

UNIT-IV
FRESH AND HARDENED PROPERTIES OF CONCRETE

1. Define workability.

Workability is the property of concrete which determines the amount of internal work necessary to produce full compaction. It is a measure with which concrete can be handled from the mixer stage to its final fully compacted stage.

2. List out the requirements of fresh concrete.

- a. Mixability
- b. Stability
- c. Mobility
- d. Compactability
- e. Finishability

3. List out the Factors affecting Workability?

- a. Water content
- b. Mix proportion
- c. Size of aggregate
- d. Shape of aggregate
- e. Surface texture
- f. Grading
- g. Admixture

4. Mention the methods to measure the workability?

- a. Slump Test
- b. Compaction Factor
- c. Vee-Bee Consistometer
- d. Kelly Ball Penetration test
- e. Flow table Test
- f. Vibrating table

5. Mention the values of different type of slump.

- True slump - up to 125mm from top
- Shear slump - up to 150 mm from top
- Collapse slump -150-225mm

6. List out the usage of slump values

- slump 0 – 25 mm are used in road making
- 10 – 40 mm are used for foundations with light reinforcement
- 50 - 90 for normal reinforced concrete placed with vibration

7. Define compaction factor?

Compaction Factor is the ratio of the weight of partially compacted concrete to the weight of the concrete when fully compacted in the same mould.

8. Define Vee bee consistometer

Consistometer is based on consistency test which is a mechanical variation of the simple slump test which includes determination of the workability of concrete. Measures consistency of concrete in terms of time required to transform by vibration a frustum of fresh concrete sample into a cylinder. This time is called VB time.

9. What is the use of Kelly Ball Penetration test

Kelly Ball Penetration method is used to determine the penetration of a hemispherical metal weight into freshly mixed concrete, which is related to the workability of the concrete.

10. What is the use of flow table method

Flow table indicates consistency and proneness to segregation. It is used for aggregate of size <40mm. The flow is determined by $= \{D-250/250\} * 100$.

11. Mention the test conducted to test the properties of hardened concrete.

- a. Compression Testing Machine
- b. Flexure Strength Testing Machine
- c. Lateral Extensometer
- d. Split Tensile Test
- e. Shear strength
- f. Bond strength

12. List out the factors affecting the results of strength test.

- a. Size and shape of aggregate
- b. Condition of casting
- c. Moisture condition
- d. Bearing condition
- e. Rate of loading

13. What are the steps adopted to control bleeding.

By adding more cement

By using more finely ground cement

By using little air entraining agent

By increasing finer part of fine aggregate

By properly designing the mix and using minimum quantity of water.

14. Define Segregation.

The tendency of separation of coarse aggregate grains from the concrete mass is called segregation.

15. Define bleeding.

The tendency of water to rise to the surface of freshly laid concrete is known as bleeding.

PART B

1. Define workability? Explain the factors affecting workability?

Workability

The lubrication required for handling concrete without segregation, for placing without loss of homogeneity, for compacting with the amount of efforts forth-coming and to finish it sufficiently easily, the presence of a certain quantity of water is of vital importance.

The quality of concrete satisfying the above requirements is termed as workable concrete.

Factors Affecting Workability

Workable concrete is the one which exhibits very little internal friction between particle and particle or which overcomes the frictional resistance offered by the formwork surface or reinforcement contained in the concrete with just the amount of compacting efforts forthcoming. The factors helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are given below:

- (a) Water Content
- (b) Mix Proportions
- (c) Size of Aggregates
- (d) Shape of Aggregates
- (e) Surface Texture of Aggregate
- (f) Grading of Aggregate
- (g) Use of Admixtures.

(a) Water Content: Water content in a given volume of concrete, will have significant influences on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

(b) Mix Proportions: Aggregate/cement ratio is an important factor influencing workability. The higher the aggregate/cement ratio, the leaner is the concrete. On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

(c) Size of Aggregate: The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction.

(d) Shape of Aggregates: The shape of aggregates influences workability in

good measure. Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates. Contribution to better workability of rounded aggregate will come from the fact that for the given volume or weight it will have less surface area and less voids than angular or flaky aggregate.

(e) Surface Texture: The influence of surface texture on workability is again due to the fact that the total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume. A reduction of inter particle frictional resistance offered by smooth aggregates also contributes to higher workability.

(f) Grading of Aggregates: This is one of the factors which will have maximum influence on workability. A well graded aggregate is the one which has least amount of voids in a given volume. Aggregate particles will slide past each other with the least amount of compacting efforts. The better the grading, the less is the void content and higher the workability. The above is true for the given amount of paste volume.

(g) Use of Admixtures: Of all the factors mentioned above, the most important factor which affects the workability is the use of admixtures. It is to be noted that initial slump of concrete mix or what is called the slump of reference mix should be about 2 to 3 cm to enhance the slump many fold at a minimum dose. One should manipulate other factors to obtain initial slump of 2 to 3 cm in the reference mix. Without initial slump of 2 – 3 cm, the workability can be increased to higher level but it requires higher dosage – hence uneconomical. Use of air-entraining agent being surface-active, reduces the internal friction between the particles. They also act as artificial fine aggregates of very smooth surface.

2. Explain the test for workability?

Measurement of Workability

Workability of concrete is a complex property. Numerous attempts have been made by many research workers to quantitatively measure this important and vital property of concrete. Some of the tests, measure the parameters very close to workability and provide useful information. The following tests are commonly employed to measure workability.

- (a) Slump Test
- (b) Compacting Factor Test
- (c) Flow Test
- (d) Kelly Ball Test
- (e) Vee Bee Consistometer Test.

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. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete.
- Repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio, provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits.
- Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. Quality of concrete can also be further assessed by giving a few tamping or blows by tamping rod to the base plate. The deformation shows the characteristics of concrete with respect to tendency for segregation.

The apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as under:

Bottom diameter: 20 cm

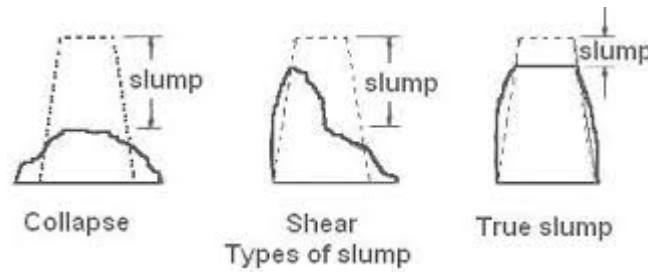
Top diameter : 10 cm

Height : 30 cm

The thickness of the metallic sheet for the mould should not be thinner than 1.6 mm. Sometimes the mould is provided with suitable guides for lifting vertically up. For tamping the concrete, a steel tamping rod 16 mm dia, 0.6 meter long with bullet end is used.

The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould is placed on a smooth, horizontal, rigid and non-absorbant surface. The mould is then filled in four layers, each approximately 1/4 of the height of the mould. Each

layer is tamped 25 times by the tamping rod taking



care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as SLUMP of concrete. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm. is taken as Slump of Concrete. Shear slump also indicates that the concrete is non-cohesive and shows the characteristic of segregation. It is seen that the slump test gives fairly good consistent results for a plastic-mix. This test is not sensitive for a stiff-mix. In case of dry-mix, no variation can be detected between mixes of different workability. In the case of rich mixes, the value is often satisfactory, their slump being sensitive to variations in workability.

K-SLUMP TESTER

It can be used to measure the slump directly in one minute after the tester is inserted in the fresh concrete to the level of the floater disc. This ester can also be used to measure the relative workability.

A chrome plated steel tube with external and internal diameters of 1.9 and 1.6 cm respectively. The tube is 25 cm long and its lower part is used to make the test. The length of this part is 15.5 cm which includes the solid cone that facilitates inserting the tube into the concrete.

Two types of openings are provided in this part: 4 rectangular slots 5.1 cm long and 0.8 cm wide and 22 round holes 0.64 cm in diameter; all these openings are distributed uniformly in the lower part.

A disc floater 6 cm in diameter and 0.24 cm in thickness which divides the tube into two parts: the upper part serves as a handle and the lower one is for testing as already mentioned. The disc serves also to prevent the tester from sinking into the concrete beyond the preselected level.

A hollow plastic rod 1.3 cm in diameter and 25 cm long which contains a graduated scale in centimeters. This rod can move freely inside the tube and can be used to measure the height of mortar that flows into the tube and stays there. The rod is plugged at each end with a plastic cap to prevent concrete or any other material from seeping inside.

An aluminium cap 3 cm diameter and 2.25 cm long which has a little hole and a screw that can be used to set and adjust the reference zero of the apparatus. There is also in the upper part of the tube, a small pin which is used to support the measuring rod at the beginning of the test. The total weight of the apparatus is 226 g.

The following procedure is used:

- (a) Wet the tester with water and shake off the excess.
- (b) Raise the measuring rod, tilt slightly and let it rest on the pin located inside the tester.
- (c) Insert the tester on the levelled surface of concrete vertically down until the disc floate rests at the surface of the concrete. Do not rotate while inserting or removing the tester.
- (d) After 60 seconds, lower the measuring rod slowly until it rests on the surface of the concrete that has entered the tube and read the K-Slump directly on the scale of the measuring rod.
- (e) Raise the measuring rod again and let it rest on its pin.
- (f) Remove the tester from the concrete vertically up and again lower the measuring rod slowly till it touches the surface of the concrete retained in the tube and read workability (W) directly on the scale of the measuring rod.

The K-slump apparatus is very simple, practical, and economical to use, both in the field and the laboratory. The K-slump tester can be used to measure slump in one minute in cylinders, pails, buckets, wheel-barrows, slabs or any other desired location where the fresh concrete is placed.

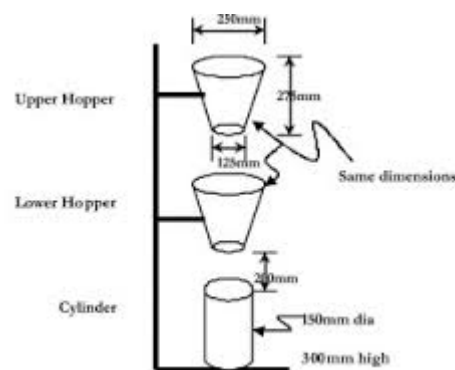
COMPACTING FACTOR TEST

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It 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. Such dry concrete are insensitive to slump test.

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.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap-door is opened so that the concrete falls into the lower hopper. Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. In the case of a dry-mix, it is likely that the concrete may not fall on opening the trap-door.

In such a case, a slight poking by a rod may be required to set the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades supplied with the apparatus. The outside of the cylinder is wiped clean. The concrete is filled up exactly upto the top level of the cylinder. It is weighed to the nearest 10 grams. This weight is known as —Weight of partially compacted concrete.



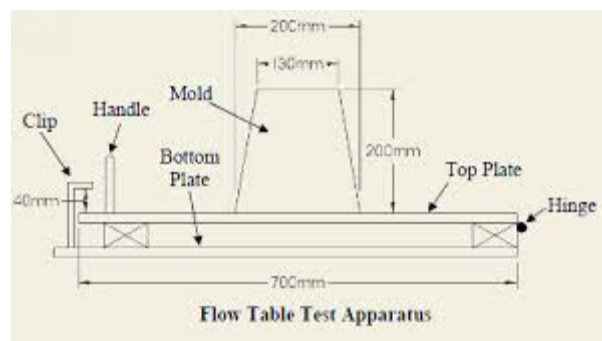
The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5 cm deep. The layers are heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 10 gm. This weight is known as —Weight

of fully compacted concrete.

$$\text{The compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

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. In this test, a standard mass of concrete is subjected to jolting. The spread or the flow of the concrete is measured and this flow is related to workability.



It can be seen that the apparatus consists of flow table, about 76 cm. in diameter over which concentric circles are marked. A mould made from smooth metal casting in the form of a frustum of a cone is used with the following internal dimensions. The base is 25 cm. in diameter, upper surface 17 cm. in diameter, and height of the cone is 12 cm. The table top is cleaned of all gritty material and is wetted. The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6 cm in diameter and 61 cm long rounded at the lower tamping end. After the top layer is rodded evenly, the excess of concrete which has overflowed the mould is removed. The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5 mm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5 mm and the average spread is noted. The flow of concrete is the percentage increase in the average diameter of the spread concrete over the base diameter of the mould

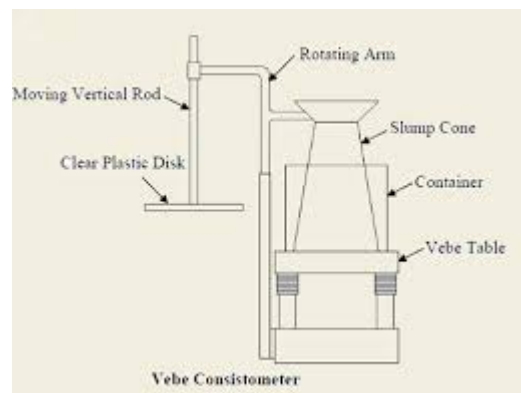
$$\text{Flow per cent} = \frac{\text{Spread diameter in cm} - 25}{25} \times 100$$

The value could range anything from 0 to 150 per cent. A close look at the pattern of spread of concrete can also give a good indication of the characteristics of concrete such as tendency for segregation.

VEE BEE CONSISTOMETER TEST

This is a good laboratory test to measure indirectly the workability of concrete. This test consists of a vibrating table, a metal pot, a sheet metal cone, a standard iron rod.

Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consistometer. The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot. The electrical vibrator is then switched on and simultaneously a stop watch started.



The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape. This can be judged by observing the glass disc from the top for disappearance of transparency. Immediately when the concrete fully assumes a cylindrical shape, the stop watch is switched off. The time required for the shape of concrete to change from slump cone shape to cylindrical shape in seconds is known as Vee Bee Degree.

This method is very suitable for very dry concrete whose slump value cannot be measured by Slump Test but the vibration is too vigorous for concrete with a slump greater than about 50 mm.

3. Explain segregation and Bleeding?

Segregation

Segregation can be defined as the separation of the constituent materials of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture. If a sample of concrete exhibits a tendency for separation of say, coarse aggregate from the rest of the ingredients, then, that sample is said to be showing the tendency for segregation. Such concrete is not only going to be weak; lack of homogeneity is also going to induce all undesirable properties in the hardened concrete.

A well made concrete, taking into consideration various parameters such as grading, size, shape and surface texture of aggregate with optimum quantity of water makes a cohesive mix. Such concrete will not exhibit any tendency for segregation.

The cohesive and fatty characteristics of matrix do not allow the aggregate to fall apart, at the same time, the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move out freely from the rest of the ingredients.

The conditions favorable for segregation are, , the badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates. Insufficiently mixed concrete with excess water content shows a higher tendency for segregation. Dropping of concrete from heights as in the case of placing concrete in column concreting will result in segregation.

When concrete is discharged from a badly designed mixer, or from a mixer with worn out blades, concrete shows a tendency for segregation. Conveyance of concrete by conveyor belts, wheel barrow, long distance haul by dumper, long lift by skip and hoist are the other situations promoting segregation of concrete. Vibration of concrete is one of the important methods of compaction. It should be remembered that only comparatively dry mix should be vibrated. If too wet a mix is excessively vibrated, it is likely that the concrete gets segregated.

A cohesive mix would reduce the tendency for segregation. For this reason, use of certain workability agents and pozzolanic materials greatly help in reducing segregation. The use of air-entraining agent appreciably reduces segregation. Segregation is difficult to measure quantitatively, but it can be easily observed at the time of concreting operation. The pattern of subsidence of concrete in slump test or the pattern of spread in the flow test gives a fair idea of the quality of concrete with respect to segregation.

Bleeding

Bleeding is sometimes referred as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete. In thin members like roof slab or road slabs and when concrete is placed in sunny weather show excessive bleeding. Due to bleeding, water comes up and accumulates at the surface. Sometimes, along with this water, certain quantity of cement also comes to the surface. When the surface is worked up with the trowel and floats, the aggregate goes down and the cement and water come up to the top surface. This formation of cement paste at the surface is known as Laitance.

Water while traversing from bottom to top, makes continuous channels. If the water cement ratio used is more than 0.7, the bleeding channels will remain continuous and unsegmented by the development of gel. This continuous bleeding channels are often responsible for causing permeability of the concrete structures.

While the mixing water is in the process of coming up, it may be intercepted by aggregates. The bleeding water is likely to accumulate below the aggregate. This accumulation of water creates water voids and reduces the bond between the aggregates and the paste. The above aspect is more pronounced in the case of flaky aggregate. Similarly, the water that accumulates below the reinforcing bars, particularly below the cranked bars, reduces the bond between the reinforcement and the concrete. The poor bond between the aggregate and the paste or the reinforcement and the paste due to bleeding can be remedied by revibration of concrete. The formation of laitance and the consequent bad effect can be reduced by delayed finishing operations.

Bleeding rate increases with time up to about one hour or so and thereafter the rate decreases but continues more or less till the final setting time of cement.

Bleeding is an inherent phenomenon in concrete. All the same, it can be reduced by proper proportioning and uniform and complete mixing.

The bleeding is not completely harmful if the rate of evaporation of water from the

surface is equal to the rate of bleeding.

Method of Test for Bleeding of Concrete

This method covers determination of relative quantity of mixing water that will bleed from a sample of freshly mixed concrete. A cylindrical container of approximately 0.01 m^3 capacity, having an inside diameter of 250 mm and inside height of 280 mm is used. A tamping bar similar to the one used for slump test is used. A pipette for drawing off free water from the surface, a graduated jar of 100 cm^3 capacity is required for test.

A sample of freshly mixed concrete is obtained. The concrete is filled in 50 mm layer for a depth of $250 \pm 3 \text{ mm}$ (5 layers) and each layer is tamped by giving strokes, and the top surface is made smooth by trowelling.

The test specimen is weighed and the weight of the concrete is noted. Knowing the total water content in 1 m^3 of concrete quantity of water in the cylindrical container is also calculated.

The cylindrical container is kept in a level surface free from vibration at a temperature of $27^\circ\text{C} \pm 2^\circ\text{C}$. It is covered with a lid. Water accumulated at the top is drawn by means of pipette at 10 minutes interval for the first 40 minutes and at 30 minutes interval subsequently till bleeding ceases. To facilitate collection of bleeding water the container may be slightly tilted.

All the bleeding water collected in a jar.

$$\text{Bleeding water percentage} = \frac{\text{Total quantity of bleeding water}}{\text{Total quantity of water in concrete}} \times 100$$

4.Explain the properties of fresh and hardened concrete?

PROPERTIES OF FRESH CONCRETE

The fresh concrete or plastic concrete is the initial stage of concrete period and it is counted from the mixing stage till it is transported, placed, compacted and finished in the position. The fresh concrete must satisfy the following requirements. Ideal Requirements of Fresh Concrete

i. Mixability

The mix should be able to produce a homogeneous and uniform fresh concrete from the

constituent materials of each batch under the action of mixing forces.

ii. Stability

The mix should be stable meaning thereby it should not segregate during transporting and placing and also the tendency of the bleeding should be minimum.

iii. Mobility/Flowability

The mix should be mobile enough to surround all reinforcement without leaving any voids behind as well as to completely fill the formwork.

iv. Compactability

The mix should be amenable to proper and thorough minimum compaction into a dense compact concrete under the existing facilities of compaction at site.

v. Finishability

It should be able to obtain a uniform and satisfying surface finish.

PROPERTIES OF HARDENED CONCRETE

The concrete is a basic prime building material because of various properties being possessed during its hardened state which starts from the day it attains the full designed strength to the end of its life. For hardened concrete, the various properties which need consideration are as follows.

(A) STRENGTH

- a. Compressive strength
- b. Tensile strength
- c. Flexural strength
- d. Shear strength
- e. Bond strength

(B) Durability

(C) Impermeability

(D) Dimensional Changes

- (a) Elasticity
- (b) Shrinkage
- (c) Creep
- (d) Thermal expansion
- (e) Fatigue

(E) Fire Resistance

STRENGTH OF CONCRETE

The strength of concrete is the most important property as far as structural designs are concerned. Indirectly, it gives the idea of other properties (Impermeability, durability, wear resistance etc) also. A strong concrete is more dense, compact, impermeable and resistant to weathering and chemical attacks. Meaning thereby, the strength of concrete gives an overall idea of its quality. Strength of concrete is defined as the ability to resist force and for structural purposes, it is taken as the unit force required to cause rupture which may be caused by compressive stress, tensile stress, flexural stress, shear stress, bond stress etc.

Compressive Strength of Concrete

The compressive strength of concrete is considered the basic character of the concrete. Consequently, it is known as the **characteristic compressive strength of concrete (f_{ck})** which is defined as that value below which not more than five percent of test results are expected to fall based on IS: 456-2000. In this definition the test results are based on 150 mm cube cured in water under temp. of $27 \pm 2^{\circ}\text{C}$ for 28 days and tested in the most saturated condition under direct compression.

Other strength viz, direct tensile stress, flexural stress, shear stress and bond stress also are directly proportional to the compressive stress. Higher is the compressive stress, higher is other stresses also. Not only stresses, other properties for example modulus of elasticity, abrasion and impact resistances, durability are also taken to be related to the compressive strength, hence, the compressive strength is an index of overall quality of concrete.

Factors Affecting Compressive Strength

Among the materials and mix variables, **water -cement ratio** is the most important parameter governing the compressive strength. Besides W/C ratio, following factors also affect the compressive strength.

- The characteristics of cement.
- The characteristics and properties of aggregates.
- The degree of compaction
- The efficiency of curing
- Age at the time of testing.
- Conditions of testing.

Water -Cement Ratio

The water -cement ratio, defined as the ratio of the mass of free water (i.e. excluding that absorbed by the aggregate) to that of cement in a mix, is the most important factor that controls the strength and many other properties of concrete. In practice, this ratio lies generally in the range of 0.35 to 0.65, although the purely chemical requirement (for the purpose of complete hydration of cement) is only about 0.25.

The compressive strength of concrete at a given age and under normal temperature, depends primarily on w/c ratio; lower the w/c ratio, greater is the compressive strength and vice versa. This was first enunciated by Abrams as $S = \frac{K_1}{K_2^{1/n} (w/c)^n}$ where S is the compressive strength, w/c is water -cement ratio of a fully compacted concrete mix, K 1 and K 2 are empirical constants.

In day- to-day practice, the constants K 1 and K2 are not evaluated, instead the relationship between compressive strength and w/c ratio are adopted which are supposed to be valid for a wide range of conditions. Effect of water -cement ratio on compressive strength at different ages. A reduction in the water cement ratio generally results in an increased quality of concrete in terms of strength, density, impermeability, reduced shrinkage and creep etc.

The probable reason, why lower w/c ratio gives higher strength of concrete may be found by considering the cement forms a paste with water and it is this paste that binds the different particles of aggregates. So thicker is the consistency of the paste, greater is its binding property. Another reason is that the quantity of water required for chemical combination is very small (about 25% of the weight of cement) compared with that required for workability and the excess water ultimately on evaporation leaves pores.

The greater is the excess of water, greater is loss of strength and water -tightness. The tensile strength and bond strength with steel do not decrease with increase in w/c ratio to the same extent as compressive strength does. Say with increase in w/c ratio from 0.5 to 0.6, the decrease in tensile strength and bond strength is 10% but decrease in compressive strength is about 25%.

Characteristics and properties of cement

The type of cement and fineness of cement affect the strength of concrete. With respect to Ordinary Portland cement (OPC), Rapid Hardening Portland Cement (RHPC) and Low Heat Portland Cement (LHPC) give higher and lower strength respectively. The rate of gain of strength depends entirely upon fineness of the cement. Finer cement increases the rate of hydration and hydrolysis which results in early development of strength though the ultimate strength is not affected.

Characteristics And Properties Of Aggregates

The strength of concrete is governed by

- strength of aggregate
- strength of mortar
- bond strength between mortar and aggregate

The strength of aggregate is normally greater than the strength of mortar and bond between mortar and aggregate. The strength of mortar depends upon w/c ratio whereas bond between mortar and aggregate depends upon the strength of mortar and the size, shape, texture and grading of aggregate. Larger maximum size of coarse aggregate gives lower compressive strength of concrete. The reasons behind may be stated as follows.

- The larger maximum size aggregate gives lower surface area for development of gel bond which is responsible for lower strength. Aggregates of smaller size, angular aggregate and aggregate of rough surface texture provides more surface area and more consumption of cement and hence more bond strength.
- Bigger aggregate size causes a more heterogeneity in the concrete and this prevents uniform distribution of load when stressed.
- For larger size aggregate the transition zone becomes much weaker due to development of

micro cracks which result in lower compressive strength.

The degree of compaction

Higher is the compaction of freshly mixed concrete, more is the reduction of the voids and consequently greater is the compressive strength of concrete.

The efficiency of curing

Curing is the name given to procedures used for promoting the hydration of cement, and consist of a control of temperature and of the moisture movement from and into the concrete. Hydration of cement takes place in capillaries filled with water.

By keeping concrete saturated, loss of water by evaporation from the capillaries is prevented and loss of water by self desiccation (due to the chemical reactions of hydration of cement) from outside.

Curing should be continued until the originally water filled space in the fresh cement paste has been filled by product of hydration to the desired extent. Curing temperature should be from 23° to 30°C (27°C average).

The curing must be adequate at favorable temperature for sufficient period which helps in attaining the maximum strength and other desirable properties. Age of Concrete The strength of concrete increases with age as the hydration of cement prolongs for a considerable time.

Conditions of Testing

After adequate curing, the concrete mould is tested in the moist saturated condition with surface wiped out under direct compression. The strength of concrete is influenced by moisture content at the time of testing, because moisture content in concrete provides lubrication effect and reduces the strength when compared with dry sample.

Strength in dry sample = 1.10 to 1.20 times the strength of the saturated sample.

Strength of Prism Vs 150 mm Strength

The characteristic strength of concrete (f_{ck}) is based on 150 mm cube but if it is tested on the prism mould, the strength of prism specimen decreases with increase in height to the side ratio and stabilizes when this ratio is 5.

Variation in Strength with Size of Cubes The characteristic strength of concrete is based on 150

mm cube but the strength of concrete determined through the cube specimen varies with the size of cubes.

The strength of specimen increases with decrease in size and vice -versa as indicated in the Cube (150 mm) Strength Vs Cylinder (150 mm dia, 300 mm ht) Strength. If the concrete is tested on cylinder having 150 mm diameter and height 300 mm instead of 150 mm cube, the cube strength can be estimated as Cylinder strength (f_{cu}) = 0.80 * cube strength (f_{ck})

TENSILE STRENGTH

- Tensile strength of concrete under direct tension is very small and generally neglected in normal design practice. Although the value ranges from 8 to 12% of its compressive strength. An average value 10% is the proper choice.
- The direct tension method suffers the problem like holding the specimen properly in the testing machine and the application of uniaxial tensile load not being free of eccentricity.
- The tensile strength can be calculated indirectly by loading a concrete cylinder to the compressive force along the two opposite ends (with its axis horizontal)
- Due to uniform tensile stress acting horizontally along the length of cylinder, the cylinder splits into two halves. The magnitude of this tensile stress (acting in a direction perpendicular to the line of action of applied compression) is given by

$S = \frac{2P}{\pi DL}$ where; S = Tensile stress in kg/cm² P = load causing rupture in kg

D = Dia in cm (15 cm)

L = Length in cm (30 cm)

- The indirect tensile stress is known as SPLITTING TENSILE STRENGTH.

FLEXURAL STRENGTH

The maximum tensile stress resisted by the plain concrete in flexure (bending) is called FLEXURAL STRENGTH (or MODULUS OF RUPTURE) expressed in N/mm² or kg/m².

- The most common plain concrete subjected to flexure is a highway/runway pavement. The

strength of pavement concrete is evaluated by means of bending test on beam specimen.

- The flexural strength (modulus of rupture) is determined by testing standard test specimens of 150 mm x 150 mm x 700 mm over a span of 600 mm or 100 mm x 100 mm x 500 mm over a span of 400 mm. under symmetrical two point loading

SHEAR STRENGTH

- Shear strength is the capacity of concrete to resist the sliding of the section over the adjacent section. A good amount of shear strength capacity is possessed by concrete depending upon the grade of concrete and percentage of tensile reinforcement in the section.
- It is difficult to obtain shear strength of concrete but I.S. code suggests the value for different grade of concrete.

BOND STRENGTH

- Bond strength is the shear stress at the interface of reinforcement bar and surrounding concrete developed to resist any force that tries slippage of the reinforcement to its surrounding concrete. It is determined by PULL OUT TEST . The av. bond strength is 10% of compressive strength of concrete The bond strength depends upon grade of concrete, higher the grade, higher is the value of bond strength.

5) Explain in detail about the determination of Compressive and Flexural strength of concrete.

Compression Test

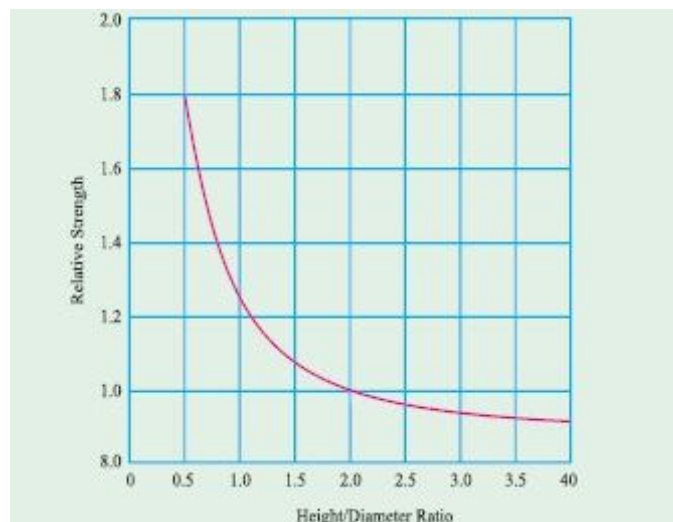
Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate

does not exceed 20 mm, 10 cm size cubes may also be used as an alternative. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.

Failure of Compression Specimen

Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson's ratio effect. The steel platens do not undergo lateral expansion to the same extent that of concrete, with the result that steel restrains the expansion tendency of concrete in the lateral direction. This induces a tangential force between the end surfaces of the concrete specimen and the adjacent steel platens of the testing machine. It has been found that the lateral strain in the steel platens is only 0.4 of the lateral strain in the concrete. Due to this the platen restrains the lateral expansion of the concrete in the parts of the specimen near its end. The degree of restraint exercised depends on the friction actually developed. When the friction is eliminated by applying grease, graphite or paraffin wax to the bearing surfaces the specimen exhibits a larger lateral expansion and eventually splits along its full length. With friction acting i.e., under normal conditions of test, the elements within the specimen are subjected to a shearing stress as well as compression. The magnitude of the shear stress decreases and the lateral expansion increases in distance from the platen. As a result of the restraint, in a specimen tested to destruction there is a relatively undamaged cone of height equal to $\sqrt{3/2} d$. But if the specimen is longer than about $1.7 d$, a part of it will be free from the restraining effect of the platen. Specimens whose length is less than $1.5 d$, show a considerably higher strength than those with a greater length.





Effect of the Height/Diameter Ratio on Strength :

Normally, height of the cylinder — h — is made twice the diameter — d —, but sometimes, particularly, when the core is cut from the road pavements or airfield pavements or foundations concrete, it is not possible to keep the height/diameter ratio of 2:1. The diameter of the core depends upon the cutting tool, and the height of the core will depend upon the thickness of the concrete member. If the cut length of the core is too long. It can be trimmed to h/d ratio of 2 before testing. But with too short a core, it is necessary to estimate the strength of the same concrete, as if it had been determined on a specimen with h/d ratio equal to 2.

High strength concrete is less affected than the low strength concrete. Figure shows the influence of h/d ratio on the strength of cylinder for different strength levels.

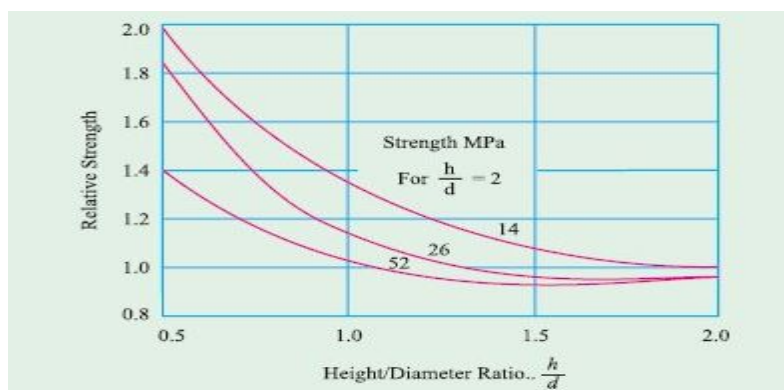


Figure shows the general pattern of influence of h/d ratio on the strength of cylinder. It is interesting to note that the restraining effect of the platens of the testing machine extends over the entire height of the cube but leaves unaffected a part of test cylinder because of greater height. It is, therefore, the strength of the cube made from identical concrete will be different from the strength of the cylinder. Normally strength of the cylinder is taken as 0.8 times the strength of the cube, but experiments have shown that there is no unique relationship between

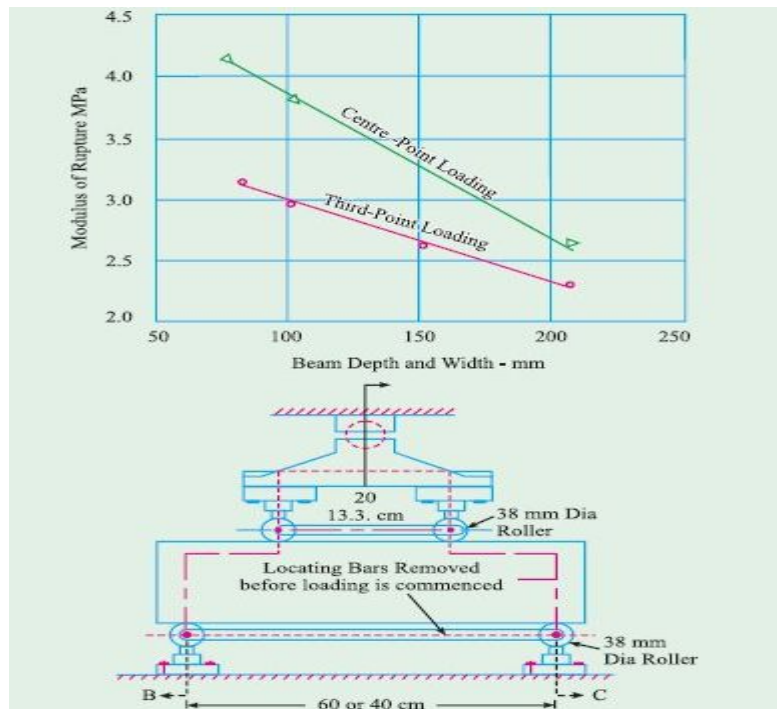
the strength of cube and strength of cylinder. It was seen that the strength relation varies with the level of the strength of concrete. For higher strength, the difference between the strength of cube and cylinder is becoming narrow. For 100 MPa concrete the ratio may become nearly 1.00.

The Flexural Strength of Concrete :

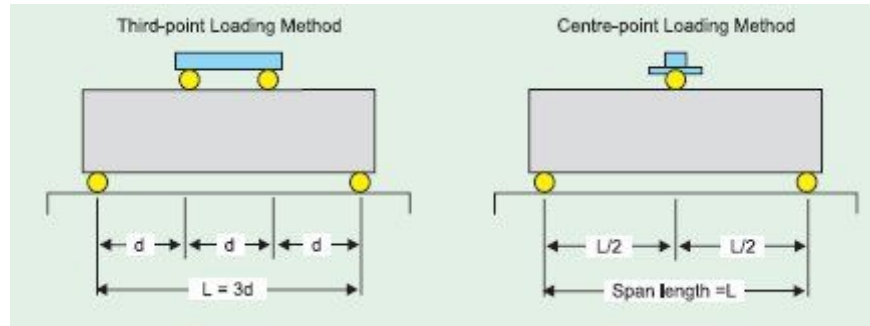
Concrete is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons.

Determination of Tensile Strength :

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied



to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete.



Procedure :

Test specimens are stored in water at a temperature of 24° to 30°C for 48 hours before testing. They are tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen should be noted before testing. No preparation of the surfaces is required.

Placing the Specimen in the Testing Machine :

The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 0.7 kg/sq cm/min that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure is noted.

The flexural strength of the specimen is expressed as the modulus of rupture f_b

which if a' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, is calculated to the nearest 0.05 MPa as follows:

$$f_b = \frac{P \times l}{b \times d^2}$$

When a' is greater than 20.0 cm for 15.0 cm specimen or greater than 13.3 cm for a 10.0 cm specimen, or

$$f_b = \frac{3p \times a}{b \times d^2}$$

when a' is less than 20.0 cm but greater than 17.0 cm for 15.0 specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen where

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure,

l = length in cm of the span on which the specimen was supported, and

p = maximum load in kg applied to the specimen.

If a' is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test be discarded.

As mentioned earlier, it is difficult to measure the tensile strength of concrete directly. Of late some methods have been used with the help of epoxy bonded end pieces to facilitate direct pulling. Attempts have also been made to find out direct tensile strength of concrete by making briquette of figure shape for direct pulling but this method was presenting some difficulty with grip and introduction of secondary stresses while being pulled. Whatever may be the methods adopted for finding out the ultimate direct tensile strength, it is almost impossible to apply truly axial load. There is always some eccentricity present. The stresses are changed due to eccentricity of loading.

These may introduce major error on the stresses developed regardless of specimen size and shape. The third problem is the stresses induced due to the grips. There is a tendency for the specimen to break near the ends. This problem is always overcome by reducing the section of

the central portion of the test specimen. The method in which steel plates are glued with the epoxies to the ends of test specimen, eliminates stresses due to gripping, but offers no solution for the eccentricity problem. All direct tension test methods require expensive universal testing machine.

5. Explain in detail about the determination of Young's Modulus and Stress-strain curve for concrete.

When reinforced concrete is designed by elastic theory it is assumed that a perfect bond exists between concrete and steel. The stress in steel is m times the stress in concrete where

m is the ratio between modulus of elasticity of steel and concrete, known as modular ratio.

The accuracy of design will naturally be dependent upon the value of the modulus of elasticity of concrete, because the modulus of elasticity of steel is more or less a definite quantity.

The modulus of elasticity is determined by subjecting a cube or cylinder specimen to uniaxial compression and measuring the deformations by means of dial gauges fixed between certain gauge length. Dial gauge reading divided by gauge length will give the strain and load applied divided by area of crosssection will give the stress. A series of readings are taken and the stress-strain relationship is established. The modulus of elasticity can also be determined by subjecting a concrete beam to bending and then using the formulae for deflection and substituting other parameters.

The modulus of elasticity so found out from actual loading is called static modulus of elasticity. It is seen that even under short term loading concrete does not behave as an elastic material.

However, up to about 10-15% of the ultimate strength of concrete, the stress-strain graph is not very much curved and hence can give more accurate value. For higher stresses the stress-strain relationship will be greatly curved and as such it will be inaccurate

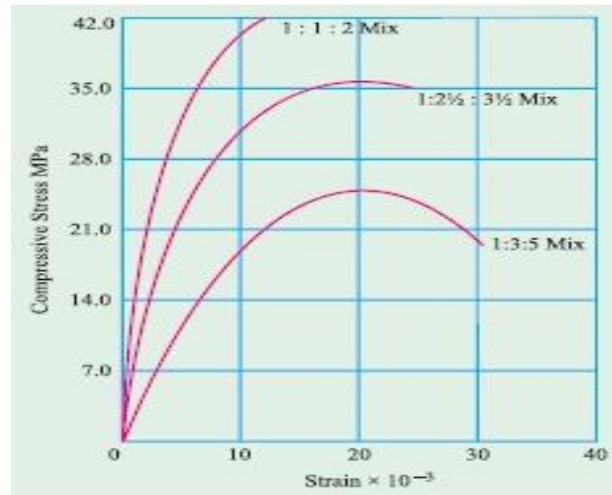
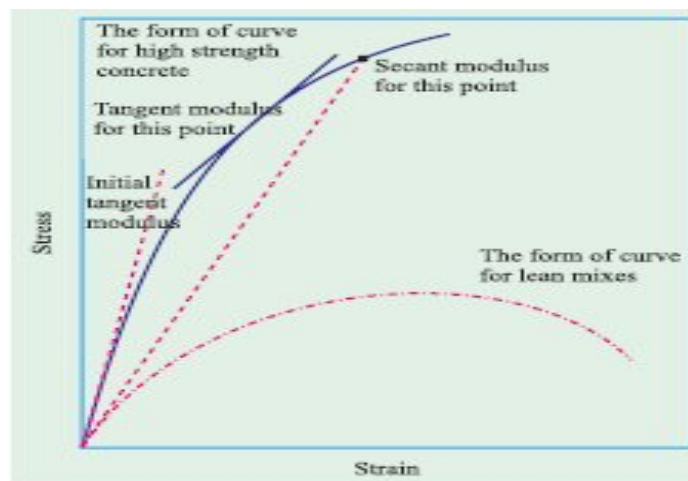


Figure shows stress strain relationship for various concrete mixes. In view of the peculiar and complex behaviour of stress-strain relationship, the modulus of elasticity of concrete is defined in somewhat arbitrary manner. The modulus of elasticity of concrete is designated in various ways and they have been illustrated on the stress-strain curve in Fig



The term Young's modulus of elasticity can strictly be applied only to the straight part of stress-strain curve. In the case of concrete, since no part of the graph is straight, the modulus of elasticity is found out with reference to the tangent drawn to the curve at the origin.

The modulus found from this tangent is referred as initial tangent modulus. This gives satisfactory results only at low stress value. For higher stress value it gives a misleading picture.

Tangent can also be drawn at any other point on the stress-strain curve. The modulus of elasticity calculated with reference to this tangent is then called tangent modulus. The tangent modulus also does not give a realistic value of modulus of elasticity for the stress level much above or much below the point at which the tangent is drawn. The value of modulus of elasticity will be satisfactory only for stress level in the vicinity of the point considered.

A line can be drawn connecting a specified point on the stress-strain curve to the origin of the curve. If the modulus of elasticity is calculated with reference to the slope of this line, the modulus of elasticity is referred as secant modulus. If the modulus of elasticity is found out with reference to the chord drawn between two specified points on the stress-strain curve then such value of the modulus of elasticity is known as chord modulus.

The modulus of elasticity most commonly used in practice is secant modulus. There is no standard method of determining the secant modulus. Sometime it is measured at stresses ranging from 3 to 14 MPa and sometime the secant is drawn to point representing a stress level of 15, 25, 33, or 50 per cent of ultimate strength. Since the value of secant modulus decreases with increase in stress, the stress at which the secant modulus has been found out should always be stated.

Modulus of elasticity may be measured in tension, compression or shear. The modulus in tension is usually equal to the modulus in compression. It is interesting to note that the stress-strain relationship of aggregate alone shows a fairly good straight line. Similarly, stress-strain relationship of cement paste alone also shows a fairly good straight line. But the stress-strain relationship of concrete which is combination of aggregate and paste together shows a curved relationship. Perhaps this is due to the development of micro cracks at the interface of the aggregate and paste. Because of the failure of bond at the interface increases at a faster rate than that of the applied stress, the stress-strain curve continues to bend faster than increase of stress. Figure shows the stress-strain relationship for cement paste, aggregate and concrete.