UNIT 4 TESTING OF HARDENED CONCRETE - I

Structure

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4.1 INTRODUCTION

You have studied about various tests conducted on ingredients of concrete and tests prescribed for admixtures. You are also aware of different tests for workability of concrete. In this Unit, you will study tests which are carried out on Hardened Concrete.

Testing of hardened concrete plays an important role in controlling and confirming the quality of concrete. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control programme for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability. The test methods should be simple, direct and convenient to apply.

One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. As the hardening of the concrete takes time, one will not come to know the actual strength of concrete for sometime. This is an inherent disadvantage in conventional tests. But when correct materials are used and careful steps are taken at every stage of the work, concretes normally give the required strength. The results of the test on hardened concrete, even if they are known late, help to reveal the quality of concrete and enable adjustments to be made in the production of further concreting. Tests are made by casting cubes or cylinders from the representative concrete or cores are cut from the actual concrete. The methods of tests for strength of concrete have been standardised and are laid down in IS:516-1959.

Objectives

After studying this unit, you should be able to:

- explain the importance of testing of hardened concrete,
- describe method of testing compressive strength of concrete,
- describe important precautions to be taken in preparation of cubes and their testing procedure,
- describe methods of determination of tensile strength of concrete, and
- describe limitations of testing methods.
4.2 COMPRESSION TEST

Compression test is carried out on specimens cubical or cylindrical in shape. Prism is also sometimes used, but it is not common in our country.

The cube specimen is of the size 15 cm × 15 cm × 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 to be maintained.

4.2.1 Moulds

Metal moulds, preferably steel or cast iron, stout enough to prevent distortion are required. They are made in such a manner as to facilitate the removal of the moulded specimen without damage and are so machined that, when it is assembled ready for use, the dimensions and internal faces are required to be accurate within the following limits.

The height of the mould and the distance between the opposite faces are of the specified size + 0.2 mm. The angle between adjacent internal faces and between internal faces and top and bottom planes of the mould is required to be 90° ± 0.5°. The interior faces of the mould, are plane surfaces with a permissible variation of 0.03 mm. Each mould is provided with a metal base plate having a plane surface. The base plate is of such dimensions as to support the mould during the filling without leakage and it is preferably attached to the mould by springs or screws. The parts of the mould, when assembled, are positively and rigidly held together, and suitable methods of ensuring this, both during the filling and on subsequent handling of the filled mould, are required to be provided.

In assembling the mould for use, the joints between the sections of the mould are thinly coated with mould oil and a similar coating of mould oil is applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould is also required to be thinly coated with mould oil to prevent adhesion of concrete.

The cylindrical mould is required to be of metal which shall be not less than 3 mm thick. Each mould is capable of being opened longitudinally to facilitate removal of the specimen and is provided with a means of keeping it closed while in use. Care should be taken so that the ends are not departed from a plane surface, perpendicular to the axis of the mould, by more than 0.05 mm. When assembled ready for use the mean internal diameter of the mould should be 15.0 cm ± 0.2 mm and in no direction the internal diameter be less than 14.95 cm or more than 15.05 cm. The height maintained is 30.0 cm ± 0.1 mm. Each mould is provided with a metal base plate, and with a capping plate of glass or other suitable material. The base plate and the capping plate are required to be at least 6.5 mm thick and such that they do not depart from a plane surface by more than 0.02 mm. The base plate supports the mould during filling without leakage and is rigidly attached to the mould. The mould and base plate are coated with a thin film, of mould oil before use, in order to prevent adhesion of concrete.

A steel bar 16 mm in diameter, 0.6 m long and bullet pointed at the lower end serves as a tamping bar.

4.2.2 Compacting

The test cube specimens are made as soon as practicable after mixing and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete is filled into the mould in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop is required to be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer is compacted either by hand or by vibration. After the top layer has been compacted, the surface of the concrete is brought to the finished level with the top of the mould, using a trowel. The top is covered with a glass or metal plate to prevent evaporation.

Compacting by Hand

When compacting by hand, the standard tamping bar is used and the strokes of the bar are distributed in a uniform manner over the cross-section of the mould. The number of strokes per layer required to produce the specified conditions vary according to the type of concrete. For cubical specimens, in no case should the concrete be subjected to less than
35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. For cylindrical specimens, the number of strokes are not less than thirty per layer. The strokes penetrate into the underlying layer and the bottom layer is rodded throughout its depth. Where voids are left by the tamping bar, the sides of the mould are tapped to close the voids.

Compacting by Vibration

When compacting by vibration, each layer is vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table until the specified condition is attained. The mode and quantum of vibration of the laboratory specimen shall be as nearly the same as those adopted in actual concreting operations.

4.2.3 Capping Specimens

Capping is applicable to cylindrical specimen. The ends of all cylindrical test specimens that are not plane within 0.05 mm are capped. The capped surfaces are not departed from a plane by more than 0.05 mm and shall be nearly at right angles to the axis of the specimens. The planeness of the cap is required to be checked by means of a straight edge and feeler gauge, making a minimum of three measurements on different diameters. Caps are made as thin as practicable and care should be taken so that flaw or fracture does not take place, when the specimen is tested. Capping can be done on completion of casting or a few hours prior to testing of specimen. Capping is required to be carried out according to one of the following methods:

Neat Cement

The test cylinders may be capped with a thin layer of stiff, neat portland cement paste after the concrete has set in the moulds. Capping is done after about 4 hours of casting so that concrete in the cylinder undergoes plastic shrinkage and subsides fully. The cap is formed by means of a glass plate not less than 6.5 mm in thickness or a machined metal plate not less than 13 mm in thickness and having a minimum surface dimension at least 25 mm larger than the diameter of the mould. It is worked on the cement paste until its lower surface rests on the top of the mould. The cement for capping is mixed to a stiff paste for about 2 to 4 hours before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of paste to the capping plate is avoided by coating the plate with a thin coat of oil or grease.

Cement Mortar

On completion of casting cylinder, a mortar is gauged using a cement similar to that used in the concrete and sand which passes IS Sieve 300 but is retained on IS Sieve 150. The mortar should have a water/cement ratio not higher than that of the concrete of which the specimen is made, and should be of a stiff consistency. If an excessively wet mix of concrete is being tested, any free water which has collected on the surface of the specimen should be removed with a sponge, blotting paper or other suitable absorbant material before the cap is formed. The mortar is then applied firmly and compacted with a trowel to a slightly convex surface above the edge of the mould, after which the capping plate is pressed down on the cap with a rotary motion until it makes complete contact with the rim of the mould. The plate should be left in position until the specimen is removed from the mould.

Sulphur

Just prior to testing, the cylindrical specimens are capped with a sulphur mixture consisting of 1 part of sulphur to 2 or 3 parts of inert filler, such as fire-clay. The specimens are securely held in a special jig so that the caps formed have a true plane surface. Care has to be taken to ensure that the sulphur compound is not over-heated as it will not then develop the required compressive strength. Sulphur caps are allowed to harden for at least 2 hours before applying the load.

Hard Plaster

Just prior to testing, specimens are capped with hard plaster having a compressive strength of at least 420 kg/sq cm in an hour. Such plasters are generally available as proprietary material. The caps can be formed by means of a glass plate not less than 13 mm in thickness, having a minimum surface dimension at least 25 mm larger than the diameter of the mould. The glass plate is lightly coated with oil to avoid sticking. Ordinary plaster of paris will not serve the purpose of capping material due to its low compressive strength.
4.2.4 Curing

The test specimens should be stored in a place free from vibration, in moist air of at least 90% relative humidity and at a temperature of $27^\circ\pm 2^\circ$C for 24 hours $\pm \frac{1}{2}$ hour from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds and unless required for test within 24 hours, immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to test. The water or solution in which the specimens are submerged, are renewed every seven days and are maintained at a temperature of $27^\circ\pm 2^\circ$C. The specimens are not to be allowed to become dry at any time until they have been tested.

4.2.5 Making and Curing Compression Test Specimen in the Field

The test specimens are stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours $\pm \frac{1}{2}$ hour from the time of addition of water to the other ingredients. The temperature of the place of storage should be within the range of 22°C to 32°C. After the period of 24 hours they should be marked for later identification, removed from the moulds and unless required for testing within 24 hours, stored in clean water at a temperature of 24°C to 30°C until they are transported to the testing laboratory. They should be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens are stored in water at a temperature of $27^\circ$C $\pm 2^\circ$C until the time of test. Records of the daily maximum and minimum temperature should be kept both during the period the specimens remain on the site and in the laboratory particularly in cold weather regions.

4.2.6 Failure of Compression Specimen

Compression test develops a rather more complex system of stresses. Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson's ratio effect.

![Figure 4.1: General Pattern of Influence of the Height/Diameter Ratio on the Apparent Strength of a Cylinder](image)

The steel platens do not undergo lateral expansion to the same extent as 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 is subject 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 $\frac{\sqrt{3}}{2} d$ (where, $d$ is the lateral dimension of the specimen). But, if the specimen is longer than about 1.7$d$, a part of it will be free from the restraining effect of the platens. Specimens whose length is less than 1.5$d$, show a considerably higher strength than those with a greater length (see Figure 4.1).

**4.2.7 Effect of 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.

Figure 4.2 shows the correction factor for height/diameter ratio of a core (IS 516-1959).

![Figure 4.2: Correction Factor for Height/Diameter Ratio of Core](image)

Murdock and Kesler found that correlation factor is not a constant one, but depends on the strength level of concrete. High strength concrete is less affected than the low strength concrete. Figure 4.3 shows the influence of $h/d$ ratio on the strength of cylinder for different strength levels.

![Figure 4.3: Influence of the Height/Diameter Ratio on the Apparent Strength of a Cylinder for Different Strength Level](image)

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. 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...
Tests for Concrete and Miscellaneous Materials

The strength relation varies with the level of the strength of concrete. Table 4.1 shows the strength pattern of cubes and cylinders.

Table 4.1: Strength of Cubes and Cylinders

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Compressive Strength kg/cm²</th>
<th>Ratio of Strengths (Cylinder/Cube)</th>
<th>Difference of Strength (cube-cylinder) kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cube</td>
<td>Cylinder</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>91</td>
<td>70</td>
<td>0.77</td>
</tr>
<tr>
<td>2</td>
<td>155</td>
<td>119</td>
<td>0.77</td>
</tr>
<tr>
<td>3</td>
<td>204</td>
<td>155</td>
<td>0.76</td>
</tr>
<tr>
<td>4</td>
<td>253</td>
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<td>0.81</td>
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<td>281</td>
<td>246</td>
<td>0.87</td>
</tr>
<tr>
<td>6</td>
<td>296</td>
<td>267</td>
<td>0.91</td>
</tr>
<tr>
<td>7</td>
<td>302</td>
<td>274</td>
<td>3.91</td>
</tr>
<tr>
<td>8</td>
<td>365</td>
<td>323</td>
<td>3.89</td>
</tr>
<tr>
<td>9</td>
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<td>352</td>
<td>0.94</td>
</tr>
<tr>
<td>10</td>
<td>429</td>
<td>372</td>
<td>0.87</td>
</tr>
<tr>
<td>11</td>
<td>450</td>
<td>415</td>
<td>0.92</td>
</tr>
<tr>
<td>12</td>
<td>482</td>
<td>450</td>
<td>0.91</td>
</tr>
<tr>
<td>13</td>
<td>535</td>
<td>513</td>
<td>0.96</td>
</tr>
</tbody>
</table>

4.2.8 Comparison between Cube and Cylinder Strength

It is difficult to say whether cube test gives more realistic strength properties of concrete or cylinder gives a better picture about the strength of concrete. However, it can be said that the cylinder is less affected by the end restraints caused by platens and hence it seems to give more uniform results than cube. Therefore, the use of cylinder is becoming more popular, particularly in the research laboratories.

Cylinders are cast and tested in the same position, whereas cubes are cast in one direction and tested from the other direction. In actual structures in the field, the casting and loading is similar to that of the cylinder and not like the cube. As such, cylinder simulates the condition of the actual structural member in the field in respect of direction of load.

The points in favour of the cube specimen are that the shape of the cube resembles the shape of the structural members often met with on the ground. The cube does not require capping whereas cylinder requires capping. The capping material used in case of cylinder may influence to some extent the strength of the cylinder.

SAQ 1

Why do cube specimen indicate more strength in comparison to cylindrical specimen? Explain.

4.3 The Flexural Strength of Concrete

Concrete as we know 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. Therefore, the knowledge of tensile strength of concrete is of importance.

A concrete road slab has to resist tensile stresses from two principal sources—wheel loads and volume change in the concrete. Wheel loads may cause high tensile stresses due to bending, when there is inadequate subgrade support. Volume changes, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the subgrade.

Stresses due to volume changes along may be high. The longitudinal tensile stress in the bottom of the pavement, caused by restraint and temperature warping, frequently amounts to as much as 25 kg/sq cm at certain periods of the year and the corresponding stress in the transverse direction is approximately 9 kg/sq cm. These stresses are additive to those produced by wheel loads on unsupported portions of the slab.

4.3.1 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.

The value of the modulus of rupture (extreme fibre stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central-point loading and third-point loading. In the central-point loading, maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two-point loading, the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum. It can be expected that the two-point loading will yield a lower value of the modulus of rupture than the centre-point loading. Figure 4.4 shows the modulus of rupture of beams of different sizes subjected to centre-point and third-point loading. I.S. : 516-1959, specifies two-point loading. The details of the specimen and procedure are now described.

Specimen

The standard size of the specimens are 15 cm x 15 cm x 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 20 mm, specimens 10 cm x 10 cm x 50 cm may be used.

Mould

The mould should be of metal, preferably steel or cast iron and the metal should be of sufficient thickness to prevent spreading or warping. The mould should be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimens without damage.

![Figure 4.4: Modulus of Rupture of Beams of Different Sizes Subjected to Centre-point and Third-point Loading](image)
The tamping bar should be a steel bar weighing 2 kg, 40 cm long and should have a ramming face 25 mm square.

**Testing Machine**

The Testing Machine may be of any reliable type of sufficient capacity for the tests and capable for applying the load at the rate specified. The permissible errors should not be greater than ±0.5 per cent of the applied load where a high degree of accuracy is required and not greater than ±1.5 per cent of the applied load for commercial type of use. The bed of the testing machine should be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported and these rollers should be so mounted that the distance from centre to centre is 60 mm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load is applied through two similar rollers mounted at the third points of the supporting span, that is, spaced at 20 cm or 13.3 cm centre to centre. The load is divided equally between the two loading rollers, and all rollers are mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints. The loading set up is shown in Figure 4.5.

![Diagram of Testing Machine](image)

**Figure 4.5 : Arrangement for Loading of Flexural Test Specimen**

**a) Procedure**

Test specimens are stored in water at a temperature of 24°C 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.

**b) 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 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 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 0.5 kg/sq cm 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

$$f_b = \frac{3p \times a}{b \times d^2}$$
Testing of Hardened Concrete

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

where,

\[ b = \text{measured width in cm of the specimen}, \]
\[ d = \text{measured depth in cm of the specimen at the point of failure}, \]
\[ l = \text{length in cm of the span on which the specimen was supported, and} \]
\[ p = \text{maximum load in kg applied to the specimen}. \]

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.

Direct Tensile Strength

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 eight (8) shape for direct pulling but this method was presenting some difficulty with the 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 a most 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.

Another problem is the stresses induced due to the grips. There is a tendency for the specimen to break near the ends. This problems 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. This explains why these tests are not used on a routine basis and are not yet standardised.

4.3.2 Indirect Tension Test Methods

Cylinder Splitting Tension Test

This is also sometimes referred as, “Brazilian Test”. This test was developed in Brazil in 1943. At about the same time this was also independently developed in Japan.

The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. Figure 4.6 shows the test specimen and the stress pattern in the cylinder respectively.

\[
\frac{2p}{\pi LD} \left[ \frac{D^2}{r(D-r)} - 1 \right]
\]

Figure 4.6 : Splitting Test – Distribution of Horizontal Stress in a Cylinder Loaded over a Width Equal to 1/12 of the Diameter

When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of
and a horizontal stress of
\[ \frac{2p}{\pi LD} \]

where,
- \( P \) = compressive load on the cylinder,
- \( L \) = length of cylinder,
- \( D \) = diameter, and
- \( r \) and \((D - r)\) = the distance of the elements from the two loads respectively.

The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension.

In order to reduce the magnitude of the high compression stresses near the points of application of the load, narrow packing strips of suitable material such as plywood are placed between the specimen and loading platens of the testing machine. The packing strips should be soft enough to allow distribution of load over a reasonable area, yet narrow and thin enough to prevent large contact area. Normally, a plywood strip of 25 mm wide, 3 mm thick and 30 cm long is used.

The main advantage of this method is that the same type of specimen and the same testing machine as are used for the compression test can be employed for this test. That is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete than the modulus of rupture. Splitting strength gives about 5 to 12% higher value than the direct tensile strength.

**4.3.3 Ring Tension Test**

Another test for finding out the tensile strength of concrete is known as "Ring Tension Test". Briefly, in this method, a hydrostatic pressure is applied radially against the inside periphery of 15 cm diameter, 4 mm thick and 4 mm high concrete ring specimen. The resulting tensile stress developed in the specimen are determined from the equations of the stress analysis of thick walled cylinders, as given below:

\[ f_t = \frac{P_i r_i^2}{r_0^2 - r_i^2} \left( 1 - \frac{r_0^2}{r^2} \right) \]

where, \( f_t \) = Tensile strength,
- \( P_i \) = Applied hydrostatic pressure,
- \( r_i \) = Internal radius,
- \( r_0 \) = External radius, and
- \( r \) = Radius at point of failure.

**Advantages of Ring Tension Test**

The nature of the load application in this test is such that no clamping and misalignment stresses are introduced in the test specimen, a condition difficult to avoid in direct tests.

The entire volume of the ring is subjected to tensile stresses with the uniformly distributed maximum stress occurring along the entire periphery of the ring. This is never achieved in the flexural tests and even in the cylinder splitting test, a compressive load acting on a diametral plane creates a uniform tensile stress over that plane only.

The magnitude of the radial compressive stress is quite small when compared with the tangential stress. This is a definite advantage over the splitting tension test in which the minimum compressive stresses occurring at the centre line of the splitting plane is about three times the corresponding tensile stress.

**Limitations of Ring Tension Test**

The drawbacks of this test are that here also, the derivation of equations used for the stress analysis is based upon Hooke's Law of linear stress-strain proportionality. The ring tensile...
strengths obtained appear to be somewhat higher than the true tensile strength of concrete, the magnitude of the exact difference has yet to be firmly established.

4.3.4 Double Punch Test

Yet another test to find out the indirect tensile strength of concrete is known as “Double Punch Test”. In this test, a concrete cylinder is placed vertically between the loading plates of the compression test machine and compressed by the steel punches located concentrically on the top and bottom surfaces of the cylinder.

An ideal failure mechanism will consist of many simple tension cracks in radial direction and two cone shaped rupture surfaces directly under the loads. Two cone shapes move towards each other as a rigid body and displace the surrounding material horizontally sideways. The formula for calculating the tensile strength has been calculated on the basis of limit analysis. The reaction is:

\[ f_i = \frac{Q}{(1.20 b H - a^2)} \]

where,

\[ a = \text{radius of punch} \]
\[ b = \text{radius of cylinder} \]
\[ H = \text{height of the cylinder} \]
\[ Q = \text{load at failure} \]

4.4 FACTORS INFLUENCING TEST STRENGTH

It has been seen already that shape and size of specimen affect the strength results. If the strength of the 15 cm size cube is taken as standard, then the strength of 10 cm size cube should be reduced by 10%. Strength of the cylinder of size 15 cm diameter and 30 cm long is taken as 0.8 of the strength of 15 cm cube. Where cubes larger than 15 cm are adopted, generally no modification to the strength is necessary unless otherwise specified.

The planeness of the end condition of specimen and capping material used for the cylinder affects the strength. The employment of lubricating material at the bearing surface of the sample affect the strength of concrete.

The effect of height to diameter ratio has already been discussed.

The rate of application of load has a considerable affect on the apparent strength of concrete: the lower the rate of application of load, the lower will be the recorded strength. The reason for this is probably the effect of creep. If the load is applied slowly, or in the application of load, if there is some time-lag, the specimen will undergo certain amount of creep which will increase the strain. The enhanced strain due to creep will be responsible for failure of the sample, at a lower value of stress applied. Figure 4.7 shows the influence of rate of application of load on the compressive strength of concrete.

![Figure 4.7: Influence of the Rate of Application of Load on the Compressive Strength of Concrete](image)

The state of moisture content of the specimen influences the observed strength to a great extent. If two cubes made from identical concrete, one wet and another dry, are tested at
the same age, the dry cube gives higher strength than the wet cube. It is quite probable that the dry cube may have undergone drying shrinkage which will have ultimately caused some amount of drying shrinkage cracks and bond failures. From this simple reason it must give an impression that dry cube must give a lower value, but on the contrary the result is the other way. The probable explanation is that due to wetting, some sort of dilation of cement gel will take place by the adsorbed water. The forces of cohesion of the solid particles are then decreased. Perhaps the decrease of strength on account of reduction of cohesion owing to the adsorbed water may be more than that of the loss of strength due to rupture of gel bonds on account of drying shrinkage.

To have a standard condition for test specimens, it is usual to test a specimen immediately on removal from the curing water tank. This condition has the advantage of being better reproducible than a dry condition which includes greatly varying degrees of dryness.

It was earlier pointed out that contrary to expectations, the wet concrete exhibits higher modulus of elasticity. Strength and modulus of elasticity do not go hand in hand in the case of wet concrete.

**SAQ 2**

How would you determine tensile strength? Write factors affecting tensile strength

4.5 **TEST CORES**

The test specimen, cube or cylinder, is made from the representative sample of concrete used for a particular member the strength of which we are interested. As the member cannot be in fact tested, we test the parallel concrete by making cubes or cylinders. It is to be understood that the strength of the cube specimen cannot be same as that of the member because of the differences with respect to the degree of compaction, curing standard, uniformity of concrete, evaporation, loss of mixing water etc. At best the result of cube or cylinder can give only a rough estimate of the real strength of the member.

To arrive at a better picture of the strength of the actual member, attempts are made to cut the cores from the parent concrete and test the cores for strength. Perhaps this will give a better picture about the strength of actual concrete in the member. The disadvantages are that while cutting the core, the structural integrity of the concrete across the full cross-section may be affected to some extent and secondly that the diameter to height ratio may be other than that of the standard cylinder. Capping of both ends will be required which will again introduce some differences in the strength. Existence of reinforcement will also present difficulty in cutting a clean core.

The cores cut to determine the strength of concrete of the actual structure may also be used to find out segregation and honeycombing of concrete. In some cases, the beam specimens are also sawn from the road and airfield slabs for finding flexural strength. In practice, it is seen that the strength of the core is found to be less than that of the strength of standard cylinders. Apart from other reasons, it is also because site curing is invariably inferior to curing under standard moist condition.

**Activity**

American Concrete Institute, Maharashtra Chapter, conducts an Annual Concrete Cube Testing Competition. You are advised to participate in this competition. For more details write to Indian Concrete Institute, Ocean Crest, 35, 3rd Main Road, Gandhi Nagar, Adyar, Chennai-600 020.
4.6 SUMMARY

There are a number of reasons for carrying out tests on hardened concrete. Some of them are:

a) Tests can help ensure that the concrete was batched properly.
b) They can indicate the statistical variability in the properties of concrete being manufactured.
c) They may give warning about inadvertent changes in quantity and quality of materials and environmental changes.
d) They ensure better supervision.
e) They help in pin-pointing the problem.

The strength, durability and other mechanical properties of concrete should not be considered as fundamental or intrinsic material properties. They are affected by variables like specimen’s geometry, preparation, moisture content, temperature, loading rate and type of testing machine. It is, therefore, necessary that when any mechanical property like compressive strength is to be defined then it is also necessary to specify the test methods. These test methods in Indian context are laid down in IS : 516-1959 and have been described and discussed in this Unit.

4.7 KEY WORDS

Capping : Application of neat cement or cement mortar or sulphur or hard plaster on cylindrical specimen to provide plane surface for testing.

Batching : Proportioning of different constituents of concrete.

Specimen : Sample for testing.

Mould : Container for casting of specimen cubical or cylindrical.

4.8 ANSWERS TO SAQs

Refer preceding text for answers.