pycnometer + Water.

Observation

Test No.	1	2	3
1. Weight of pycnometer empty (W_1).			
2. Weight of pycnometer + Weight of Soil (W_2).			
3. Weight of pycnometer + Soil + Water (W_3).			
4. Weight of pycnometer + Water (W_4).			
5. Weight Contents (w).			

Reporting of results

Moisture content shall be expressed as percentage of the weight of dry soil average of three values shall be reported.

(B) Object

To determine the water content of soil sample by oven dried method in Lab.

Apparatus

- Container : Air tight and non-corrosible.
- Balance, sensitivity 0.01 gm.
- Oven : Thermostatically controlled with interior of non-corroding material to maintain the temperature at $110\text{ C} \pm 5\text{ C}$.
- Desiccator : A desiccator with any suitable desiccating agent.

Soil specimen

The soil specimen taken shall be representative of the soil mass. The size of the specimen selected depends on the quantity required for good representation, which is influenced by the gradation and the maximum size of particles, and on the accuracy of weighing. The following quantities are recommended for general use (I.S. 2720 (Part II)).

Size of particles more than 90% of passing I.S. Sieve	Minimum quantity of soil specimen to be taken for test mass in gms
425 micron	25

2 mm	50
4.75 mm	200
10 mm	300
20 mm	500
40 mm	1000

Procedure

Clean the container with lid, dry and weight (w.1). Take the required of soil specimen in container crumbled and placed loosely and weigh with lid (w.2). Then keep it in an oven with the lid removed and maintain the temperature of the oven at $110\text{ }^{\circ}\text{C} + 5\text{ }^{\circ}\text{C}$. Dry the specimen in the oven for 24 hours and then container is taken out from oven for weighing. Replace the lid on the container and cool the container in desiccator. Record the final mass (w.3) of the container with lid with dried soil sample.

Calculations

The percentage of water content shall be calculated as follows:

$$w = \frac{(W2 - W3)}{(W3 - W1)} \times 100$$

Where :

W = Water content percentage.

W1 = Weight of container with lid in grams.

W2 = Weight of container with lid with wet soil in grams.

W3 = Weight of container with lid with wet dry in grams.

Observations

1. Container No. :

2. Weight of container + Wet soil W2 grams. :

3. Weight of container + Dry soil W3 grams. :

4. Weight of container W1 grams. :

5. Weight of Dry soil (W3 – W1 gm. :

6. Weight of moisture (W2 – W3 gm. :

7. Water content :
- $$w = \frac{(W2 - W3)}{(W3 - W1)} \times 100$$
-

(C) Object

To determine the water content of soil sample by oven dried method in field.

Apparatus :

Sample as sin case of oven dried method except that oven used is field oven and is heated by using stone.

Soil specimen

Same as before.

Procedure

Same as before except that sample is dried in field oven by using stone for heating of oven.

Calculation

Same as before

Observation

Same as before.

(D) Object

To determine water content of soil by sand bath method.

Apparatus

- a) Container : Any suitable non-corrodible air tight container.
- b) Heat resistant tray : of suitable metal and about 5 to 7 cm deep.

- c) Balance, sensitivity to 0.01 gm.
- d) Sand bath of suitable size and containing clean sand to a depth of at least 3 cm.
- e) Equipment for heating the sand bath – kerosene stove or spirit lamp.
- f) Palette knife or steel spatula – a convenient size is one having blade 10 cm. long and 2 cm wide.
- g) Scoop – a convenient size is one about 20 cm long and 10 cm wide.

Soil Specimen

The soil sample is taken same as test in oven dried method.

Procedure

Take the required quantity of the soil specimen in the container crumbled and placed loosely and weight (W2). Place the container on sand bath and heat sand bath. Care shall be taken not to get sand bath too hot. During heating, the specimen shall be turned frequently and thoroughly with the blade to assist the evaporation of water, care being taken to see that no soil is lost in this process. Dry the specimen to constant weight indicated by the difference between the consecutive weight of the container with the dried specimen taken at suitable interval after initial drying, being a maximum of 0.1% of the original weight of the soil specimen. When drying is complete, remove the container from the sand bath, cool and weigh (W3).

Calculations

$$w = \frac{(W2 - W3)}{(W3 - W1)} \times 100$$

Where :

W = Water content percentage.

W1 = Weight of container.

W2 = Weight of container + Wet soil.

W3 = Weight of container + Dry soil.

Observations

Same as earlier.

(E) Object

Rapid determination of water content by Infra-Red Lamp Torsion Balance moisture meter.

Apparatus

- (a) Infra-red Lamp and Torsion Balance Moisture Meter : The equipment has two main parts; the infra and red lamp, and the torsion. The infra-red radiation should be provided by 250 watt lamp built in the balance for use with the alternating current 220 – 230 V, 50 cycles, single phase mains supply. Provision should be made to adjust the input voltage to the infra-red lamp to control the heat for drying of specimen. A suitable thermometer graduated from 40 C to 150 C should be provided for ascertaining the temperature of drying in the pan housing. The weighing mechanism of torsion balance should have a built-in magnetic damper. The balance scale should be divided in terms of water percentages from 1 to 100 percent water content in 0.2 percent division.
- (b) Palette knife or steel spatula – having a blade 10 cm long and 2 cm wide.

Soil Specimen :

The soil specimen taken shall be a representative of the soil mass. The specimen 25 gms, passing from 2 mm I.S. Sieve is taken.

Procedure :

Keep the test samples always in suitable containers so that the water content to be determined is not affected by ambient conditions.

Set the 100 percent scale division of the calibrated drum to align with the index mark with the help of drum drive knob.

With the pan placed on the pivot, check that the pointer is aligned with the index line and 100 percent scale division. If not, set the pointer with the help of initial setting knob.

Rotate the drum drive knob anti-clockwise and bring the 0 percent scale division in line with the index mark, thus pre-stretching the wire through the amount equal to 100 percent (this represents the amount of unbalance). The pointer will now be above the index mark.

Raise the lamp housing and carefully distribute the test material evenly on the sample pan until the pointer returns to the index mark (approximately 25 gms of the material will be needed in one operation).

Lower the lamp housing and switch on the infra-red lamp with the help of switch provided on the left hand side. Insert the thermometer in its socket and bracket. Adjust the Variac Control Knob between 95 and 100 on the scale if it is desired that the temperature of drying is around 110 C. The sample will not begin to lose water and the pointer will rise above the index.

To determine the percentage reduction of mass at any instant, rotate the drum scale by turning the drum drive knob until the pointer returns to the index. Read the percentage directly from the scale. The percent water which is read from the scale is the percent water based upon the initial mass of the sample, that is, the wet mass of the sample.

The criterion for taking the final reading is that the pointer should remain steady on the index mark which shows that the sample has dried to constant mass. Note the drum scale reading against the pointer which is the percent water on the total mass taken. Remove the thermometer from its bracket.

Repeat steps with a fresh sample using a cool and clean pan.

Calculations

From the water content (m) as obtained on the moisture balance scale, the water content (w) on the dry weight basis shall be calculated as follows:

$$w = \frac{m}{100 - m} \times 100$$

(F) Object

To determine moisture content by rapid moisture meter (using calcium carbide).

Apparatus

- a) Metallic pressure vessels, with clamp for ceiling-cum-gauge calibrated in percent water content.
- b) Counter poised balance for weighing samples.
- c) Scoop for measuring calcium carbide.
- d) Bottle of calcium carbide.
- e) One cleaning brush.
- f) Three steel balls of about 10.5 mm diameter and one steel ball of 25 gms.

Soil Specimen

Sand requires no special preparation. Coarse powder may be ground and pulverized. Cohesive and plastic soils are tested with addition of balls in the pressure vessels. This test requires 6 gms of specimen.

Procedure

In this method, a weighed quantity of wet soil is mixed with calcium carbide in an air-tight container. The pressure of the acetylene gas produced by the reaction of calcium carbide with water present in soil is read on a dial gauge located on one end of the container (moisture tester), the dial gauge being calibrated to read in percentage of water based on the wet weight of the sample. The moisture testers are usually available in two sizes; one for a 6 gm sample and the other for a 26 gm sample. It is preferable to use a large size tester. The instrument can be calibrated for converting the moisture tester readings to the equivalent of water contents obtained by oven drying. The method is quick, taking less than 5 minutes and fairly accurate. Difficulty is experienced in proper pulverization and mixing of clay soils inside the tester. Two steel balls of about 30 mm diameter can be put inside the larger size tester for proper pulverization.

Calculation

From the water content (m) as obtained on the moisture balance scale, the water content (w) on the dry weight basis shall be calculated as follows :

$$w = \frac{m}{100 - m} \times 100$$

2) GRAIN SIZE DISTRIBUTION OF SOIL

(I.S. : 2720 (Part IV) 1975)

Object

To determine grain size distribution of soil by :

- a) Dry Sieve Analysis.
- b) Wet Sieve Analysis.

DRY SIEVE ANALYSIS

Procedure

A minimum quantity of sample (obtained from larger sample either by quartering or by means of a sample divider) as given in table below should be taken dried, cooled and weighed and it should then be passed successfully through the sieves specified in para given above starting with the largest. Care should be taken that the sieves are clean before use.

If sieving is carried out by hand each sieve should be shaken separately over a clean tray for a period of not less than two minutes. The shaking should be done with a varied motion backwards and forwards, left to right, circular, clockwise and anti-clockwise and with frequent jarring, so that the material is

kept moving over the sieve surface in frequently changing directions. Material smaller than 20 mm should not be heaped through the sieve by hand or by brushing. Lumps of fine materials, if present, may be broken by gentle pressure with fingers against the side of the sieve.

If sieving is carried out with pest of sieves on a machine not less than 10 minutes sieving will be required for each test.

On completion of sieving the material retained on each sieve, together with any material cleaned from the mesh shall be weighed on a balance.

The percentage by weight retaining on each sieve shall be calculated and the results shall be given to the nearest 0.1 percent. From these results the cumulative percent by weight of the total sample passing each of the sieves will be calculated and recorded to the nearest whole number, the results of sieving tests may be recorded graphically on the chart for recording sieve analysis.

TABLE

Minimum weight of laboratory samples required for sieve analysis

Test	Minimum weight of sample to be taken for sieving
SIEVE ANALYSIS :	KG.
Maximum size of aggregate :	
1. 63 mm	50
2. 50 mm	35
3. 40 mm	15
4. 20 mm	2
5. 12.5 mm	1
6. 10 mm	0.5
7. 4.75 mm	0.2
8. 2.36 mm	0.1

Observation Sheet

Weight Table

Sl. No.	I.S. Sieve No.	Weight	% Weight	Cumulative	% Passing
---------	----------------	--------	----------	------------	-----------

	Retained	Retained	% Retained	
--	----------	----------	------------	--

WET SIEVE ANALYSIS

To determine grain size distribution of soil by wet sieve analysis.

Note : This method describes a procedure for grain size distribution of that fraction of soil which is finer than 2 mm size.

Apparatus

- a) Sieve
 - 2 mm I.S. Sieve
 - 1 mm I.S. Sieve
 - 600 Micron I.S. Sieve
 - 300 Micron I.S. Sieve
 - 212 Micron I.S. Sieve
 - 150 Micron I.S. Sieve
 - 75 Micron I.S. Sieve
- b) Balance to weigh 0.1 gm accurately.
- c) Oven – 105 C to 110 C.
- d) Trays.
- e) Brushes
- f) Mechanical Sieve Shaker.

Sodium hexameta-phosphate or a mixture of sodium hydroxide and sodium carbonate or other dispersing agent which has been found suitable.

Procedure

Take about 100 gms of the sample of soil oven-dried at 105 C to 110 C and passing through 2 mm I.S. Sieve. The fraction shall be weighed accurately to 0.1 gm, and its weight recorded. The weighed fraction shall be spread out in a large tray or bucket and covered with water.

Two grams of sodium hexameta-phosphate or one gram of sodium hydroxide and one gram of sodium carbonate per litre of water used shall then be added to the soil (See Note). The mixture should be thoroughly stirred and left for soaking. The soil soaked specimen should be washed thoroughly over the next sieve specified in 1:1b:1 nested in order of their fineness with the finest sieve (75 micron I.S. Sieve) at the bottom. Washing shall be continued until the water passing each sieve is substantially clean. Care shall be taken to see that the sieves are not overloaded in the process. The fraction retained on each sieve should be emptied carefully without any loss of material in separate trays, oven-dried at 105 C to 110 C and fraction weighed separately and weight recorded.

Note : A dispersing agent may not be required in the case of all soils, in such cases the wet sieving may be carried out without the addition of dispersing agent.

Calculations

The cumulative weight of soil fraction retained on each sieve shall be calculated. The percentage of soil fraction retained in each sieve shall be calculated on the basis of the weight of the sample passing 2 mm I.S. Sieve taken for the initial analysis. The combined gradation on the basis of the total soil sample taken for analysis shall then be calculated.

3(a) DETERMINATION OF LIQUID LIMIT OF SOIL BY CASAGRANDE METHOD

(I.S. : 2720 (Part-V) 1970)

Object

To determine the liquid limit of the given soil sample.

Apparatus

Liquid limit device and grooving tools, spatula, porcelain dish, balance of sensitivity 0.01 gm and containers for moisture content determination drying oven, beaker and measuring jar.

Theory

Liquid limits is the water contents at which the soil has such a low shear strength that it flows to close a groove of standard dimensions for a length of 12.0mm which when jarred 25 times using the standard liquid limit device. (It is the water content corresponding to the boundary between liquid and plastic states of a soil mass).

Procedure

1. Weigh about 200 gms of air dried soil passing through 425 micron I.S. Sieve (0.425mm size).
2. Take the soil in a porcelain dish and add clean water till it becomes a paste. Mix the soil thoroughly (certain soils may require mixing upto 40 minutes).
3. Check and adjust the fall of the liquid limit device cup to exactly 1 cm, using the gauge on the handle of the grooving tool.
4. Place the soil paste in the cup of liquid limit device and level it horizontal with lowest edge of the cup, with spatula so that the maximum depth of soil in the cup is 1 cm.
5. Using the standard grooving tool, make a groove in the middle of the soil along the diameter, dividing the soil into two parts.

6. Turn the handle of the liquid limit device at the rate of 2 revolutions per second, till the two parts of the soil in the cup join together i.e. the groove closes by 12.0mm length. Ensure that the groove closes by flow and not by slipping of soils on the surface of the cup.
7. Note the number of blows imparted to the cup. Repeat and re-check this value. Take a small quantity (about 10 gms) of the moist soil from the centre of the groove into a moisture determination container and determine the moisture content.
8. By altering (increasing the water content of the soil and repeating the above operation, obtain five or six water content determinations for blows in the range of 10 to 40 blows.
9. The test should proceed from drier (more blows) to the wetter (less blows) condition of the soil. Each time the soil is thoroughly mixed to ensure that the water content is uniform throughout the soil mix.
10. Interpretation of results : Plot the results of the experiment of a semi-log sheet. The percentages of moisture content are marked as ordinates on the arithmetical scale and the corresponding number of blows are marked as abscissa on the logarithmic scale. The various points obtained are joined by a straight line and the moisture content corresponding to 25 blows is denoted as the liquid limit of the soil. At least four readings should be taken though live readings are desirable. The above straight line is known as FLOW CURVE. It shall be extended at either ends, so as to intercept the ordinate corresponding to 10 and 100 blows. The slope of this line expressed as the difference in water content at 10 blows and at 100 blows shall be reported as the flow index (1f).

The flow index may be calculated from the following equation also :

$$w = \frac{W1 - W2}{\log_{10} \frac{N2}{N1}}$$

Where :

1f = flow index.

W1 = moisture content in % corresponding to 'N1' blows.

W2 = moisture content in % corresponding to 'N2' blows.

4) DETERMINATION OF PLASTIC LIMIT OF SOIL

(I.S. : 2720 (Part V) 1970)

Object

Plastic limit is defined as the minimum moisture content at which a soil when rolled into a thread of 3mm dia meter just begins to crumble. It is the water content corresponding to the boundary between plastic and semi-solid states of soil mass.

Procedure

1. Take about 30gms of the air dried soil passing through 425 micron I.S. Sieve (0.425 mm size).
2. Place the soil in a porcelain dish and mix with sufficient quantity of water until the mass becomes plastic enough to be easily moulded with fingers.
3. Take a portion of the wet soil and form it into a ball and roll it quickly on a glass plate with the palm of hand into a thread of uniform diameter. (If the soil cannot be rolled into thread at all or even if the thread on first rolling breaks before reaching a diameter of 3mm, the initial trial water content is less than plastic limit of the soil. Hence add a little more water to make it more plastic. Continue this process and the rolling till the threads reach a diameter of 3mm.
4. The soil is then kneaded together, re-rolled again on the glass plate till it begins to crumble at 3mm diameter. (The crumbling may occur even when the thread has a diameter slightly greater than 3mm).
5. Take some of the crumbled soil pieces and determine the water content.
6. Repeat the experiment for at least 3 times and the average water content is recorded as the plastic limit of the soil.

Plastic limit test

Determination No.	1	2	3
Container No.			
Wt. of container + wet soil (gms)			
Wt. of container + oven dry soil (gms)			
Wt. of water (gms)			
Wt. of container (gms)			
Wt. of dry soil (gms)			
Moisture content (%)			

Nature of water content w_n % = (of a field soil sample if any)

Result Summary

Liquid Limit W_1	Flow Index I_f	Plastic limit w_p	Plasticity Index $I_p = w_1 - w_p$	Toughness Index $\frac{I_t - I_p}{I_f}$	Liquidity Index $I_L = \frac{w - w_p}{I_p}$	Consistency Index $I_C = \frac{W_1 - W_n}{I_p}$
1	2	3	4	5	6	7

SHRINKAGE LIMIT TEST
(I.S. 2720 – Part IV – 1972)

Object

Determination of shrinkage limit

Apparatus

Evaporating dish, shrinkage dish of diameter 4.5cm and height 1.5cm (both internal), spatula, straight edge, glass cup 5 to 6cm in internal diameter and 2.5cm height, two glass plates 7.5cm x 7.5cm, one plane and the other having three metal prongs. Also other equipment needed are a 25ml graduated jar to read 0.2ml, balance sensitive to 0.01gm, mercury sufficient to fill the glass cup and a dessicator.

Procedure

About 30g of dry pulverized soil passing 425 micron sieve is weighed out. The soil is placed in the evaporating dish and thoroughly mixed with distilled water to make a paste that may be readily worked out into without entrapping air bubbles. The water content required may be more than the liquid limit. The inside of the shrinkage dish is coated with a thin layer of Vaseline or heavy grease to prevent adhesion of soil to the dish. The soil paste equal to roughly one third the volume of dish is placed in the centre of the dish and the paste is allowed to flow to the edges by tapping the dish on a firm surface cushioned with a few layers of blotting paper on similar material. Then another equal quantity of paste is added and trapped so that all the air bubbles entrapped come to the top and the paste gets compacted. The process is continued till the paste fills the dish completely and starts overflowing. The excess paste is struck off by a straight edge and the outside of the dish is wiped clean.

The dish is immediately weighed and the pat is allowed to dry in air till the colour of the pat becomes lighter. Then the dish is kept in an oven at 105° C to 110°C to constant weight and cooled in a desiccators and weighed to find the dry weight. The weight of the empty dish is determined. The volume of shrinkage dish is found by pouring mercury, until the over flows removing the excess by pressing the plain glass plate flush with surface of glass cup and measuring the volume of the mercury in the dish by pouring in the graduate.

The glass cup is filled with mercury until it overflows and is pressed with the glass plate having three prongs. This cup full of mercury is placed in a clean evaporating dish, the dry soil pat floated on the mercury and is carefully forced under by the glass plate with prongs. The plate is firmly pressed flush with the surface. Care is taken to ensure that no air is entrapped under the pat. The volume of mercury displaced is measured in the graduate and this is recorded as the volume of the dry pat.

Calculations

Moisture content of the soil past taken in the shrinkage dish is calculated :

$$W\% = \frac{W_1 - W_2}{W_1 - W_3} \quad 100 \text{ per cent}$$

where W_1 , W_2 and W_3 are respectively the weights of dish plus wet soil, dish plus dry soil and dish only.

Shrinkage limit w is calculated from the relation :

$$W\% = w - \frac{V - V_o}{W_o} \quad 100$$

Where :

w = moisture content of paste forming wet pat.

V = Volume of wet pat, cm³.

V_o = Volume of dry pat, cm³.

W_o = Weight of oven dry pat = ($w_2 + w_3$) gm.

Shrinkage ratio, is given by $R = W_o / V_o$

Volumetric shrinkage, V_s is given by $V_s = (w_1 - w_s) R$

Where :

W_1 = stipulated moisture content, %

W_s = Shrinkage limit

R = Shrinkage ratio

Linear shrinkage, L_s is given by :

$$L = 100 = 1 - \frac{100}{V_s + 100}$$

Shrinkage limit can also be calculated just by knowing the oven dry weight and volume of a part of soil and the specific gravity G of soil particles. This method is especially suitable for finding the shrinkage limit of undisturbed soils.

Shrinkage limit is given by :

$$W_s = \frac{V_o - 1}{W_o \cdot G} \quad 100\%$$

Where :

V_o = volume of dry part of soil

- W_o = weight of dry part of soil
G = specific gravity of particles

DETERMINATION OF SPECIFIC GRAVITY OF SOIL PARTICLES
(BY PYCNOMETER METHOD)

(I.S. : 2720 (Part-III/Sec. XI) 1980)

Object

To determine the specific gravity of soil particles of the given sample passing 4.75mm sieve insitu.

Theory

Specific gravity is the ratio of weight in air of a given volume of dry soil solids to the weight in air of an equal volume of distilled water at a temperature of 27 °C. To specific gravity of soil particles is useful mainly for deriving other needed properties of soils like void ratio, grain size distribution etc. For sand grains the average value of specific gravity is about 2.65 and for clay particles it varies from 2.5 to 2.9 with a statistical average of about 2.7.

Apparatus

Glass jar or pycnometer or density bottle, vacuum pump, balance, thermometer, and distilled water.

Procedure

1. Determine the natural water content of the given soil sample (say w) if oven dried sample is not supplied.
2. Dry the pycnometer thoroughly and find its weight with cap (m₁).
3. Take about 200gms of the given soil into the pycnometer and find the weight of the pycnometer with soil correctly (m₂).
4. Add sufficient water (up to about half the capacity of pycnometer to cover the soil). Screw on the pycnometer cap tightly.
5. Shake the pycnometer well and connect it to a vacuum pump to remove the entrapped air. Allow the air to be evacuated for 15 minutes shaking the pycnometer completely with water.
6. Make sure that all the entrapped air has been expelled and then disconnect the pump till pycnometer completely with water.

7. Mark the cap and the pycnometer with a vertical line parallel to the axis of the pycnometer so that each time the cap is screwed to the same extent with reference to the vertical line as a guide.
8. Wipe out any excess water on the outer surface on the pycnometer and find out its weight (m3).
9. Throw out the contents of the pycnometer and wash it thoroughly.
10. Fill the pycnometer completely with water and screw on the cap as before.
11. Wipe off any excess water on the outer surface of the pycnometer and find its weight (m4).
12. Take the average value of at least three sets of readings. Report that the specific gravity of the soil corresponding to the standard temperature of 27°C.

Record of results and calculation for determination of specific gravity

Date : _____ Soil Type : _____
 Room Temperature : _____ Tested by : _____

Sl.No.	Description	Test-1	Test-2	Test-3
1.	Weight of dry pycnometer (Circular ar – ml)			
2.	Weight of the pycnometer + soil m2 gms			
3.	Weight of the dry soil taken m2 – ml (Wd) gms			
4.	Weight of pycnometer + soil Water $\frac{W3}{m}$ gms			
5.	Weight of pycnometer + water m4 $\frac{W}{4}$ gms			
6.	Specific gravity corresponding to 27 C (GO) $G = \frac{m2 - m1}{(m4 - ml) - (m3 - m2)}$			

The specific gravity shall be calculated at 27°C. If the room temperature is different, then 27°C, the following correction to be done.

$$G' = KG$$

Where :

G' = corrected specific gravity at 27°C and

K = $\frac{\text{Relative density of water at room temperature}}{\text{Relative density of water at 27° C}}$

(b) DETERMINATION OF THE BEARING CAPACITY BY PLATE LOAD BEARING TEST IN THE FIELD

Object

Determination of bearing capacity by plate load bearing method.

Scope

- a) This standard lays down the method of conducting the load test and the evaluation of bearing capacities and settlement from this test.
- b) This method assumes that down to the depth of influence of stresses the soil strata is reasonable uniform. This should be verified by bearing or sounding.

Description of the Loading Test

In this test a bearing plate of mild steel should be subjected to a gradual increment of load and the corresponding settlement should be noted. The ultimate bearing capacity shall be taken as the load at which the plate starts sinking at a rapid rate.

When a plate bigger than 30cm square is used a series of smaller and smaller plates should be used eccentrically in order to reduce the upward deflection of free edges of the plate resting on the soil and ensure the series proper distribution of the plate resting on the soil and ensure the series recommended are 30cm, 40cm, 50cm and 75cm square plates.

Size and shape of plate: For clayey soils and sandy and silty soils normally met with, the size of the plate shall be 60cm square. In the case of gravelly and dense sand soils, the smallest size of larger sizes to be used may be upto 75cm square depending on practical considerations. The thickness shall be minimum 25mm.

Placing of test plate: The plate shall be added to placing the soil by plaster of paris aluminous cement slurry of fine sand, carefully leveled and set horizontally at the bottom of the hole dug at foundation level in the test pit. The ground under test shall be protected from rain. Suitable divide should be

used to prevent tilting when loaded. At the commencement of the test the plate shall be preloaded with a load of 70 kg/cm and released.

Application of load: The load should be applied to the test plate either by gravity loading or by reaction loading. Take care to avoid impact fluctuation or eccentricity so as to reach the soil at a static load. The loading shall be applied in increments of about one-fifth of the estimated bearing capacity, but not exceeding 10 tonnes upto a maximum of one and a half times the estimated load.

Settlement and observations: Settlement should be observed for each increment of load after an interval of 1, 4, 10, 20, 40 and 60 minutes and thereafter at hourly intervals. In the same case of clayey soil the 'time settlement' curve should be plotted at each load stage and increased to the next stage either when the curve indicates that the settlement has exceeded 70 to 80 percent of the probable ultimate settlement at that stage or at the end of 24 hour period. For soils other than clayey soils each load increment shall be kept for not less than one hour and upto a time when the rate of settlement gets appreciably reduced. The next increments of load shall then be applied and observations repeated.

If needed, rebound observations may be taken while releasing the load in a similar manner as the settlement observations for at least an hour.

Computation of Bearings Capacity of soils

From plate load test observations: A settlement curve of arithmetical scale is first drawn and zero correction if any is applied. The settlement v/s load is again drawn on log-log scale and yield load is determined, which is the ultimate bearing capacity. This, divided by suitable factor of safety and also taking into consideration the conditions of water table will give the SBC of the soil.

(A) Normal Consistency

Object

Determination of the quantity of water required to produce a cement paste of standard consistency.

Apparatus

Vicat apparatus (conforming to IS: 5513– 1968) with plunger (10mm in dia).

Theory

The standard consistency of a cement paste is defined as that consistency which will permit the vicate plunger to penetrate to a point 5 to 7 mm from the bottom of the vicat mould, when the cement paste is tested as described in the following procedure.

Procedure

Prepare a paste of weighted quantity of cement (350 gms) with a weighted quantity of water, start with 30% water of 350 gms of cement taking care that the time of gauging is not less than 3 minutes and not more than 5 minutes and the gauging shall be completed before any sign of setting occurs. The gauging time shall be counted from the time of adding the water to the dry cement until commencing to fill the mould. Fill the vicat mould with this paste, the mould resting upon a non-porous plate. After completely filling the mould, trim off the surface of the paste, making it in level with the top of the mould. The mould may slightly be shaken to expel the air.

Place the test block with the mould, together with the non-porous resting plate, under the rod bearing the plungers (1 cm dia) lower the plunger gently to touch the surface of the test block and quickly release, allowing it to penetrate into the paste. This operation shall be carried out immediately after filling the mould.

Prepare trial pastes with varying percentages of water and test as described above until the amount of water necessary for making the standard consistency as defined above is obtained. Express the amount of water as a percentage by weight of the dry cement. The observations will be tabulated as shown below:

Sl. No.	Wt. of cement taken (in gms) (a)	Wt. of water taken (in gms) (b)	Plunger penetration (in mm)	Time taken from the adding of water to cement	Consistency of cement in % by weight $b/a \times 100$
1	2	3	4	5	6

Precautions

Use clean appliances for gauging. The temperature of cement and water and that of test room, at the time when the above operations are being performed, shall be 27 ± 2 °C. The room temperature shall be maintained at 27 ± 2 °C.

(B) Initial and Final Setting Times

Object

Determination of the Initial and Final setting times of cement.

Apparatus

The vicat apparatus (conforming to IS : 5513 – 1969).

Sample

350 gms of cement is taken.

Procedure

Preparation of Test Block

Prepare a neat cement paste by gauging 350 gms of cement with 0.85 times the water required to give a paste of standard consistency. The paste shall be gauged in the manner and under the conditions prescribed in determination of consistency of standard cement paste. Start a stop watch at the instant when water is added to the cement. Fill the mould with the cement paste gauged as above, the mould resting on a non-porous plate, fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

Use clean appliances for gauging. The temperature of water and that of the test room, at the time of gauging, shall be 27 ± 2 °C.

During the test, the block shall be kept at a temperature of 27 ± 2 °C and at not less than 90% relative humidity.

Determination of initial Setting Time

Replace the needle of the vicat apparatus by the needle with an annular ring. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the outer ring fails to do so. The period elapsing between the time when water is added to the cement and the time at which the needle makes an impression on the surface of the test block while the attachment fails to do so, shall be the final setting time.

Limits

Initial setting time minimum = 30 minutes

Final setting time maximum = 600 minutes

3) DETERMINATION OF FINENESS OF CEMENT

(IS : 269 and IS : 4031 – 1968)

Object

To determine the fineness of cement by dry sieving.

Apparatus

- 1) Standard balance with 100 gm. Weighing capacity
- 2) IS : 90 micron sieve conforming to IS : 460– 1962 and a brush.

Procedure

- 1) Break down any air-set lumps in the cement sample with fingers.
- 2) Weigh accurately 100 gms of the cement and place it on a standard 90 micron IS sieve.
- 3) Continuously sieve the sample for 15 minutes.
- 4) Weigh the residue left after 15 minutes of sieving. This completes the test.

Result

The percentage weight of residue over the total sample is reported.

$$\% \text{ weight of residue} = \frac{\text{Wt of Sample Retained on the Sieve}}{\text{Total Weight of the Sample}}$$

Limits

As per IS : the percentage residue should not exceed 10%.

Precautions

Sieving shall be done holding the sieve in both hands and with gentle wrist motion, this will involve no danger of spilling the cement, which shall be kept well spread out on the screen. More or less continuous rotation of the sieve shall be carried out throughout sieving.

Washers, shots and slugs shall not be used on the sieve. The underside of the sieve shall be lightly brushed with a 25 or 40 mm bristle brush after every five minutes of sieving.

Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method.

4) DETERMINATION OF COMPRESSIVE STRENGTH OF CEMENT

(IS : 269 – 1976 and IS : 4031 – 1968)

Object

Determination of the compressive strength of standard cement mortar cubes compacted by means of a standard vibration machine.

Standard Sand

The standard sand to be used in the test shall conform to IS : 650 – 1966.

Apparatus

Vibration machine and cube moulds of size 7.06 cms (conforming to IS : 4031 – 1968).

Procedure

Mix Proportions and Mixing : Clean appliances shall be used for mixing and the temperature of the water and that of the test room at the time when the above operations are being performed shall be 27 ± 2 °C.

Place in a container a mixture of cement and standard sand in the proportion of 1:3 by weight; mix it dry, with a trowel for one minute and then with water until the mixture is of uniform colour. The quantity of water to be used shall be as specified below. In any event, it should not take more than 4 minutes to obtain uniform coloured mix. If it exceeds 4 minutes, the mixture shall be rejected and the operation repeated with a fresh quantity of cement, sand and water.

The material for each cube shall be mixed separately and the quantity of cement, standard sand and water shall be as follows:

Percentage of water to be added to the cement and sand in (1:3) cm $(P/4 + 3) \times \%$ combined weight of cement and sand = $(P/4 + 3) 800/100$.

Cement 200 gms, standard sand 600 gms, water $(P/4 + 3.0)$ per cent of combined weight of cement and sand, where P is the percentage of water required to produce a paste of standard consistency.

Moulding Specimens

In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply a similar coating of petroleum jelly between the contact surfaces of the bottom of the mould and its base plate in order to ensure that no water escapes during vibration. Treat the interior faces of the mould with a thin coating of mould oil.

Place the assembled mould on the table of the vibration machine and firmly hold it in position by means of suitable clamps.

Securely attach a hooper of suitable size and shape at the top of the mould to facilitate filling and this hooper shall not be removed until completion of the vibration period.

Immediately after mixing the mortar, place the mortar in the cube mould and rod with a rod. The mortar shall be rodded 20 times in about 8 seconds to ensure elimination of entrained air and honey combing. Place the remaining quantity of mortar in the hooper of the cube mould and rod again as specified for the first layer and then compact the mortar by vibration.

The period of vibration shall be two minutes at the specified speed of 12,000 = 400 vibrations per minutes.

At the end of vibration remove the mould together with the base plate from the machine and finish the top surface of the cube in the mould by smoothing surface with the blade of a trowel.

Curing Specimens

Keep the filled moulds at a temperature of $27 \text{ }^{\circ}\text{C} \pm 2 \text{ }^{\circ}\text{C}$ in an atmosphere of at least 90% relative humidity for about 24 hours after completion of vibration. At the end of that period remove them from the moulds immediately submerge in clean fresh water and keep them under water until testing. The water in which the cubes are submerged shall be renewed every 7 days and shall be maintained at a temperature of $27 \text{ }^{\circ}\text{C}$. After they have been taken out and until they are tested, the cubes shall not be allowed to become dry.

Testing

Test three cubes for compressive strength at the periods mentioned under the relevant specifications for different hydraulic cements, the periods being reckoned from the completion of vibration. The compressive strength shall be the average of the strengths of the three cubes for each period of curing.

The cubes shall be tested on their sides without any packing between the cube and the steel platens of the testing machine. One of the platens shall be carried base and shall be self-adjusting and the load shall be steadily and uniformly applied, starting from zero at a rate of 350 kgs/cm²/min.

Calculation

Calculate the compressive strength from the crushing load and the average area over which the load is applied. Express the results in Kgs/cm² to the nearest 0.5 kg/cm².

Compressive strength, in kg/cm²

= P/A , Where 'P' is the crushing load in kg, and 'A' is the area in cm² (50 cm²).

Limits

Compressive strength of cement

	3 days	7 days	28 days
1. OPC	160 kg/cm ²	220 kg/cm ²	-
2. PPC	-	220 kg/cm ²	350 kg/cm ²
3. Low Heat	100 kg/cm ²	160 kg/cm ²	350 kg/cm ²

DETERMINATION OF SPECIFIC GRAVITY OF CEMENT

(IS : 269 – 1976 & IS : 4031 – 1968)

Object

Determination of the specific gravity of hydraulic cement.

Apparatus

- 1) Specific Gravity Bottle of 50 ml capacity (ordinary capillary type).
Material : Kerosene (free of water).

Procedure

Clean, dry and weigh the specific gravity bottle together with the stopper (W1). Fill the specific gravity bottle with cement sample at least to half of the bottle and weigh with the stopper (W2). Fill the specific gravity bottle containing the cement, with kerosene (free of water) placing the stopper and weigh it (W3). While doing the above do not allow any air bubble to remain in the specific gravity bottle. After weighing the bottle, the bottle shall be cleaned and dried again. Then fill it with fresh kerosene and weigh it with stopper (W4). All the above weighings should be done at the room temperature of 27 °C ± 0.1 °C.

Calculations

Calculate the specific gravity of the cement as follows:

$$\text{Specific Gravity} = \frac{\text{Weight of cement in gms}}{\text{Displaced volume of kerosene ml} \times \text{sp. G of kerosene}}$$

$$\text{Specific Gravity} = \frac{(W2 - W1)}{(W4 - W1) - (W3 - W2)} \times 0.79$$

Where,

W1 = Weight of the specific gravity bottle

W2 = Weight of specific gravity bottle about half filled with cement

W3 = Weight of specific gravity bottle about half filled with the Cement and rest with kerosene

W4 = Weight of specific gravity bottle filled with kerosene

Note: Specific gravity of kerosene is taken as 0.79

Precautions

- 1) Only kerosene which is free of water shall be used.
- 2) At no time of weighing shall the temperature of the apparatus be allowed to exceed the specified temperature.
- 3) All air bubbles shall be eliminated in filling the apparatus and inserting the stopper.
- 4) Weighing shall be taken to prevent expansion and over flow of the contents resulting from the heat of the hand when wiping the surface of the apparatus.
- 5) Precautions shall be taken to prevent expansion and over flow of the contents resulting from the heat of the hand when wiping the surface of the apparatus.

Limits

Specific gravity of cement should be 3.15.

7) TEST FOR COMPRESSIVE STRENGTH OF CEMENT CONCRETE (IS : 516 – 1999)

Object

Determination of the compressive strength of cement concrete specimens.

Apparatus

Testing machine, two steel bearing platens with hardened faces (as per IS : 516 – 1959).

Theory

Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days, ages of 13 weeks and one year are recommended if

tests at greater ages are required. Where it may be necessary to obtain the early strengths, test may be made at the ages of 24 hours = ½ hour and 12

hours + 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.

Number of Specimens

At least three specimens, preferably from different batches, shall be made for testing at each selected age.

Procedure

Specimens stored in water shall be tested immediately on removal from water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fines removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing.

Placing the Specimen in the Testing Machine

The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimens which are to be in contact with the compression platens. In the case of the cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen, that movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min. Until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Calculation

The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test, by the cross sectional area, calculated from the mean dimensions of section and shall be expressed to the nearest kg/sq.cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than + 15% of the average. Otherwise, repeat tests shall be made.

In case of cylinders, a correction factor according to the height to diameter ratio of specimen after capping shall be obtained from the curve shown in fig.1 of IS : 516– 1999. The product of this correction factor and the measured compressive strength shall be known as the corrected compressive strength, this being the equivalent strength of a cylinder having a height/

diameter ratio of two. The equivalent cube strength of the concrete shall be determined by multiplying the corrected cylinder strength by 5/4.

Reporting of Results

The following information shall be included in the report on each test specimen :

a) Identification mark; b) date of test; c) Age of specimen; d) curing conditions including date of manufacture of specimen in the field; e) weight of specimen; f) Dimensions of specimen; g) Compressive strength; h) Maximum load, and i) Appearance of fractured faces of concrete and type of fractures if these are unusual.

9) DETERMINATION OF CONSISTENCY OF CONCRETE

(BY SLUMP TEST)

Object

To find out the slump of the course mix (Method for measuring workability).

Apparatus

Mould for Test specimen (Frustum of cone 20 cm in diameter at bottom, 10 cm at the top and 30 cm in height, tamping rod 16 mm dia and 60 mm long.

Test Procedure

The mould is filled with concrete in 7.5 cm layers and each layer is compacted with 25 strokes of 16 mm diameter tamping rod. The strokes should be applied uniformly over the entire area and with such a force that the rod just penetrates the full depth of the layer being compacted. The mould is then removed just after filling, care being taken not to disturb concrete and the concrete is allowed to settle the vertical settlement is known as slump.

ULTRASONIC PULSE VELOCITY METHOD:

PRINCIPLE:

The underlying principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete is honey combing, void or flaw inside the concrete, the pulse velocity will be lower. If there is a crack inside the concrete, which comes in the way of transmission of the pulses, the pulse will pass around the crack/discontinuity, thereby making the path length longer. Consequently, lower velocities are obtained. The actual pulse velocity will depend primarily upon the materials; mix proportions, and also the density and the modulus of elasticity of aggregate in concrete.

The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks, segregation etc. indicative of the level of workmanship employed, can be assessed using the guidelines given in Table 1, which have been evolved for characterizing the quality of concrete in structures in terms of ultrasonic pulse velocity.

Table 1 Velocity criterion for concrete Quality Grading
(As per IS 13311 (Part – 1))

Sl.No	Pulse Velocity by Cross Probing (Km/Sec)	Concrete Quality Grading
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

In case of 'doubtful' quality, it may be necessary to carry out further tests.

Influence Of Test Conditions:

When the concrete surface is rough, it is necessary to smoothen the surface to make the pulse velocity measurement possible. Pulse velocity through concrete increases with increased moisture content of concrete. The pulse velocity of saturated concrete may be up to 2% higher than that of similar dry concrete.

The shape and size of the concrete member do not influence the pulse velocity unless the least lateral dimension is less than a certain minimum value, e.g. the minimum lateral dimension of 80mm for 50Khz natural frequency of the transducer.

Variations of the concrete temperature between 5° and 30°C do not significantly affect the pulse velocity measurement in concrete. At temperatures between 30° and 60°C, there can be a reduction in pulse velocity up to 5%. Below freezing temperature, the free water freezes within concrete resulting in an increase in pulse velocity up to 7.5%.

When concrete is subjected to high stress, the pulse velocity may be reduced due to the development of micro-cracks. The influence is generally insignificant unless the stress is greater than about 60% of the ultimate surface of the concrete.

The pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete in the same composition. This is because the pulse velocity in steel is 1.2 to 1.9 times the velocity in plain concrete.

INTERPRETATION OF TEST RESULTS:

The rebound hammer method can be used to assess the likely compressive strength of concrete with the help of a suitable correlation (established for similar materials) between rebound index and compressive strength of concrete. The method is good for assessing the uniformity of concrete, for assessing the quality of

concrete in relation to standard requirements, and to assess the quality of one element in relation to another structural element.

But the rebound indices are indicative of compressive strength of concrete to a limited depth (may be upto about 3cm) from the surface. If the concrete in a particular member has internal micro-cracking, flaws or heterogeneity across the cross the cross-section, rebound hammer indices will not indicate the same. As such, the estimation of strength of concrete by rebound hammer can not be held to be very accurate, and probable accuracy of prediction of concrete compressive strength in a structure is $\pm 25\%$.

THE COVER METER:

The cover meter is available to measure depth of cover to reinforcements in structural elements. The apparatus works on magnetic principle, the magnetic flux generated in the apparatus touches the steel surface, and the depth of cover is indicated in the instrument. Upto about 8 cm cover can be measured by this instrument. The cover meter is also used to locate the reinforcement positions in the structural elements, in order to facilitate extraction of concrete cores in the space available between two reinforcement positions.

THE HALF CELL POTENTIAL METHOD:

The copper-copper sulphate half-cell is used to determine the corrosion activity in reinforced concrete structures. The half-cell is electrically connected to the exposed reinforcement at one end of the structural element, using a voltmeter. The concrete member is wetted in order to make the concrete electrolyte. The potential measurement indicates the corrosion activity in the steel reinforcement inside the concrete. As per ASTM C 876, if the potentials over an area are more negative than 0.35V CSE, there is a greater than 90% probability that

the reinforcement if corroding in that area. If the potential over an area are more negative than -0.20V CSE , there is a greater than 90% probability that no corrosion is occurring in the reinforcement.

INTERPRETATION OF TEST RESULTS:

The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. This in turn, depends upon the as well as the material and mix proportions used in making concrete, as well as the method of placing, compaction and curing of concrete. For example, if the concrete is not compacted thoroughly, or if there is segregation of concrete during placing or there are internal cracks and flaws, the pulse velocity will be lower, although the same materials and mix proportions have been used.

DETERMINATION OF COMPRESSIVE STRENGTH OF BRICKS

(IS : 3495 Part I – 1976)

Object

To determine compressive strength of bricks.

A. SOLID BRICKS

Apparatus

A compression testing machine, the compression plate of which shall have a ball seating in the form of portion of a sphere the centre of which coincides with the centre of the plate, shall be used.

Preconditioning

Remove unevenness observed in the bed faces to provide two smooth and parallel faces by grinding. Immerse in water at room temperature for 24 hours. Remove the specimen and drain out any surplus moisture at room temperature. Fill the frog (where provided) and all voids in the bed face flush the cement mortar of grade 1 Cement, 1 clean Course Sand. Then cover it with wet jute bags for 24 hours followed by immersion in clean water for 3 days. Remove and wipe out any traces of moisture.

Procedure

Place the specimen with flat faces horizontal, and mortar filled face, facing upwards between two 3-ply plywood sheets each of 3 mm thickness and carefully centred between plates of the testing machine. Apply load axially at a uniform rate of 14 N/mm² (140 kg. f/cm²) per minute till the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

Note: In place of plywood sheets plaster of paris may be used to ensure a uniform surface for application of load.

Report

The report shall be as given below :

$$\text{Compressive strength in } \frac{\text{N}}{\text{mm}^2} \text{ (kg f/cm}^2\text{)} = \frac{\text{Max load at failure in N (kg.f)}}{\text{Average area of the bed faces in mm}^2 \text{ (cm}^2\text{)}}$$

The average of results shall be reported.

B. FOR PERFORATED BRICKS

Apparatus

Same as per Solid Bricks.

Preconditioning

Immerse the specimen in water at normal room temperature for 24 hours. Remove the specimen from water and drain out any surplus water. No mortar shall be filled in perforation and no mortar capping shall be provided.

Procedure

Place the perforated faces of the brick between two 3-ply plywood sheets each of 3mm thickness and carefully centered between the plates of the testing machine. Apply the load at uniform rate of 14 N/mm² per minute till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

Note: In place of plywood sheets plaster of paris may be used to ensure a uniform surface for application of load.

Reporting of Results

The report shall be given below:

$$\text{Compressive strength in N/mm}^2 \text{ (kg f/cm}^2\text{)} = \frac{\text{Max load at failure in N (kg.f)}}{\text{Average net area of the two faces under compression in mm}^2 \text{ (cm}^2\text{)}}$$

The average of results shall be reported.

DETERMINATION OF WATER ABSORPTION OF BRICKS

(IS : 3495 – Part II 1976)

Object

To determine water absorption of bricks.

Methods

A. 24-hour Immersion cold water test

Apparatus

A sensitive balance capable of weighing within 0.1 per cent of the mass of the specimen and a ventilated oven.

Preconditioning

Dry the specimen in a ventilated oven at a temperature of 105 to 115 °C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (M1). Specimen warm to touch shall not be used for the purpose.

Procedure

Immerse completely dried specimen in clean water at a temperature of 27 °C + 2 °C for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (M2).

Water Absorption

Percent by mass, after 24 hour immersion in cold water is given by the following formula :

$$\frac{M2 - M1}{M1} \times 100$$

The average of results shall be reported.

B. 5-hour boiling water test

Apparatus

Same as above.

Preconditioning

Fresh samples shall be preconditioned as in (a) above. For samples obtained after 24-hour immersion test, no preconditioning is required.

Procedure

Immerse the specimen immediately into a tank, and place it in such a way that water can circulate freely on all sides of the specimen. Stir the water occasionally to ensure complete expulsion of air.

Heat the water to boiling in one hour, and boil it continuously for 5 hours. Then allow it to cool to 27 °C + 5 °C by natural loss of heat for 16 to 19 hours. Remove, drain out any surplus moisture and rub with damp cloth. Weigh the specimen, completing the same in 3 minutes (M3).

Reporting of Results

Water absorption, percent by mass, after 5 hours of immersion in boiling water is given by the following formula :

$$\frac{M_2 - M_1}{M_1} \times 100$$

The average of results shall be reported.

TEST FOR WORKABILITY OF CONCRETE

TEST FOR COMPACTION FACTOR

(IS : 1199 – 1959)

Object

Determination of the workability of concrete, where the nominal maximum size of the aggregate exceeds 38mm.

This determination is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration.

Apparatus

Compaction factor apparatus which consists of two conical hoppers; one above the other mounted above a cylindrical mould; two ordinary brick laying trowels, one hand scoop, a rod of steel and balance.

Sampling

When the test is due in the field, for obtaining the representative samples of fresh concrete from the mixture atleast 3 approximately equal sample increments totaling 0.02 cum shall be taken from a batch during its discharge and each sample shall be collected by passing a clean and dry metalling receptable across the stream of concrete, likewise, the representative samples from concrete at the time and place of deposition may be taken while a batch of concrete is discharged on the site. The sample shall be collected from not less than five well disturbed positions, avoiding the edge of the mass where segregation may have occurred.

The composite sample obtained by either of the methods said above shall be mixed on a non-absorbent base either with a shovel or by other suitable implement in such a manner as to ensure uniformity. The date, time and method of sampling, mix proportions, the mixture from which delivered, the location of the sample batch after placing and the temperature and weather conditions shall be recorded.

Procedure

The sample of concrete to be tested shall be placed gently in the hopper using the hand scoop. The hopper shall be filled level with its brim and the trap door at the lower end of the hopper shall be opened so that the concrete falls into the lower hopper. The cylinder shall be covered by the towels during the above process.

Immediately after the concrete has come to rest, the cylinder shall be uncovered, the trap door of the lower hopper opened and the concrete allowed to fall into the cylinder. The excess of concrete remaining above the level of the top of the cylinder shall then be cut off by holding a trowel, in each hand. The outside of the cylinder shall then be wiped clean.

The weight of the concrete in the cylinder shall then be determined to the nearest 10 gms. This weight shall be known as the weight of partially compacted concrete. The cylinder shall be refilled with concrete from the sample in layers approximately 5 cm deep, the layers, being heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted surface shall be carefully struck off level with the top of the cylinder. The outside of the cylinder shall then be wiped clean.

Calculation

The compacting factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall be stated to the nearest second decimal place.

$$\text{Compacting factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

AMENITIES & INFRASTRUCTURE

HOUSE WIRING:

Conduit pipe system of wiring is the best and it is protected well from mechanical damages. This system is also fire proof and to an extent fire resistant. Therefore, for all buildings this system may be adopted.

Planning and Designing:

General:

The design and planning of an electrical installation shall take into account all the prevailing conditions which may include some or all the following:

- a) Type of supply
- b) Envisaged load having regard to the requirements of the owner or occupier.
- c) The probable modifications and future extensions.
- d) The degree of electrical and mechanical protection necessary.
- e) The probable operation and maintenance cost taking into account the electricity supply tariffs available.
- f) The relative cost of various alternative methods, and
- g) The need for radio and telecommunication interference abatement.

It is recommended that advice of a competent electrical engineer be sought at the planning stage with a view to providing an installation that will prove adequate for its intended purpose and safe and efficient in its use.

Layout and Installation Drawing:

The electrical layout should be considered after proper locations of all outlets for lamps, fans, appliance both fixed and transportable, motors, etc., have been selected and best methods of wiring determined.

All runs of wiring and the exact positions of all points of switch-boxes and other outlets shall be first marked on the plans of the building and approved by the engineer-in-charge or the owner before actual commencement of the work.

The design of the wiring system and the size of the cables should be decided taking into account two factors.

- a) **Voltage Drop:** this should be kept as low as economy permits to ensure proper functioning of all electrical appliances and equipment including motors.
- b) First cost against operating losses.

VOLTAGE AND FREQUENCY OF SUPPLY

It should be ensured that all equipment connected to the system including any appliances to be used on it are suitable for the voltage and frequency of supply of the system. The nominal values of low and medium voltage systems in India are 240 V and 415 V ac respectively and the frequency 50 Hz.

RATINGS:

The current-carrying capacity of different types of cables shall be chosen in accordance with good practice.

The current ratings of switches for domestic and similar purposes are 5 A and 15 A.

The current ratings of isolators and normal duty switches and composite units of switches and fuses shall be selected from one of the following values:

16, 25, 32, 63, 100, 160, 200, 320, 400, 500, 800, 1000 and 1250 A.

The ratings of rewirable and HRC fuses shall be in accordance with good practice.

The current rating of the distribution fuse board shall be selected from one of the following values:

6, 16, 25, 32, 63 and 100 A.

Note: The above ratings are for each fuse way of the distribution fuse-board.

LIGHTING AND LEVELS OF ILLUMINATION:

General:- Lighting installation shall take into consideration the many factors on which the quality and quantity of artificial lighting depends. The modern concept is to provide illumination with the help of a large number of light sources not of higher illumination level. Also much higher levels of illumination are called for than in the past, often necessitating the use of fluorescent lighting suitably supplemented with incandescent fittings, where required.

FUTURE DEMAND:

However, if for financial reasons, it is not possible to provide a lighting installation to give the commended illumination levels, the wiring installation at least should be so designed that at a later date, it will permit the provision for additional lighting fittings or conversion from incandescent to fluorescent lighting fittings to bring the installation to the required standard. It is essential that adequate provisions should be made for all the electrical services which may be required immediately and during the intended useful life for the building.

Principles of Lighting:

When considering the function of artificial lighting, attention shall be given to the following principal characteristics before designing an installation.

- b) Illumination and its uniformity.
- c) Special distribution of light. This includes a reference to the composition of diffused and directional light, direction of incidence, the distribution of luminance's and the degree of glare; and
- d) Colour of the light and colour rendition.

The variety of purpose which have to be kept in mind while planning the lighting installation could be broadly grouped as:

- a) industrial buildings and processes.
- b) Offices, schools and public buildings;
- c) Surgeries and hospitals, and
- d) Hostels, restaurants, shops and homes.

It is important that appropriate levels of illumination for these in accordance with 9 are provided and the types and positions of fittings determined to suit the task and the disposition of the working places.

For specific requirements for lighting of special occupancies, reference shall be made to good practice.

FANNAGE:

Where ceilings fans are provided, the bay sizes of a building which control fan point locations, play an important part. Fans normally cover an area of 9 cm² to 10 m² and therefore in general purpose of the buildings, for every part of a bay to be served by the ceiling fans, it is necessary that the bays shall be so designed that full number of fans could be suitably located for the bay, otherwise it will result in ill-ventilated pockets, in general, fans in long halls may be spaced at 3 m to 3.5 m in both the directions. If building modules do not lend themselves for proper positioning of the required number of ceiling fans, other types of fans, such as air circulators or bracket fans, would have to be employed for the areas uncovered by the ceiling, fans. For this, suitable electrical outlets shall be provided although result will be disproportionate to cost on account of fans.

Proper air circulations could be achieved either by larger number of smaller fans or smaller number of larger fans. The economics of the system as a whole should be a guiding factor in choosing the number and type of fans and their locations.

Exhaust fans are necessary for spaces, such as community toilets, kitchens and canteens and godowns to provide the required number of air changes. Since the exhaust fans are located generally on the outer walls of a room,

appropriate openings in such walls shall be provided for in the planning stage.

Positioning of fans and light fittings shall be chosen to make these effective without causing shadows on the working planes.

Reception and Distribution of Main Supply:

Central at point of commencement of supply:

There shall be a circuit breaker or miniature circuit breakers or a linker switch on each live conductor of the supply mains at the point of entry. The wiring throughout the installation shall be such that there is no break in the neutral wire in the form of switch or fuse unit. The neutral shall also be distinctly marked in this connection. Rule 32 (2) of Indian electricity Rules, 1956 shall also be referred.

The main switch shall be easily accessible and situated as near as practicable to the termination of service line.

On the main switch, where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system of a conductor which is to be connected thereto an indication of a permanent nature shall be provided to identify the earthed neutral conductor. In this connection rule 32(1) of the Indian Electricity Rules, 1956 shall be referred.

Main Switches and Switchboard:

All main switches or miniature circuit-breakers shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply.

Location:

- b) Open type switch boards shall be placed only in dry and ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes.
- c) In damp and dusty situation the switch-board shall be totally enclosed in accordance with accepted standards.
- d) Switch boards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms of laundries or in bathrooms, lavatories or toilets or kitchens.
- e) The location of switchboards shall be so chosen as to facilitate easy attendance to maintenance such as replacement of fuses, clearing etc.

Metal-clad switchgear shall preferably be mounted on any of the following types of boards.

a) Hinged-Type Metal Boards:

These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover. The joints shall be welded to a wooden board protected on both sides with insulating varnish and of not less than 6.5 mm thickness, shall be provided at the back. There shall be a clear distance of not less than 2 – 5 cm between the board and the cover, distance being increased for larger boards. Alternatively hinged-type metal boards shall be made of sheet covering mounted on channel or angle iron frame.

Note: Such type of boards are particularly suitable for small switchboards for mounting metal-clad switchgear connected to supply at low voltages.

b) Fixed-Type Metal Boards:

These shall consist of an angle or channel iron frame fixed on the wall or on the floor and supported on the wall at the top, if necessary. There shall be a clear distance of 1 m in front of the switchboard. If there are any attachments of bare connections at the back of the switchboard, Rule 51 (1) © of Indian Electricity Rules 1956 shall apply.

Note: Such type of boards are particularly suitable for large switchboards or higher capacity metal-clad switchgear or both.

c) Wood Boards:

For small installations connected to a single-phase 240 volts supply, these boards may be used as main boards or sub-boards. These shall be of seasoned and durable wood with solid back impregnated with varnish with all joints dove-tailed.

In large size medium voltage installations, before proceeding with the actual construction of the boards, a proper drawing showing the detailed dimensions and design including the disposition of the mountings which shall be symmetrically and neatly arranged for arriving at the overall dimensions shall be prepared and approved by the engineer-in-charge.

Recessing of Boards

Where so required the switch boards shall be recessed in the wall. The depth of recess provided at the back for connection and the space at the front between the switchgear mountings shall be adequate.

Arrangement of Mountings:

- a) Mounting which is on the front of a switchboard shall be so arranged that inadvertent personal contact with live parts is unlikely during the manipulation of switches, charging of fuses or like operation.

- b) No mounting shall be mounted within 2.5 cm of any edge of the panel and no hole other than the holes by means of which the panel is fixed shall be drilled closer than 1.3 cm from any edge of the panel.
- c) The various live parts, unless they are effectively screened by substantial barriers of non-hygroscopic, non-inflammable insulating material, shall be so spaced that they cannot maintain between such parts and earth.
- d) The arrangement of the gear shall be such that they shall be readily accessible and their connections to all instruments and apparatus shall also be easily traceable.
- e) In every case in which switches and fuses are fitted on the same pole, these fuses shall be so arranged that the fuses are not alive when their respective switches are in the off position.
- f) No fuses other than fuses in instrument circuit shall be fixed on the back of or behind a switchboard panel or frame.

Main and Branch Distribution Boards:

Main and branch distribution boards shall be of any type mentioned in 12.2.3

Main distribution boards shall be provided with a switch or circuit-breaker on each pole of each circuit, fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

Branch Distribution Boards:

Branch Distribution Boards shall be provided with a fuse or a miniature circuit – breaker or both of adequate rating/setting on the live conductor each circuit and the earthed neutral conductor shall be connected to a common link and the capable of being disconnected individually for testing purposes. At least one spare circuit of the same capacity shall be provided on each branch distribution board.

In residential installations lights and fans may be wired on a common circuit. Such sub-circuit shall not have more than a total of ten points of lights, fans and socket outlets. The load of such circuit shall be restricted to 800 watts. If a separate fan circuit is provided, the number of fans in the circuit shall not exceed ten. Power sub-circuits shall be designed according to the load but in no case shall there be more than two outlets on each-circuit.

In wiring installations at construction sites, stadium shipyards, etc., where large number of high wattage lamps may be required, there shall be no restriction on load on any circuit but conductors used in such circuits shall be of adequate size for the load and proper circuit protection shall be provided.

Installation of Distribution Board:

- b) The distribution fuse-boards shall be located as near as possible to the centre of the load they are intended to control.
- c) These shall be fixed on suitable sanction or wall and shall be accessible for replacement of fuses.
- d) These shall be of either metal-clad type or all-insulated type. But if exposed to weather or damp situations, they shall be totally enclosed in accordance with accepted standards.
- e) Where apparatus is to be operated at medium voltage or where medium voltage exists between two or more adjacent low-voltage circuits all terminals or other fixed line parts not permanently shrouded in insulating material shall either be installed so as to be accessible only to authorized personnel or shall be enclosed in earthed metal or non-combustible insulating material and the distribution boards shall be fixed not less than 2 m. apart.
- f) All circuits shall be marked distinctly on distribution boards as lighting or 'power' as the case may be and also marked with the voltage and number of phases of the supply. Each board shall be provided with a circuit list giving details of each circuit which it controls and the current rating of the circuit and size of fuse-element.

Wiring of Distribution Board:

- b) In wiring a branch distribution board, total load of the consuming devices shall be distributed, as far as possible evenly between the number of ways of the boards, leaving the spare circuit for future extension. Spare circuits on branch distribution boards shall be at least 10 percent of the number of ways of the board subject to a minimum of 1 in 6 way board and above.
- c) All connections between placed of apparatus or between apparatus and terminals on a board shall be neatly arranged in a definite sequence, following the arrangements of the apparatus mounted thereon, avoiding unnecessary crossings.
- d) Cables shall be connected to a terminal only by soldered or welded lugs, unless the terminal is of such a form that it is possible to securely clamp them without cutting away of the cable strands. Aluminium conductors should be tinned before insertion in clamps.
- e) If required, a pilot lamp shall be fixed and connected through an independent single pole switch and fuse to the bus-bars of the board.
- f) In a hinged type board, the in-coming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board leaving suitable space in between cables, and shall also, if possible, be fixed at the corresponding points on the

switchboard panel. The cables between these points shall be arranged to form a 'U' or 'S' shaped loop which shall be of such length as to allow the switchboard panel to swing through an angle of not less than 90.

Protection of Circuits:

- a) Appropriate protection shall be provided at switch boards and distribution boards for all circuits and sub-circuits against over current and earth faults, and the protective apparatus shall be capable of interrupting any fault current that may occur, without danger. The ratings and settings of fuses and the protective devices shall be coordinated so as to afford selectivity in operation where necessary.
- b) Where circuit breakers are used for protection of a main circuit and of the sub-circuits derived there from discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuit-breakers to operate at lower current settings and shorter time lag than the main circuit breaker.
- c) Where HRC type fuses are used for back-up protection of circuit-breakers, or where HRC fuses are used for protection of main circuits, and circuit breakers for the protection of sub-circuits derived there from, in the event of short-circuits exceeding the breaking capacity of the circuit breakers, but for smaller overloads within the breaking capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse blows.
- d) If rewirable type fuses are used to protect sub-circuits derived from a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short circuit or earth fault occurring on a sub-circuit, although currents. The use of rewirable fuses is restricted to the circuits with short circuit level of 4 KA, for higher level either cartridge or HRC fuses shall be used.
- e) A fuse carrier shall not be fitted with a fuse-element larger than that for which the carrier is designed.
- f) The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.
- g) Every fuse shall have its own case or cover for the protection of the circuit and an indelible indication of its appropriate current rating in an adjacent conspicuous position.
- h) For detailed information regarding selection, installation and maintenance of fuses, reference may be made to good practice.

Branch Switches:

Where the supply is derived from a three-wire or four-wire source, and distribution is done on the two-wire system, all branch switches shall be placed in the outer or live Conductor of the circuit and no single-phase switch or fuse shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit. Single-pole switches (other than for multiple control) carrying not more than 15 amperes may be of tumbler type which shall be 'on' when the handle or knob is down.

Wiring**Provision for Maximum Load:**

All conductors, switches and accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which will normally flow through them.

Estimation of Load Requirements:

In estimating the current to be carried by any Conductor the following ratings shall be taken, unless the actual values are known or specified for these elements:

Element	Rating in Watts.
Incandescent lamps	60
Ceiling fans Table fans	60
Ordinary socket outlet points	
Fluorescent tubes	
Length: 600 mm	25
1200 mm	50
1500 mm	90
Power socket - outlet	1000

Selection of Size of Conductor:

The size of conductors of circuits shall be so selected that the drop in voltage from consumer's terminals in a public supply (or from the bus-bars of the main switchboard controlling the various circuits in a private generating plant) to any and every point on the installation does not exceed three percent of the voltage at the consumer's terminals (or at the bus-bars as the case may be) when the conductors are carrying the maximum current under the normal conditions of service.

If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit every cable shall have a current rating not less than that of the fuse which protects the circuit or sub-circuit, respectively.

Conductors:

All conductors shall be of copper or aluminium. Conductors for power and lighting circuits shall be of adequate size to carry the designed circuit Load without exceeding the permissible thermal limits for the insulation. The conductor for final sub-circuit for fan and light wiring shall have a normal cross sectional area not less than 1.00 mm² copper and 1.50 mm² aluminium. The cross sectional area of conductor for power wiring shall be not less than 1.50 mm² copper and 2.5mm² aluminium. The minimum cross sectional area of conductor of flexible cord shall be 0.50mm² copper.

Flexible Cables and Flexible Cords:

Unless cables and cords are protected by flexible conduits or tough rubber or PVC sheath, they shall not be used in places where they are liable to be subjected to mechanical damage.

Stranded conductors having a nominal cross sectional area exceeding 6.0 mm² shall always be provided with soldered terminals.

When a standard conductor having a nominal cross sectional area less than 6.0 mm² is not provided with cable sockets, all strands at the exposed end of the cable shall be soldered together. 'No-oxide' grease shall be provided on the exposed end of the conductor after soldering.

Passing Through Walls and Floors:

Where conductors pass through walls, one of the following methods shall be employed, care shall be taken to see that wires pass freely through protective pipe or box and that the wires pass through in a straight line without any twist or cross in wires on either ends of such holes.

- a) A wooden box extending through the whole thickness of the wall shall be buried in the wall and casing or conductors shall be carried so as to allow 1.3cm. air space on three sides of the casing or conductor.
- b) The conductor shall be carried either in a rigid steel conduit conforming to accepted standards or a rigid non metallic conduit conforming to accepted, standards or in a percellin tube of such a size which permits easy drawing in.
- c) Insulated conductors while passing through floors shall be protected from mechanical injury by means of rigid steel conduit to a height not less than 1.5m above the floors and flush with the ceiling below. This steel conduit shall be earthed and securely bushed.

Where a wall tube passes outside a building so as to be exposed to weather, the outer end shall be bell mouthed and turned downwards and properly bushed on the open end.

Fixing to Walls and Ceilings:

Plugs for ordinary walls or ceilings shall be of seasonal wood not less than 5cm long and 2.5 cm square on the outer end. They shall be cemented into walls to within 6.5 mm of the surface, the remainder being finished according to the nature of the surface with plaster or lime punning.

Where owing to irregular coursing or other reasons the plugging of the walls or ceilings with wood plugs presents difficulties, the wood casing, wood batten, metal conduit or cleat (as the case may be) shall be attached to the wall or ceiling in an approved manner in the case of new buildings, wherever possible, wooden plugs shall be fixed in the walls before they are plastered, keeping in mind the thickness of plaster to obtain a flush surface.

To achieve neatness, plugging of walls or ceilings may be done by an approved type of asbestos metallic or a fibre fixing plug (rawl plugs).

Fittings and Accessories

Ceiling Roses and Similar Attachments:

A ceiling rose or any other similar attachment shall not be used on a circuit the voltage of which normally exceeds 250 volts.

Normally only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

A ceiling rose shall not embody fuse terminal as an integral part of it.

Earthing: The object of earthing is to drain away any leakage of current due to poor insulation.

DESIGN OF WATER SUPPLY DISTRIBUTION SYSTEM

General:- Design of distribution system inside building involves (a) estimation of water requirement, (b) determination of the size of the distribution pipes and (c) design of pipe layout according to certain basic principles.

Water Requirement:- (IS: 1172 – 1983): The National Building code (SP:7 – 1983) of India recommends that water requirement of 135 liters per head per day may be adopted in the design of water supply system for residential buildings with full flushing system. For residential buildings, the population may be calculated on the basis of five members per family and the number of dwelling units in the building.

Design of the pipe layout : The following broad principles should be borne in mind:

- a) Plumbing fixtures and devices shall be as per IS: Codes.
- b) It must be ensured that there is no risk of contamination of water supply provided for drinking and culinary purposes. There shall, therefore, be no cross connection whatsoever between a pipe or fitting conveying potable supply and pipe or fitting containing impure or waste water.
- c) There shall be no back flow from any cistern or appliance towards the source of supply.
- d) All pipe work shall be planned so that the piping is accessible for inspection, replacement and repairs.
- e) No service pipe shall be connected to any water closet or urinal. All such supplies shall be from flushing cisterns which shall be supplied from storage tanks.

CAPACITY OF OVERHEAD STORAGE TANK:-

- All the mains should be laid preferably with D.I pipes preferably.
- As the system is proposed to be maintained by concerned municipality /PH/HMWW&SS it is appropriate to consult them and propose the distribution system.
- Sufficient No. of air valves shall be provided in elevated zones for maintaining uniform pressure of supply.
- Scorer valves shall be provided at the lowest points to collect the mud and impurities.
- As per HMWW 40% of total demand may be considered for design of ELSR capacity. The ELSR shall be located in the highest point of the layout.
- The ELSR stagning shall be designed keeping the residual head of 6 m to 7.5 mts for providing of water supply with good pressure.

Storage of water for fire fighting purposes (IS: 9668- 1980)

- For building not greater than 15 m in height, no separate provision is necessary for fire fighting purposes except that an underground static tank of capacity 50,000 liters shall be provided.
- **The Ground level Reservator**:- 60% of the total demand may be considered for designing the storage of water in GLSR.

Galvanized Iron (GI) Pipes (IS : 1239, Part 1 – 1990):

GI pipes are made from hot coils of specified thickness. They are available in light, medium and heavy grades depending on the thickness of the sheet used. The thickness of 15 mm GI pipe of light, medium and heavy grade is 2.00, 2.65, and 3.25 mm respectively and the corresponding weight per meter is 1.00, 1.28 and 1.50 kg.

The pipes and sockets should be cleanly finished, well galvanized in and out and free from cracks, surface flaws and laminations. All screw threads shall be clean and well cut.

GI Pipe Fittings (IS 1239, Part 2 – 1990): GI Pipe fittings commonly used in plumbing systems are socket, elbow, tee, union, nipple, reducing socket/ elbow / tee, etc. These are manufactured from GI pipe with parallel threaded connections. The fittings are designated by the respective nominal bore of the pipes for which they are intended.

Laying And Jointing GI Pipes: For internal work, the GI pipes and fittings shall run on the surface of the walls or the ceiling (not in chase) unless otherwise specified. When it is found necessary to conceal the pipes, chasing may be adopted provided there is sufficient space to work on the pipes with the usual tools. Before embedding the pipe in the walls or floors, it should be painted with anticorrosive bitumastic paints of approved quality. The pipe shall not come in contact shall be filled with lime mortar or lime concrete as the pipe is affected by lime. The chases shall be filled with mortar as described.

Threading: The ends of the pipe to be rethreaded shall be carefully filed out to provide chamfer and to ensure that no obstruction to bore is offered. The ends of the pipe shall be carefully threaded with pipe threading dies, pipe vice, etc. in such a manner that there shall be no slackness when the two pipes are screwed together. The screw threads of the pipe and fitting shall be protected from damage until they are fitted.

Jointing: The pipes shall be cleaned and cleared of foreign matter before being laid. In jointing the pipes, the inside of the socket and the screwed end of the pipes shall be oiled and rubbed over with white lead; a few turns of spun yarn shall be wrapped round the screwed end of the pipe. The end shall then be screwed in the socket, tee, etc. with the pipe wrench. Burr from the joint shall be removed after screwing. After laying, the open ends of the pipes shall be temporarily plugged to prevent ingress of water, soil or any other foreign matter.

Care shall be taken that all pipes and fittings are properly jointed so as to make them completely watertight.

Fixing: All pipes and fittings shall be fixed truly vertical and horizontal unless unavoidable. The pipes shall be fixed with standard pattern holder bat clamps of required shape and size so as to fit tightly on the pipes when tightened with screwed bolts, keeping the pipes about 1.5 cm clear of the wall.

The Specials shall be confirmed to IS code.

Stop Valve (IS: 781 – 1984):

Bib Valve (IS: 781 – 1984)

Gate Valve (IS: 9763–84)

Ball Valve (IS: 1703 – 1989)

Pillar Tap (IS:1795– 1982)

Fire Hydrant, Landing Valves For Nozzles, etc: Hydrants are invariably used for fire fighting purposes to derive water from the street mains. These shall be of spindle type with 65 mm outlet combined with sluice valve conforming to IS: 780. The hydrants could be of the stand post type or the underground type. The size is 80 mm in case of single outlet and 100 mm in case of double outlets. A duck foot bend is used below the standpipe. The hydrant incorporates a 65 mm male coupling instantaneous pattern to which a standpipe could be attached and cast iron cap permanently secured to duck foot bend. (IS: 908 – 1975 & 5714 – 1981).

DRAINAGE & SANITATION :

Two – Pipe System:In this system of plumbing, the soil and the waste pipes are distinct and separate. The soil pipes are connected to the building sewer direct. Waste pipes are connected to the building sewer through a trapped gully. The gully trap forms a barrier to the passage of foul air from the sewer into the waste pipe.

All traps of soil appliances are completely ventilated through separate ventilating pipes. Likewise traps all waste appliances are also completely ventilated through a separate ventilating pipe. Thus this system of plumbing contains and soil pipe, one waste pipe and two ventilating pipes.

Single Pipe System :- One Pipe System(Fully Ventilated):-

The system of plumbing in which the waste connections from sinks, baths and washbasins and the soil pipe branches from water closets are all collected into one main pipe, which is connected, directly to the drainage system. Gully traps and pipes are dispensed with but all traps of water closets, basins etc., are completely ventilated to preserve the water seal.

PLANNING AND DESIGN OF BUILDING DRAINAGE (IS: 1742– 1983)

The drainage system commences within the building premises at the plumbing fixtures, where the water that is supplied to them, is used or washed and is then drained into the drainage pipes and finally into the public sewer or an individual waste disposal system (septic tank, etc.) The flow in a sewer system is by gravity and not under pressure as in the case of water supply pipes.

House drainage consists of the following three sub-systems.

Soil Appliances: The soil appliances (WC, urinal, etc.), which collect and discharge excretory matter, discharge through traps into a soil pipe. The soil pipes discharge into a building (drain) sewer.

Waste Appliances: The waste appliances (wash basin, sinks, shower, etc.) collect and discharge wastewater through traps into waste pipes. The waste pipes discharge into a building sewer directly or through a trapped gully.

Rainwater Systems: The rainwater collected within the premises is carried down the rainwater gutters and pipes. In a partially separate system, where a portion of the rainwater is mixed with the sewage, the building sewer carries rainwater also.

Self-cleansing Velocity: It is the velocity of flow in a conduit at which the grit and other solids remain in a state of suspension and keep flowing. It is necessary to ensure a minimum velocity in a sewer to prevent deposition of suspended solids and blocking of the drainage system. A velocity of 0.75 m/s for at design peak flow is recommended subject to a minimum velocity of 0.6 m/s for present peak flows. The maximum velocity should not exceed 3 m/s to avoid erosion due to sand and other gritty material carried in the sewer.

Depth Of Flow: From consideration of ventilation, sewers should not be designed to full. Up to 400 mm diameter, sewers may be designed to run at half depth; 400 to 900 mm at two-thirds depth and larger sewers at three-fourth depth at ultimate peak flows.

Gradient of the Sewer Line: Normally, the sewer shall be designed for discharging three times the dry weather flow flowing half-full with a minimum self-cleansing velocity of 0.75 m per second. The approximate gradients, which give this velocity for the sizes of sewer pipes commonly used in the buildings, are given in the Table.

Diameter mm	Minimum Gradient	
	Gradient	Discharge (cum./min.)
100	1 in 57	0.18
150	1 in 100	0.42
200	1 in 145	0.73
230	1 in 175	0.93
250	1 in 195	1.10
300	1 in 250	1.70

When it is not practicable to provide minimum gradients indicated in Table, a flatter gradient may be adopted but the minimum velocity in such cases should not be less than 0.6 meter per second.

Guidelines For Execution Of Pipe Work: The following precautions may be kept in view while designing and executing sanitary pipe layout for building drainage.

- a) The pipe work in branch connections should always be arranged to allow free drainage of the system. Connections to main or branch pipes should be so arranged as to prevent cross flow from one appliance to another. Connections should be made with an easy sweep in the direction of flow particularly in connections in the single stack system.
- b) Branch connections should be of large radius along the invert. The connections are not desirable.
- c) The minimum diameter of soil and waste stacks shall be 100 and 75 mm respectively.
- d) When the pipes are concealed, inaccessible or laid exposed along the internal face of the walls, they should preferably be of cast iron. In the ground floor, all the pipes including those laid on the external face of the wall should be of cast iron.
- e) Ample provision should be made for access to all pipe work and the embedding of joints in walls should be avoided as far as possible.
- f) All appliances directly connected to stack are trapped.
- g) It must be ensured that the soil, waste and building sewer pipes are not reduced in diameter in the direction of flow.
- h) Cast iron fittings and branches for waste pipes shall be of the same quality as for soil pipe and all waste pipe shall be made gas tight.

General Specifications: The pipes and fittings shall be free from cracks, laps, pinholes and other imperfections and should be neatly dressed and carefully fettled. All pipes and fittings should be true to shape, smooth and cylindrical, their inner and outer surface being as nearly as practicable concentric. All CI pipes and fittings are hot dip coated inside and out with a composition having tar or other suitable base. The coating material shall have good adherence and shall not scale off. The coating of tar shall be smooth and tenacious and hard

enough not to flow when exposed to temperature of 77°C but not so brittle at a temperature of 0°C as to chip off when scribed lightly with a pen knife.

Cement Mortar Jointing Of CI Pipes: Before jointing, the interior of the socket and the exterior of the spigot should be thoroughly cleaned and dried. The spigot end is inserted into the socket right up to the back of the socket and carefully centered such that there is uniform annular space for filling with a few turns of spun yarn formed into ropes of uniform thickness soaked in neat cement slurry. These shall be pressed home (rammed) into the socket by means of a caulking tool. No piece of rope should be shorter than the circumference of the pipe. More skins of yarns shall be wrapped if necessary and shall be rammed home. The joint shall then be filled with stiff cement mortar 1:2 (1 cement: 2 fine sand) well pressed with caulking tool and finished smooth at top at an angle of 45° sloping up.

The joint must be kept wet for not less than 7 days by tying a piece of gunny bag, four fold, to the pipe and keeping it moist constantly.

Lead Jointing Of CI Pipes: For all the concealed pipes in sunken slabs etc shall be treated with lead. The interior of the socket and exterior of the spigots shall be thoroughly cleaned and dried. The spigot end shall be inserted into the socket right up to the back of the socket and carefully centered by two or three laps of treated spun yarn, twisted into ropes of uniform thickness, well packed into the back of the socket leaving 25 mm from the lip of the socket for the lead. The jointed pipeline shall be at required levels and alignment.

The lead shall be melted so as to be thoroughly fluid and each joint shall be filled in one pouring. The following precautions shall be taken for melting lead:

- a) The pot and the ladle in which lead shall be put shall be clean and dry.
- b) Sufficient quantity of lead shall be melted.
- c) Any scum or dross, which may appear on the surface of the lead during melting, shall be skimmed off.
- d) Lead shall not be overheated.

Fixing Of CI Pipe And Fittings: The pipes are either fixed on face of wall or embedded in masonry. Pipes (without ears) and fittings should be secured to the walls at all joints with MS or CI holder bat clamps. The pipes shall be fixed perfectly vertical unless otherwise specified. Wooden cleats shall be fixed so that the pipes are kept at a distance of 25 – 30 mm from the wall to facilitate cleaning, painting, etc.

General Specifications: The pipes and fittings should be free from any visible defects, such as fire cracks, hair cracks etc. The glaze of the pipe should be free from crazing. The pipe should give a sharp clear tone when struck with a light hammer. There should not be any broken blisters.

Jointing of Pipes: For jointing the pipes, a gasket of unwoven yarn soaked in thick cement slurry is placed around the spigot of each pipe and the spigot is then slipped well into the socket of the pipe previously laid. The pipe is adjusted and placed in the correct position and the gasket is rammed tightly home so as to fill about $1/4^{\text{th}}$ of the total depth of the socket. The remainder of the socket is filled with stiff mixture of cement mortar in the proportion of 1:1 (1 cement: 1 fine sand). When the socket is filled, a fillet is formed around the joint with a trowel to form an angle of 45° with the barrel of the pipe. As the joint is rigid, it has to be ensured that undue settlement of the underground sewer line does not take place.

Laying Of SW Pipes (IS : 4127 – 1983):

Trenches: The **trenches shall be so dug that the pipe can be laid** to the required alignment at the required depth. When the pipe line is under a roadway, a minimum cover of 90 cm is recommended for adoption. The bed of the trench, if in soft or made up earth, shall be well watered and rammed before laying the pipes and the depressions, if any shall be properly filled with earth and consolidated in 20 cm layers.

If the trench bottom is extremely hard or rocky, the trench shall be excavated at least 15 cm below the trench grade. Rocks, stones or other hard substances from the bottom of the trench shall be removed and the trench brought back to the required grade by filling with selected fine earth or sand and compacted so as to provide smooth bedding for the pipe.

Laying: The pipe shall be carefully laid to the required alignment, levels and gradients. Great care shall be taken to prevent sand, etc. from entering the pipe. The pipes between two manholes shall be laid truly in a straight line without vertical or horizontal undulations. The pipes shall be laid with socket up the gradient. It may be necessary to support or surround pipe sewers by means of concrete in certain circumstances.

Testing Of Joints: Stoneware pipes used for sewer shall be subjected to a test pressure of 2.5 m head of water at the highest point of the section under test. The test shall be carried out by suitably plugging the lower end of the sewer and the ends of the branch connections, if any, and filling the system with water. A knuckle bend shall be temporarily jointed in at the top end and a sufficient length of vertical pipe jointed to it so as to provide the required head.

Any joint found leaking or sweating, shall be rectified or embedded into 15 cm layer of cement concrete (1:2:4) 30 cm in length and the section retested.

SMOKE TEST:- All soil pipes, waste pipes and vent pipes and other pipes above ground shall be approved gas-tight by a smoke test conducted under a pressure of 25 mm of water and maintain for 15 minutes after all trap seals have been filled with water. The smoke is produced by burning oiled waste or tat paper or similar material in the combustion chamber of a smoke machine.

Back-filling: In cases where pipes are not bedded on concrete special care shall be taken in refilling the trenches to prevent the displacement and subsequent settlement at the surface resulting in uneven street surfaces and danger to foundations etc. The backfilling material shall be packed by hand under and around the pipe. No tamping should be done within 15 cm of the top of the pipe.

The refilling shall rise evenly on both sides of the pipe, continued up to 60 cm above the top of the pipe so as not to disturb the pipe.

ROADS

W.B.M. ROADS

PREPARATION OF BASE :

The sub-grade/sub-base to receive the WBM course shall be prepared to the specified grade and can be made free of dust and other extraneous material. Where renewal of WBM is to be done, the entire existing surface shall be picked up and the useful material shall be reused, where water bound macadam is to be laid over an existing black topped surface 50mm x 50mm furrows shall be cut at an angle of 45° to the centre line of the road at 1 m intervals in the layer before laying the coarse aggregates. Any ruts for soft yielding places shall be corrected in an approved manner and rolled until the sub-grade/surface to be renewed is firm.

The WBM shall be laying either in a trench cut chamber or between suitable earth-bounds for any other suitable arrangement made on either side of the prepared sub-grade or sub-base course to confine the aggregates while spreading and rolling.

Soling: The primary function of soling is to distribute the load over a soft sub-grade in such a way that there will be no sinking of the road crust into the sub-grade.

Soling is generally laid in a trench made in the road and kept one foot wider than the finished road surface. The trench should be dug to have a profile of the same camber as the finished road surface and this trench should be well rolled before laying the soling. The soling stones shall be round and free from decay and weathering. The soling should also preferably be rolled before laying metalling. All soft places in sub-grade should be excavated and filled in with firm soil and well rammed before laying the bottom or other foundations. The soling is nothing but water bound macadam surface, which reduces the cost comparatively with WBM surface.

SPREADING COARSE AGGREGATES:

The coarse aggregate shall be spread uniformly and evenly upon the prepared sub-base in required quantities from the pre-measured stacks along the side of working area. The aggregates shall be spread uniformly to proper profile by using templates placed at intervals about 6 m apart. In case of yards of Bus depot and Bus Station longitudinal as well as lateral gradients are to be checked.

The surface of the aggregate spread shall be carefully dressed up and all high or low spots remedied by removing or adding aggregate as may be required.

The WBM course shall be normally constructed in layers of not more than 75mm compacted thickness.

ROLLING:

Immediately following the spreading of the coarse aggregates rolling shall be started with power rollers of 8 to 10 tonne capacity tandem or vibratory rollers of approved type.

The rolling shall start from edges with roller running forward or backward. The roller should be allowed to move inward parallel to centre line of the road in successive passes uniformly lapping proceeding tracks by atleast one half width.

The rolled surface shall be checked transversely and longitudinally with camber board and straight edge and irregularities collected by loosening the surface, adding or removing necessary amounts of aggregate and re-rolling until the entire surface conforms to desired camber and grade.

APPLICATION OF FILLER MATERIALS/SCREENINGS:

After rolling, filler materials/screening to completely fill the interstices shall be applied gradually over the surface. The filler material/screenings are used where single graded aggregate is used. These shall not be damp or wet at the time of application. Dry rolling shall be done while the filler materials/screening are being spread so that vibrations of the roller cause them to settle into voids of the coarse aggregates. The filler material/screenings shall be applied at uniform rate so as to ensure filling of all voids. Rolling and brooming shall continue with spreading. These operations shall continue until no more filler materials can be forced into the voids of coarse aggregates. The spreading, rolling and brooming shall be carried out in only such length of road which could be completed within one day's operation.

SPRINKLING AND GROUTING:

After filler materials/screening have been applied, the surface shall be sprinkled with water swept and rolled. Hand brooms shall be used to sweep wet filler materials/screening into voids and to distribute them evenly. The sprinkling, sweeping and rolling operations shall be continued with additional filler material/screenings applied as necessary until the coarse aggregate has been thoroughly keyed, well bonded, and firmly set in its full depth and grout has been formed of filler material/screenings. Care shall be taken to see that the sub-base or sub-grade does not get damaged due to excessive quantities of water during constructions.

APPLICATION OF BINDING MATERIAL:

The binding material where it is required to be used shall be applied successively in two or more thin layers at a uniform rate. After each application, the surface shall be copiously sprinkled with water and the resulting slurry swept in with brooms to fill the voids properly and rolled. Inadequate watering causes the binding material to stick to the roller wheels. This can be eliminated by sprinkling sufficient water with the binding material. Even after this, if sticking of binding material continues, water shall be applied to the wheels to wash down such sticking. Dry rolling on binding materials renders no useful purpose.

SETTING AND DRYING:

After the final compaction of WBM course, the road shall be allowed to dry overnight. No traffic shall be allowed on the road until the macadam has set.

WATERING:

WBM base shall be kept lightly sprinkled with water and kept moist for 15 days. Spreading and consolidation of materials shall be worked out in sq.m. The length being taken along with centre line of the base and the width along line at right angles to the centre line.

CAMBER:

Camber or cross slope is, the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.

The rate of camber depends on (i) the type of pavement surface & (ii) the amount of rainfall, that the surface is likely to receive.

Recommended Values of Camber for different Types of road surfaces:

Sl. No.	Type of Road Surface	Ranges of camber in areas of rainfall.	
		Heavy	Light
1.	Cement concrete and high type Bituminous surface.	1 in 50	1 in 60
2.	Thin bituminous surface	1 in 40	1 in 50
3.	Water bound macadam	1 in 33	1 in 40
4.	Earthen roads	1 in 25	1 in 33

GRADIENT:

Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio 1 in x (1 vertical unit to x horizontal), sometimes the gradient is also expressed as a percentage i.e. $\frac{1}{X} \times 100$.

Example: 1 in 200 or $1/200 \times 100 = 0.5\%$

Maximum values of gradients recommended by the IRC at different terrains are given in the following table.

Gradients for Roads in Different Terrains:

Terrain	Ruling gradient	Limiting gradient	Exceptional gradient
Plain or rolling	3.3% (1 in 30)	5% (1 in 20)	6.7% (1 in 15)
Mountainous terrain and steep terrain having elevation more than 3,000 m above the mean sea level.	5% (1 in 20)	6% (1 in 16.7)	7% (1 in 14.3)
Steep terrain upto 3,000 m high above mean seal level	6% (1 in 16.7)	7% (1 in 14.3)	8% (1 in 12.5)

DRAINAGE:

One of the important factors that damage the WBM surface is improper drainage arrangements, WBM structure is weak under saturated conditions and application of load under such conditions disintegrates the structure slowly and damages the surface. Hence, it is always necessary to provide adequate drainage arrangements by means of side drains or cross drains. While camber and gradients help in dispersing the water from the surface, the adequate number of drains shall be provided to lead off the collected storm water from the road surface adequate number of cambers shall be provided to lead off the collected storm water from the road surface to an eventual outfall.

IRC: 37-1970 specified the various measures of providing the drainage system.

QUALITY CONTROL CHECKS:

1. Compaction of sub-grade should be satisfactory and shall attain the required CBR value.
2. It could be checked whether the gradient of sub-grade, base is as per IRC recommendations.

3. It should be checked that the material collected are conforming to the specifications laid down in the technical sanction and agreement.
4. Representative sampling of materials should be preserved at site office.
5. The size, shape and quality of soling stones should be within the allowable limits.
6. Rejected materials shall be removed from the work site.
7. It should be ensured to mark the finished levels with suitable gradients on the plan.
8. In case soling work is adopted as a base course of foundation, level pegs according so as to ensure proper levels and gradients of the road/yard.
9. It should be checked whether the placement of soling stone with broad face downwards, packing and voids filling is satisfactory completed.
10. It should be checked whether the power rolling on soling work (dry rolling) is completed to the required level.
11. The levels of surface layer after spreading, sectioning and rolling shall be checked.
12. The blindage materials shall conform to the specifications provided in the technical sanction/agreement.
13. It should be checked that the quantity of materials collected vs the spread over areas executed are tallied. This check shall be conducted at close intervals of time.
14. It should be ensured that compaction of each course is done to the required degree.
15. Watering is done adequately during the process and setting period.
16. Traffic shall be allowed only after complete setting of the W.B.M. surface.

CEMENT CONCRETE ROADS

There are two methods for laying of CC pavement.

17. Alternate bay methods: It means constructing a bay or one slab in alternate succession leaving the next or intermediate bay to follow up.
18. Continuous construction method: In this method all the slabs or bays are laid in sequence.

It is advisable to lay CC roads when the atmosphere temperature is between 4 °C to 40 °C.

PREPARATION OF SUB -GRADE OR SUB -BASE:

The sub-grade should be dressed to required profile and cross section before cement concrete pavement is laid. The sub-grade or sub-base is prepared to a width of at least 30 cm. beyond each edge of the pavement to be constructed. The sub -grade/base should be kept in moist condition.

FIXING OF FORM WORK:

Material of wooden or steel may be used. The steel forms minimum of 3 m length are to be used. The steel forms when set in grade, should not have a maximum deviation more than 3 mm between top surface of section and straight line. In the case of wooden frames, the base width of minimum 10 cm for slab thickness of 20 cms and 15 cms for slabs over 20 cms thick.

BATCHING OF MATERIALS:

The coarse aggregate, fine aggregate and cement are proportioned by weight in weigh -batching plant and placed into the hopper. In some cases, the volumetric quantities are also being used for nominal mix.

MIXING OF MATERIALS:

The mixing of concrete should be done in power driven batch mixer to ensure uniform distribution of materials throughout the mass.

TRANSPORTING AND SPREADING OF CONCRETE:

Soon after mixing, the concrete should be transported and placed on the prepared base between the form work in such a manner so as to avoid segregation and uneven compaction. The concrete should not be dropped from a height greater than 90 cm and should be deposited within 20 minutes from the time to discharge from the mixer.

COMPACTION:

The concrete should be compacted fully using vibrating screed/internal vibrators. Compaction should be so controlled as to prevent excess mortar and water working on the top due to over vibration.

The slab should be tested for trueness with a 3m straight edge while the concrete is still plastic after longitudinal floating. The depressions are first enlarged to above 8 to 10 cms, and filled with fresh concrete compacted and finished. These operations should be completed within 1 hr.15min. of mixing. Wherever the slab is to be laid in two layers the 2nd layer should be laid within 30 min. of compaction of the lower layer.

FINISHING:

Before the concrete becomes hard the surface should be finished by belting, brooming and edging. Brooming is always done perpendicular to centre line of pavement. Before the concrete develops initial set, the edges of the slab are carefully finished with an edging tool.

CURING:

The mats or used gunny bags are thoroughly saturated with water and should be placed duly extending beyond the pavement edges at least by 0.5m. The initial curing should be continuous from a period of 24 hours. The concrete pavement is generally opened to the traffic after 28 days of curing or when the concrete attains the required strength.

CONSTRUCTION OF JOINTS IN CEMENT CONCRETE PAVEMENTS.**PURPOSE OF JOINTS:**

Joints are provided in CC roads for expansion, contraction and warping of the slabs due to the variation in temperature of slabs. The rise and fall of atmosphere temperatures make the pavement slabs to expand and contract. Joints in concrete pavements are provided both longitudinally and transversely. These joints are provided to keep within safe limits the stresses caused due to variation in temperature, moisture and frictional restraint in sliding. Utmost care shall be taken in the installation of joints in concrete pavements.

Detailed definitions are given in IS 6509-1976. These joints shall be filled with suitable plastic material to

- i) allow freedom for expansion / contraction
- ii) to prevent water penetration which would damage the structure.

MATERIALS:

a) Joint Filler, b) Joint sealing compound c) Dowel bars and tie bars.

a) Joint Filler: It should possess the following qualities, i) Compressibility ii) Elasticity and iii) Durability. It shall be premoulded type and shall be resistant to insects and decay in buried position. It shall not deteriorate under any weather conditions. Further details are available in IS: 1838-1961. Ex: Soft wood, impregnated fibre board, cork or cork bound with bitumen.

b) Joint Sealing compound or joint Sealer: Ordinary joint sealing compound with Gr.A is given in IS: 1834 -1961. Joint spaces are first filled with compressible filler material and top of joints are sealed using a scaler.

It should possess the following specifications to serve for a long period.

- a) Adhesion to cement concrete b) Extensibility without fracture
c) Resistance to ingress of grit. d) Durability.

IRC recommends following requirements for joint sealer:

S.No.	Characteristics	Requirements
1.	Pour point	180 °C max.
2.	Softening point	75 °C min.
3.	Increase in softening point after reaching to 20 °C above pour point for 3 hours	5 °C max.
4.	Penetration value	15 to 50
5.	Extensibility	6 mm max.
6.	Resistance to grit Penetration (on impact at 35% C in terms of mm)	20 max.

Bitumen is used either alone or with mineral filler as a sealing compound. Rubber bitumen compound is also used. Air blown bitumen may be used.

c) Dowel bars and The bars: These shall be made from steel conforming to IS: 432 (Part-1).

The bar shall be made from steel conforming to IS: 432-Part-I, Part-II, IS:1139, IS:1786.

QUALITY CONTROL MEASURES:

The following checks are necessary to ensure effective control on the quality:

1. It should be checked whether the compaction of sub grade is satisfactory.
2. It should be checked whether the gradient of sub-base is suitable to lay the CC pavement.
3. It should be ensured that the plan showing the levels of existing sub-grade and proposed CC pavement top surface is prepared and approved by competent authority. This is necessary to ensure suitable gradients and disposal of surface water from the CC pavement.

B.T. ROADS

Preparing the base: Surface dressing is done on an existing or new WBM road surface. It should be prepared in accordance with specified grade and cross section. As necessary, the cleaning of surface should be done first with hard brushes, then with soft brushes, and finally by blowing with sacks or gunny bags.

Application of Binder: The binder is heated to 163 to 177 °C and then sprayed on the prepared base in a uniform manner preferably with the help of mechanical sprayer.

Application of Stone Chippings: Immediately after the application of binder, stone chippings in a dry and clean state are spread uniformly on the layer of binder. The spreading of stone chippings is preferably done by means of mechanical gritter. If necessary, the surface may be broomed to ensure uniform spreading of stone chippings.

Rolling: Soon after the application of stone chippings, rolling is done by 8 to 10 tonnes smooth wheeled roller. Rolling is done longitudinally, starting from edges and working gradually towards the centre except in super elevated portions where it should proceed from the inner edge to the outer. Each pass of the roller should uniformly overlap not less than one-third of the strip rolled in the preceding pass. Rolling should be continued until all aggregate particles are firmly bedded in the binder and present a uniform closed surface.

Finishing the surface and opening to traffic: After final rolling, the road is opened to traffic after 24 hours.

DESIGN CRITERIA:

The thickness of the B.T. pavement depends upon the intensity of traffic volume, speed of the vehicles etc., and the type of soil met within sub-grades. The strength of the sub-grade soil and other construction materials is determined from an adhoc penetration test and the required thickness of pavement obtained from design curves evolved from experience. The CBR design curves evolved by Road Research Laboratory U.K. which owing to their simplicity and experience with their use have been found reasonably well suited for Indian conditions, are recommended for design. The thickness of different layers of sub-base, base and surfacing can be determined by repeated use of these curves. IRC: 37-1970 specifies the design criteria for flexible pavements.

SEAL COAT:

A final coat of bituminous material provided on the top of surface course for sealing the voids against entry of moisture is known as seal coat.

Functions: The following are the main functions for providing seal coat on bituminous surface.

1. To make the surface water tight.
2. To provide a more desirable surface texture.
3. To reduce slipperiness of the surface.
4. To enliven an existing dry or weathered surface.

Seal coat may be either of the following two types:

Type A: This type of seal coat is liquid seal coat which consists of a layer of bituminous binder followed by a cover of stone chippings.

Type B: This type of seal coat is premixed seal coat which consists of a thin application of fine aggregate premixed with bituminous binder.

Materials for seal coat : The materials required for providing a seal coat are binder, stone chippings and sand or fine grits.

Type A Seal Coat: The binder to be used for providing a seal coat is bitumen of a suitable grade. The quantity of binder in terms of straight run bitumen should be 9.80 kg/10 sqm area for type-A seal coat. The stone

chippings for type-A seal coat should consist of clean, hard, rough and durable rock of uniform quality throughout. They should be of 6 mm size defined as 100% passing through 10mm sieve and retained on 2.36 mm sieve. The quantity of stone chipping used for Type-A seal coat should be 0.09 cum/10 sqm area.

Method of construction of Type-A seal coat: For constructing Type-A seal coat, the binder is heated in a boiler of suitable design and to the temperature appropriate to the grade of bitumen, then the seal coat is applied in accordance with the construction operations described in case of surface dressing.

Type-B Seal Coat: The quantity of binder in terms of straight run bitumen should be 6.8 kg/10 sqm area for type-B seal coat. The fine aggregate for Type-B seal coat is sand or fine grits which should be clean, hard, durable, uncoated dry particles. The aggregate should pass through 1.7 mm sieve and be retained on 180 micron sieve. The quantity of fine aggregate used for type-B seal coat should be 0.06 cum/10 sqm area.

Method of construction of Type-B seal coat: For constructing type-B seal coat, the binder is heated in a boiler of suitable design and to the temperature appropriate to the grade of bitumen. Then fine aggregates, in dry state, are also heated to specified temperature before the same are placed in a mixer. After this, mixing of binder with aggregates to the specified temperature proportions is done in the mixer. Mixing should be continued till the aggregates are thoroughly coated with the binder. Then the mix is immediately transported from the fixing plant to the point of use and spread uniformly and bituminous surface to be sealed. As soon as sufficient length of the bituminous surface has been covered with the premixed mix, the surface is rolled with 6 to 9 tonne smooth wheeled power roller. Rolling should be continued until the premixed material completely seals the voids existing in the bituminous course and a smooth uniform surface is obtained.

GROUTED OR PENETRATION MACACAM:

This type of construction in which a bituminous binder is applied in a fluid state to partially compacted aggregate layer. When binder is allowed to penetrate to full depth, it is known as full grouted macadam and when it is allowed to penetrate half the depth, it is known as semi-grout macadam. IRC-20-1966 gives the recommended practice for bitumen penetration Macadam (full grout).

MATERIALS:

The binder should be straight run bitumen of grade 80/100 or 60/70 or 30/40. Quantity of 50 to 68 kg per 10 sqm area for 5 cm and 7.5 cm compacted thickness respectively. Road tars RT-4 and cut backs also be used.

Physical requirements for stone aggregate are given in Road materials Chapter.

The coarse aggregate and key aggregate require for 5 cm compacted thickness should 0.60 cum and 0.15 cum/10 sqm area respectively.

ROAD MIX SURFACE:

In this type of construction, the binder and aggregates are mixed on the top of an existing surface or a base.

- a) *Open graded mix*: If aggregates used are of uniform it is called open graded mix.
- b) *Dense graded mix*: If aggregates used are well graded it is called dense graded mix.

The road mix surfaces are suitable for light to moderate traffic condition on old or new bases.

CAMBER / CROSS FALL:

It is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.

Sl.No.	Type of Road surfaces	Ranges of Camber in areas of rainfall
1.	For High type Bituminous surface	1 in 50 to 1 in 60
2.	Thin Bituminous surface	1 in 40 to 1 in 50

THE QUALITY CONTROL TESTS ON BITUMEN:

1. Determination of penetration value of Bitumen – IS: 1203-1978
2. Determination of Ductility of Bitumen – IS: 1208-1978
3. Determination of Softening point of Bitumen – IS: 1205-1978
4. Determination of Flash point of Bitumen – IS: 1209-1978
5. Determination of Specific gravity (Pycnometer method)– IS: 1202-1978
6. Determination of Water content in Bitumen by Dum & Stak method – IS: 1211-1978

EARTH QUAKE TIPS

EARTH QUAKE TIPS

SEISMIC ZONES OF INDIA:

The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required so that buildings and other structures located in different regions can be designed to withstand different level of ground shaking. The current zone map subdivided India into five zones – I, II, III, IV and V. The maximum modified Mercalli (MM) intensity of seismic shaking expected in these zones are V or less, VI, VII, VIII and IX and higher, respectively. Parts of Himalayan boundary in the north and northeast and the Kachchh area in the west are classified as zone V. **Hyderabad City falls in Zone .**

Flow of Inertia Forces to Foundations:

Under horizontal shaking of the ground, horizontal inertia forces are generated at level of the mass of the structure (usually situated at the floor levels). These lateral inertia forces are transferred by foundations, and finally to soil system underneath. So, each of these structural elements (floor, slabs, walls, columns and foundations) and the connections between them must be designed to safely transfer these inertia forces through them.

Walls or columns are the most critical elements in transferring the inertia forces. But in traditional construction, floor slabs, and beams receive more care and attention during designing and construction, than walls and columns. Walls are relatively thin and often made of brittle material like masonry. They are poor carrying horizontal earthquake inertia forces along the direction of their thickness. Failures of masonry walls have been observed in many earthquakes in the past. Similarly, poorly designed and constructed reinforced concrete columns can be disastrous. The failure of the ground-storied columns resulted in numerous building collapses during the 2001 Bhuj (India) earthquake.

Inertia Forces in Structures:

Earthquake causes shaking of the ground. So a building resting on it will experience motion at its base. From Newton's First Law of Motion, even though the base of the building moves with the ground, the roof has a tendency to stay in its original position. But since the walls and columns are connected to it, they drag the roof along with them. This is much like the situation that you are faced with when the bus you are standing in suddenly starts; your feet move with the bus, but your upper body tends to stay back making you fall backwards. This tendency to continue to remain in the previous position is known as **inertia**. In the building, since the walls or columns are flexible, the motion of the roof is different from that of the ground.

Consider a building whose roof is supported on columns. Coming back to the analogy of yourself on the bus: when the bus suddenly starts, you are thrown backwards as if someone has applied a force on the upper body. Similarly, when the ground moves, even the building is thrown backwards, and the roof experiences a force, called inertia force. If the roof has a mass M and experiences an acceleration a , then from Newton's Second Law of Motion, the inertia force F_1 is mass M times acceleration a , and its direction is opposite to that of the acceleration. Clearly, more mass means higher inertia force. Therefore, lighter buildings sustain the earthquake shaking better.

Importance of Architectural Features:

The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. Hence, at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and a good building configuration is chosen.

Horizontal layout of Buildings: In general buildings with simple geometry in plan have Performance well during strong earthquakes. Buildings with re-entrant corners, like those U, V, H and + shaped in plan have sustained significant damage. Many times, the bad effects of these interior corners in the plan of buildings are avoided by making the buildings in two parts. For example,

an L-shaped plan can be broken up into two rectangular plan shapes using a separation joint at the junction. Often, the plan is simple, but the columns/walls are not equally distributed in plan. Buildings with such features tend to twist during earthquake shaking.

Vertical Layout of Buildings: The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks (like hotel buildings with a few storeys wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated. Buildings that are irregular shapes in plan tend to twist under it. The floors twist and displace horizontally.

QUALITY CONTROL IN CONSTRUCTION:

The capacity design concept in earthquake-resistant design of buildings will fail if the strengths of the brittle links fall below their minimum assured values. The strength of brittle construction materials, like masonry and concrete, is highly sensitive to the quality of construction materials, workmanship, supervision, and construction methods. Similarly, special care is needed in construction to ensure that the elements meant to be ductile are indeed provided with features that give adequate ductility. Thus, strict adherence to prescribed standards of construction materials and construction processes is essential in assuring an earthquake-resistant building. Regular testing of construction materials at qualified laboratories (at site or away), periodic training of evaluation of the technical work are elements of good quality control.

INDIAN SEISMIC CODES:

Seismic codes are unique to a particular region or country. They take into account the local seismology, accepted level of seismic risk, building typologies, and materials and methods used in construction. Further, they are indicative of the level of progress a country has made in the field of earth-quake engineering.

The first formal seismic code in India, namely IS 1893, was published in 1962. Today, the Bureau of Indian Standards (BIS) has the following seismic codes:

IS 1893 (Part I, 2002, Indian Standard Criteria for Earthquake Resistant Design of Structures (5th Revision)

IS 4326, 1993, Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings (2nd Revision)

IS 13827, 1993, Indian Standard Guidelines for Improving Earthquake Resistant of Earthen Buildings

IS 13828, 1993, Indian Standard Guidelines for Improving Earthquake Resistant of Low Strength Masonry Buildings

IS 13920, 1993, Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces

IS 13935, 1993, Indian Standard Guidelines for Repair and Seismic Strengthening of Buildings.

HOW TO IMPROVE BEHAVIOUR OF MASONRY WALLS:

Masonry walls are slender because of their small thickness compared to their height and length. A simple way of making these walls behave well during earthquake shaking is by making them act together as a box along with the roof at the top and with the foundation at the bottom. A number of construction aspects are required to ensure this box action. Firstly, connections between the walls should be good. This can be achieved by (a) ensuring good interlocking of the masonry courses at the junctions, and (b) employing horizontal bands at various levels, particularly at the lintel level. Secondly, the sizes of door and

window openings need to be resistance smaller the openings, the larger are the resistance offered by the wall. Thirdly, the tendency of a wall to topple when pushed in the weak direction can be reduced by limiting its length-to-thickness and height-to-thickness ratios. Design codes specify limits for these ratios. A wall that is too tall or too long in comparison to its thickness is particularly vulnerable to shaking in its weak direction.

CHOICE AND QUALITY OF BUILDING MATERIALS:

Earthquake performance of a masonry wall is very sensitive to the properties of its constituents, namely masonry units and mortar. The properties of these materials vary across India due to variation in raw materials and construction methods. A variety of masonry units are used in the country, e.g., clay bricks (burnt and un burnt), concrete blocks (solid and hollow), stone blocks. Burnt clay bricks are most commonly used. These bricks are inherently porous, and so they absorb water. Excessive porosity is detrimental to good masonry behaviour because the bricks suck away water from the adjoining mortar, which results in poor bond between brick and mortar, and in difficulty in positioning masonry units. For this reason, bricks with low porosity are to be used, and they must be soaked in water before use to minimize the amount of water drawn away from the mortar.

Various mortars are used, e.g., mud, cement-sand, or cement-sand-lime. Of these, mud mortar is the weakest; it crushes easily when dry, flows outward and has very low earthquake resistance. Cement-sand mortar with lime is the most suitable. This mortar mix provides excellent workability for laying bricks, stretches without crumbling at low earthquake shaking, and bonds well with bricks. The earthquake response of masonry walls depends on the relative strengths of brick and mortar. Excessive thickness of mortar is not desirable. A 10mm thick mortar layer is generally satisfactory from practical and aesthetic

considerations. Indian Standards prescribe the preferred types and grades of bricks and mortars to be used in buildings in each seismic zone.

ROLE OF HORIZONTAL BANDS:

Horizontal bands are the most important earthquake-resistant features in masonry buildings. The bands are provided to hold a masonry building as a single unit by tying all the walls together, and are similar to a closed belt provided around cardboard boxes. There are four types of bands in a typical masonry building, namely gable band, roof band, lintel band and plinth band named after their location in the building. The lintel band is the most important of all, and needs to be provided in almost all buildings. The gable band is employed only in buildings with pitched or sloped roofs. In buildings with flat reinforced concrete or reinforced brick roofs, the roof band is not required, because the roof slab also plays the role of a band. However, in buildings with flat timber or CGI sheet roof, roof band needs to be provided. In buildings with pitched or slopes roof, the roof band is very important. Plinth bands are primarily used when there is concern about uneven settlement of foundation soil.

The lintel band ties the walls together and creates a support for walls loaded along weak direction from walls loaded in strong direction. This band

also reduces the unsupported height of the walls and thereby improves their stability in the weak direction. During the 1993 Lathur earthquake (Central India), the intensity of shaking in Killari village was IX on MSK scale. Most masonry houses sustained partial or complete collapse. On the other hand, there was one masonry building in the village, which had a lintel band and it sustained the shaking very well with hardly any damage.

