CONCRETE TECHNOLOGY

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TESTING OF HARDENED CONCRETE

COMPRESSION TESTS

Compression test is the most common test conducted on hardened concrete partly because it is an easy test to perform and is also extensively used as an index of the other concrete properties and of the quality of the concrete.

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection.

Compression test is carried out on specimens cubical or cylindrical in shape.

MOULDS :- Metal moulds, preferably of steel or cast iron, thick enough to prevent distortion are required. The height of the mould and the distance between the opposite faces are of the specified size ±0.2 mm. The angle between the 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.
In assembling the mould 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 surface of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. A steel bar 16mm in diameter 0.6m long and bullet pointed at the lower end serves as a tamping bar.

COMPACTING :- The test cube specimens are made as soon as practicable after mixing and full compaction of concrete without segregation and excessive laitance. The concrete is filled into the mould in the mould in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop is 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 finished in 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 an 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 subject to less than 35 strokes per layer for 15 cm or 25 strokes per layer for 10 cm cubes. For cylindrical specimens in no case should the concrete be subject to less than 35 strokes per layer.

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 operation. care must be taken while compacting high slump concrete.

TENSION TESTS

Tensile strength is determined indirectly by breaking beams of plain concrete in flexure or by splitting specimens by applying line loads.

Flexural Test Specimen

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The bearing surfaces of the supporting and loading rollers are wiped clean; 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. 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 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 in MPa.

$$f_b = \frac{Pl}{bd^2}$$

For centre point loading,

$$F_b = \frac{3Pl}{2bd^2}$$

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d = depth measured in mm of the specimen.
l = distance between the axes of supporting rollers, mm
P = maximum breaking load in N
f_b = flexural strength, MPa.

CYLINDER SPLITTING TENSION TEST

This is sometimes referred as "Brazilian Test".
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.

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

$$\frac{2P}{\pi L D}\left[\frac{D^2}{r(D-r)} - 1\right]$$

and a horizontal stress of

$$f_b = \frac{2P}{\pi L D}$$

P = compressive load at failure, N.
l = length of the cylinder, mm.
D = Diameter
f_b = Tensile strength of concrete, MPa
r and (D-r) are the distances 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.

RING TENSION TEST

A hydrostatic pressure is applied radially against the inside periphery of 15cm diameter 4cm thick and 4mm 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 follows:-

$$f_b = \frac{P_i - r_i^2}{r_o^2 - r_i^2}\left(1 - \frac{r_o^2}{r^2}\right)$$

corresponding tensile stress.

DOUBLE PUNCH TEST

In this test a concrete cylinder is placed vertically between the loading plates of the compression test machine and compressed by steel punches located concentrically on the top and bottom surfaces of the cylinder.

$$f_t = \frac{Q}{(1.20bH - a^2)}$$

where
a = radius of Punch.
b = radius of cylinder.
H = height of cylinder.
Q = load at failure.

PULL OUT TEST

A pull-out test measures the force required to pull out from the concrete a specially shaped rod whose enlarged end has been cast into that concrete. The stronger the concrete the more is the force required to pull out. The ideal way to use pullout test in the field would be to incorporate pre-planned assemblies in the structure. These standard specimens could then be pulled at any point of time. The force required denotes the strength of the concrete.

where, f_t = Tensile strength.
P_i = Applied hydrostatic pressure
r_i = Internal radius.
r_o = External radius.
r = Radius at point of failure.

Advantages of Ring Tension Test.

① 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.

② 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.

③ 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

MODULUS OF ELASTICITY

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. Modulus of elasticity may be measured in tension, compression or shear. The modulus in tension is usually equal to modulus in compression.

The major factors affecting the modulus of elasticity are the strength of the paste phase, the stiffness of the embedded aggregate and the nature of the interstitial zone (ITZ) between aggregate and phase.

DYNAMIC MODULUS OF ELASTICITY

In dynamic tests the applied loads are very small and the rates of application and release of the loads are rapid, the effects of creep are therefore negligible.

The modulus of elasticity can be determined by subjecting the concrete member to longitudinal vibration at their natural frequency. This method involves the determination of either resonant frequency through a specimen of concrete or pulse velocity travelling through the concrete.

$$E_d = kn^2L^2\rho$$

E_d = Dynamic modulus of elasticity.
k = constant.
n = Resonant Frequency.
L = Measured in millimetres.
ρ in kg/m^3

$$E_d = 4n \times 10^{-15} n^2 L^2 \rho \text{ GPa}$$

The value of E found out in this method by the velocity of sound or frequency of sound is referred as dynamic modulus of elasticity.

POISSON'S RATIO

Poisson's ratio is the ratio between lateral strain to the longitudinal strain, where strains are caused by uniaxial stresses only. It is denoted by μ. For normal concrete poisson's ratio lies between 0.15 to 0.20.

Poisson's ratio can also be determined from ultrasonic pulse velocity method

$$\left(\frac{V^2}{2nL}\right)^2 = \frac{1-\mu}{(1+\mu)(1-2\mu)}$$

V = Pulse velocity (mm/s)

CREEP

Creep may be defined as time dependent increase in strain of a solid body under constant or controlled stress. The gradual increase in strain, without increase in stress with the time is due to creep.

Creep can also be defined as the increase in strain under sustained stress.

- Factors influencing Creep:

① Influence of Aggregate → Aggregate undergo very little creep. It is really the paste which is responsible for the creep. The aggregate influences the creep of concrete through a restraining effect on the magnitude of creep. The paste which is creeping under load is restrained by aggregates which do not creep. The stronger the aggregate the more is the restraining effect and hence the less is the magnitude of creep.

② Influence of mix proportions → The amount of paste content and its quality is one of the most important factors influencing creep. A poorer paste structure undergoes higher creep. Creep increases with increase in water/cement ratio. Creep is inversely proportional to the strength of concrete.

③ Influence of age at loading → Age at which a concrete members is loaded will have a predominant effect on the magnitude of creep. strength of concrete increases with age provided adequate curing is done, therefore concentrates loaded at later ages will creep less.

Relation between Creep and Time

$$c = \frac{t}{a+bt}$$

a and b are constants
t = time
c = Specific creep.

Effects of the Creep

Creep has both benefitial and detrimental effect on concrete structures. The beneficial effects are the relief of tensile stresses induced by shrinkage or thermal strains. The detrimental effects are on serviceability of structures and substanstive loss of Prestress may occur in prestressed concrete.

SHRINKAGE

The term shrinkage is loosely used to describe the various aspects of volume changes in concrete due to loss of moisture at different stages due to different season.

TYPES OF SHRINKAGE

shrinkage is classified in 5 types.

(i) Plastic shrinkage.
(ii) Drying shrinkage.
(iii) Autogenous shrinkage.
(iv) Carbonation shrinkage.
(v) Thermal shrinkage.