4. CONCRETE

CORROSION OF STEEL IN CONCRETE

The term corrosion is used to indicate the conversion of metals by natural agencies into various compounds. The term rusting is used to refer corrosion of ferrous metals.

THEORIES OF CORROSION

1. **Chemical Action Theory**

$$Fe + O + 2CO_2 + H_2O = Fe(HCO_3)_2 \quad ...(i)$$

$$2Fe(HCO_3)_2 + O = 2Fe(OH)CO_3 + 2CO_2 + H_2O \quad ...(ii)$$

$$Fe(OH)CO_3 + H_2O = Fe(OH)_3 + CO_2 \quad ...(iii)$$

   - The combined action of oxygen, carbon dioxide and moisture on steel results in soluble ferrous bicarbonate $Fe(HCO_3)_2$. This ferrous bicarbonate is then oxidized to basic ferric carbonate $2Fe(OH)CO_3$. This basic ferric carbonate is converted into hydrated ferric oxide $Fe(OH)_3$ (final product) and carbon dioxide is liberated.

2. **Electrolytic Theory:** According to this theory, metal contains anodic and cathodic areas and these areas, when connected by electrolytes such as water, moisture, aqueous solutions, etc. cause corrosion.

CAUSES OF CORROSION

(i) Congested reinforcement in small concrete sections.
(ii) Excessive water-cement ratio.
(iii) Improper construction methods.
(iv) Inadequate design procedure.
(v) Insufficient cover to steel from exposed concrete surface.
(vi) Presence of moisture in concrete.
(vii) Presence of salts.

EFFECT OF CORROSION

Important effect of corrosion is the formation of cracks and these cracks usually progress or advance most rapidly where shearing stresses are the greatest and where slipping occurs due to loss of bond.

WATER-CEMENT RATIO

Important properties of water to be used for cement concrete are:

- Content of organic solids not more than 0.02%.
- Content of inorganic solids not more than 0.30%
- Content of sulphates not less than 0.05%.
- Content of sulphate alkali chlorides not more than 10%.
- Turbidity not more than 2000 ppm.
- Acid not more than 10,000 ppm.
- pH should be between 4.5 to 8.5.

BLEEDING OF CONCRETE

If excess water in the mix comes up at the surface causing small pores through the mass of concrete, it is called bleeding.

SEGREGATION

It is caused when coarse aggregate is separated out from the finer materials resulting in large voids, less durability and less strength.

Some rules-of-thumb are developed for deciding the quantity of water in concrete.

- Weight of water = 28% of the weight of the cement + 4% of the weight of total aggregate.
- Weight of water = 30 % of the weight of the cement + 5% of the weight of total aggregate.

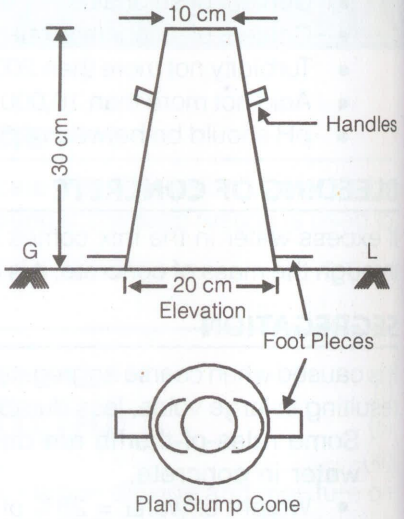
WORKABILITY OF CONCRETE

- Workability is the amount of work to produce full compaction.
- The important facts in connection with workability are:
  (i) If more water is added to attain the required degree of workmanship, it results into concrete of low strength and poor durability.
  (ii) If the strength of concrete is not to be affected, the degree of workability can be obtained:
    - by slightly changing the proportions of fine and coarse aggregates, in case the concrete mixture is too wet; and
    - by adding a small quantity of water cement paste in the proportion of original mix, in case the concrete mixture is too dry.
  (iii) The workability of concrete is also affected by the maximum size of the coarse aggregates to be used in the mixture.

In order to measure the workability of concrete mixture, various tests are developed. Tests such as flow test, Vee-Bee test and compaction factor test are used in great extent in laboratory. Slump test, which is commonly used in the field, is briefly described below. Test for workability

SLUMP TEST

- Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.
- It is not a suitable method for very wet or very dry concrete and stiff mix.
- It does not measure all factors contributing to workability.
- The diameter of the rod is 16 mm and its length is 60 cm. The strokes to be given for ramming vary from 20 to 30.



RECOMMENDED SLUMPS OF CONCRETE

No.	Type of concrete	Slump
1.	Concrete for road construction	20 to 40 mm
2.	Beams and slabs	50 to 100 mm
3.	Normal RCC work	80 to 150 mm
4.	Mass concrete	25 to 50 mm
5.	Concrete to be vibrated	10 to 25 mm
6.	Impermeable work	75 to 120 m

Workability, Slump and Compacting Factor of Concretes with 20 mm or 40 mm Maximum Size of Aggregate

Degree of workability	*Slump mm*	*Compacting factor*		*Use for which concrete is suitable*
		Small apparatus	*Large apparatus*	
Very Low	–	0.78	0.80	Roads vibrated by power-operated machines.
Low	25-75	0.85	0.87	Roads vibrated by hand-operated machines.
Medium	50-100	0.92	0.935	At the less workable end of this group, manually compacted flat slabs using crushed aggregates.
High	100-150	0.95	0.96	For sections with congested reinforcement.
Very High	–	–	–	Flow table test is more suitable.

COMPACTION FACTOR TEST

- In the compaction factor test the degree of workability of concrete is measured in terms of internal energy required to compact the concrete thoroughly.
- A compaction factor of 0.95 represents flowing concrete having high workability; 0.92 plastic concrete having medium workability; 0.85 stiff plastic concrete having low workability and a compaction factor of 0.75 represents stiff concrete having very low workability.
- The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.
- The degree of compaction called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

VEE-BEE TEST

- This is carried out in such a manner that the specimen concrete in the test receives more or less same treatment in respect of the method of placing as it would in actual execution of the work. This test is preferred for finding workability of stiff concrete mix having very low workability.
- In this test a Vee-Bee time of 5 to 3 seconds represent stiff plastic concrete having medium workability, 10 to 15 seconds represents stiff concrete of low workability and Vee-Bee time to 18 to 10 seconds represent very stiff concrete having very low workability.

VEE BEE CONSISTOMETER

- This is a good laboratory test to measure indirectly the workability of concrete.
- This test consists of a vibrating table, metal pot, a sheet metal concrete a standard iron rod.
- The time required for the shape of concrete to change from slump concrete shape to cylindrical shape in second is known as Vee Bee Degree.
- This method is very suitable for very dry concrete whose slump value can not be measured by slump test but the vibration is too vigorous for concrete with a slump greater than about 50 mm.

FLOW TEST

- This is a laboratory test which gives an indication of the quality of concrete with respect to consistency cohesiveness and the proneness to segregation.

- The spread or the flow of the concrete is measured and this flow is related to workability.

$$\text{Flow percent} = \frac{\text{Spread diams in cm} - 25}{25} \times 100$$

The value could range anything from 0-150%.
It can be realized that the compacting factor test measures the inherent characteristics of the concrete which relates very close to the workability requirements of concrete and as such it is one of the good test to depict the workability of concrete.

ESTIMATING YIELD OF CONCRETE

- A rule-of-thumb as given below, may be used to find out the approximate yield of concrete from a given concrete mix.
- If the proportion of concrete is a : b : c, i.e., if a parts of cement, b parts of sand and c parts of coarse aggregates are mixed by volume, the resulting concrete will have a volume of 2/3 (a + b + c).
- Let w, a, b and c be absolute volumes of water, cement, fine aggregate and coarse aggregate respectively. Then, w + a + b + c = 1.

$$\text{Absolute volume} = \frac{\text{Weight of the materials}}{\text{Apparent sp. gr.} \times \text{Unit wt. of water}}$$

METHODS FOR PROPORTIONING CONCRETE MIXES

1. **Minimum voids method**
   The quantity of sand used should be such that it completely fills the voids of the coarse aggregate and similarly the quantity of cement used should be such that it fills the voids of sand. However in actual practices the quantity of sand used in the mix is kept 10% more than the voids in the coarse aggregate and the quantity of cement is taken 15 % more than the voids in the sand.
2. **Maximum density method**
   Method of minimum voids was later improved by Fuller. For maximum density of mix.
   He gave following expression.

$$P = 100\left(\frac{d}{D}\right)^{1/2}$$

D = Maximum size of aggregate.

P = % by weight of matter finer than diameter d.

3. **Abram's water-cement ratio law**
   - This law states that for any given conditions of test the strength of workable concrete mix is dependent only on the water cement ratio. It means that if the concrete is fully compacted, the strength is not affected by aggregate shape, type or surface texture or the aggregate grading. According to this law, the strength of mix increases with decrease in water content.
   - In terms of crushing strength after 7 days curing $P_7 = \frac{984}{7^x}\ kg/cm^2$

     where P_7 is cylinder crushing strength in kg/cm^2 and x is water cement ratio by volume.
   - In terms of crushing strength after 28 days curing $P_{28} = \frac{984}{4^x}\ kg/cm^2$

     where P_{28} is cylinder crushing strength after 28 days curing.
   - Strength of concrete increases with age.

Months	Age factor
1	1.00
3	1.10
6	1.15
12	1.20

MIX DESIGN

- When the task of deciding the proportion of the constituents of concrete is accomplished by use of certain established relationships (which are based on inferences drawn from large number of experiments) the concrete thus produced is termed as Design mix concrete.
- When the proportions of cement, aggregate and water are adopted based on arbitrary standard the concrete produced is termed as Nominal mix concrete.
- Nominal mix concrete is used in works where the quality control requirement for design mixes are difficult to be implemented. Nominal mix concrete can be produced by taking cement, fine and coarse aggregate in the ratio of 1 : n : 2n for normal work. However, the ratio of the coarse aggregate to fine aggregate can vary from 1.5 : 2.5 :1 in situations where denser or more workable concrete is to be produced.

AGGREGATES SIZE

- For RCC work the maximum size of aggregates is limited to 20-25 mm.

- For a concrete of given workability rounded aggregates require least water cement ratio. Particle shape is very important since the water cement ratio governs greatly the strength of concrete.
  Coarse aggregates > 4.75 mm size.
  Fine aggregates < 4.75 mm size.

FINENESS MODULUS

- The fineness modulus of an aggregate is an index number which is roughly proportional to the average size of the particles in the aggregate. The coarser the aggregate, the higher the fineness modulus.
- Fineness modulus is obtained by adding the % of the weight of the material retained on the total 10 number of IS sieves (between 80 mm to 150 μm) and dividing it by 100.

Aggregate	Fineness modulus
Coarse aggregate	6 to 8.5 (in general 6.93)
Fine aggregate	2 to 3.5 (in general 3.05)
Mixed aggregate	4.7 to 7.0
Fine sand	2.2 to 2.6
Medium sand	2.6 to 2.9
Coarse sand	2.9 to 3.2

VIBRATORS

Following are the four types of vibrators:

1. **Internal Vibrators:** These vibrators consist of a metal rod which is inserted in fresh concrete. Skilled and experienced men should handle internal vibrators. These vibrators are more efficient than other types of vibrators.
2. **Surface Vibrators:** These vibrators are mounted on platform or screeds. They are used to finish concrete surfaces such as bridge floors, road slabs, station platform, etc.
3. **Form Vibrators:** These vibrators are attached to the formwork and external centering of walls, columns, etc. The vibrating action is conveyed to concrete through the formwork during transmission of vibrations. Hence they are not generally used. But they are very much helpful for concrete sections which are too thin for the use of internal vibrators.
4. **Vibrating Tables:** These vibrators are widely used for making precast products.
5. **Period of Curing:** The curing period is about 7 to 14 days.

WATER-PROOFING CEMENT CONCRETE

- Cement concrete to a certain extent may be made impermeable to water by using hydrophobic cement.

Following are the three methods adopted for water-proofing of RCC flat roofs:

1. **Finishing:** For ordinary building of cheap construction, finishing of roof surface is done at the time of laying cement concrete. The finishing of flat roof is carried out in cement mortar of proportion 1:4, i.e., one part of cement to four parts of sand by volume.
2. **Bedding Concrete and Flooring:** In this method, the surface of RCC slab is kept rough and on this surface, a layer of concrete is laid. The concrete may be brickbats lime concrete (1:2:4) or brickbats cement concrete (1:8:14). The thickness of the concrete layer is about 10 cm.
3. **Mastic Asphalt and Jute Cloth:** In this method, a layer of hot mastic asphalt is laid on the roof surface. Jute cloth is spread over this year.

LIGHTWEIGHT CONCRETE

The bulk density of ordinary concrete is about 2300 kg/m^3. Concrete having bulk density between 500 to 1800 kg/m^3 is known as lightweight concrete and it is prepared from the following materials:

1. **Binding material :** Ordinary Portland cement and its varieties can be used as binding material.
2. **Aggregates :** For lightweight concrete, loose porous materials are used as aggregates.
3. **Steel :** Lightweight concrete is highly porous and hence, it leads to corrosion of reinforcement.

- The volume of one 50 kg bag of cement is 34.5 liters.
- About 19 liters (38 per cent) of water is required to hydrate 50 kg cement in sealed container.

- The ordinary Portland cement when tested for its compressive strength at 28 days according to the method described by the standard specification, yields a minimum compressive strength of 43 N/mm^2 is called 43 grade cement.
- Too fine cement is susceptible to air set and deteriorates earlier.
- The setting time of cement can be controlled by varying the quantity of gypsum in cement.
- Sometimes with the addition of water to cement, a premature set occurs within 5 minutes. This is called false set and is due to the presence of anhydrous gypsum which is formed due to grinding of gypsum with too hot clinker. This is not to be worried. Continuous

mixing aggregates, cement and water will break the false set without harming any property of the concrete.

- The ability of cement to maintain a constant volume is known as soundness of cement.
- The ability of aggregate to resist excessive changes in volume due to changes in physical conditions is known as soundness of aggregate. In laboratory, it is found by determining resistance of aggregate to disintegration by saturated solution of sodium sulphate or magnesium sulphate.
- Concrete with increased workability without adding more water is called flowing concrete.
- M20 is the designation of concrete mix. Letter M refers to the mix and number 20 refers to the characteristic strength of 15 cm cube after 28 days equal to 20 N/mm^2.
- **Bleeding of Concrete :** is said to occur when unreacted water in the mix tends to rise to the surface of freshly placed concrete due to sedimentation of constituents of concrete. This produces continuous capillary pores which provides a clear straight access to chemicals and deleterious materials in concrete and lowers the strength and workability of concrete.
- $$\text{Compaction factor} = \frac{\text{mass of partially compacted concrete}}{\text{mass of fully compacted concrete}}$$
- The normal tensile stress in concrete when cracking occurs in a flexure test is known as modulus of rupture of concrete. It is measured by performing a flexure test on un-reinforced concrete beam of specified size and span considering concrete to be homogeneous.

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