RPSC 2024

Rajasthan Public Service Commission

Assistant Engineer

CIVIL ENGINEERING

Design of Reinforced Concrete and Masonry Structures

CONTENTS

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1 INTRODUCTION

BASIC COMPOSITION OF CONCRETE

- Concrete basically consists of water, cement and aggregate.
- Aggregate is characterised as coarse aggregate (size > 4.75 mm ϕ, where ϕ is square opening of 4.75 mm × 4.75 mm) and fine aggregate (size < 4.75 mm ϕ).
- The ratio of fine to coarse aggregate is generally 1: 2 and it generally depends upon the fineness of sand.
- Sands are classified in 4 zones. They are zone-1 (coarse), zone-2 (medium), zone-3 (fine), zone-4 (very fine).
- The ratio of fine to coarse aggregate for finer sands is less than 1 : 2, for medium sands is equal to 1 : 2 and for coarse sands is greater than 1 : 2.

STRENGTH AND DURABILITY OF CONCRETE

- These two important properties depend on water/cement ratio. W/C = 0.4 – 0.6 (by wt.) for majority of structural concrete. Under moderate conditions of exposure, concrete with W/C = 0.5, durability is very low.
- In general there are five categories of exposure conditions viz. mild, moderate, severe, very severe and extreme. For these conditions of exposure minimum cement content (kg/m^3), maximum free water-cement ratio, maximum grade of concrete are specified both for plain and reinforced concrete (Refer IS : 456 – 2000, page 18 and 20).

STRENGTH OF CONCRETE

(a) Compressive Strength of Concrete

- It is considered as a measure of the quality of concrete, because its other desired qualities-permeability, durability etc. depend on its compressive strength.
- Standard size of the cube = 150 mm.

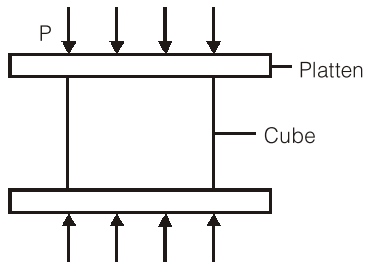


Figure 1

- Strength obtained is greater for smaller specimen. Maximum size of aggregate must not exceed one fourth of the size of the cube. Maximum size of aggregate generally used is 20 mm.
- Rate of loading specified is 14 N/mm^2 per min. This strength is known as cube strength,

$$f_{cu} = P/A \text{ N/mm}^2$$

- American practice is to test a cylinder instead of a cube. Standard size of cylinder is 150 mm dia × 300 mm high. Cylinder strength of concrete,

$$f_c' = P'/A' \text{ N/mm}^2.$$

- For the same concrete cylinder strength of concrete is less than cube strength [$f_c' \approx 0.75$ to $0.85\ f_{cu}$].

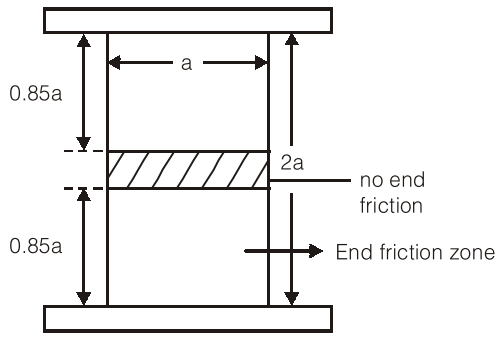


Figure 2 Cylinder

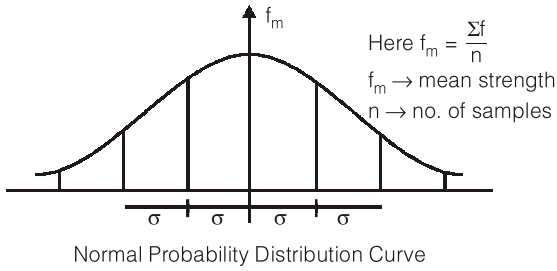
- End friction restrains the specimen from failure. In case of cube, the end friction acts on the whole length, but in case of cylinder, since the height is taken twice, end friction works only upto 0.85 a from each end, so its compressive strength is lower.
- Cylinder strength is the true compressive strength.
- Before, testing the cylinder, its top surface needs to be smoothened and the required plainness should be 0.05 mm (which is equal to that of plates).
- In case of a cylinder we put a cap of 1.5-3 mm and it should be as strong as the cylinder.
- Strength is reported to the nearest of 0.5 N/mm^2.
- One sample consists of 3 specimens. Average of the strengths of the specimens is the strength of the sample.

(b) Variations in Strength

- If we test samples of same concrete, they will have different strengths due to the fact that no material is perfectly homogeneous.
- Now accordingly we draw a histogram of strength vs frequency density where, frequency density

$$= \frac{\text{Number of samples in an interval}}{\text{Total number of samples}}$$

- If the number of samples are very large and the strength interval is reduced then this histogram changes into a curve known as probability distribution curve.



Normal Probability Distribution Curve

Figure 3

- For most engineering materials this curve is symmetrical about the mean and this type of curve is known as normal probability distribution curve.
- In the above diagram $\sigma = \sqrt{\frac{\Sigma(f - f_m)^2}{n}}$ where $n < 30$, σ is standard deviation.
- Spread of the curve depends upon σ. So σ is an index of the degree of quality control at site (for better control σ should be smaller).

(c) Guidelines for Concrete Mix Design

- Degree of control for concrete
  - Very Good
  - Good (Batching by wt.)
  - Fair (Batching by volume)
- At ordinary sites, batching is done by volume. When batching is done by volume, degree of control is fair only.
- Nominal mix – 1 : 2 : 4 : : cement: fine aggregate : Coarse aggregate
- Volume of measuring box is equal to the volume of one bag of cement.
- Volume of one bag of cement = 34.5 litres
- Volume = 30 cm × 30 cm × 38 cm
- Nominal mix = 1 : 1½ : 3
- For measuring this half bag we have another box of the dimension (15 × 15 × 19) cm^3.

(d) Equation of Normal Distribution Curve

- Taking mean as origin $Z = \left(\frac{f - f_m}{\sigma}\right)$ then equation of the normal probability distribution curve

$$y = \frac{1}{\sqrt{2\pi}} e^{-(Z^2/2)}$$

y = probability density

- Area between any two x-ordinates gives the probability of strength falling in that range, i.e. probability density.
- Total area under the curve = 1.

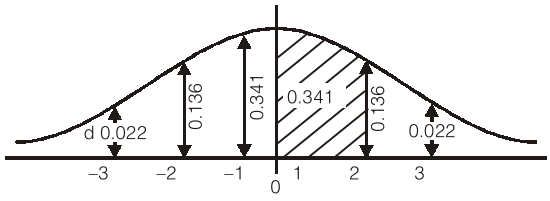


Fig. 4. Probability distribution curve

- Probability of strength falling below for $-\sigma$
  $= 1 - (0.5 + 0.341)$
  $= 0.159 = 15.9\%$
- In the same way probability of strength falling below $f_m - 3\sigma$
  $= 1 - (0.5 - 0.341 - 0.136 - 0.022) = 0.001$
  $= 0.1\%$
- Area under the curve to the left of any ordinate gives the probability of strength below which the test results are likely to fall.
- If we want to know the strength below which 5% of the test results are likely to fall then:
  $0.05 = 1 - (0.5 -) \Rightarrow x = 0.45$

$\Rightarrow x$ lies between $f_m - \sigma$ and $f_m - 2\sigma$.

It comes out to be $f_m - 1.65\sigma$

This is nothing but f_{ck}.

(e) Characteristic Strength

- It is the strength below which not more than 5% of the test results are expected to fail.

$$f_{ck} = f_m - 1.65\sigma$$

where $$f_m = \frac{\Sigma f}{n}$$

and $$\sigma = \sqrt{\frac{\Sigma(f - f_m)^2}{n}}$$

- These values are acceptable for $n \geq 30$, other wise error will be too large.

  If $n < 30$, then

$$\sigma = \sqrt{\frac{\Sigma(f - f_m)^2}{n-1}}$$

- Concrete is designated by f_{ck} where f_{ck} is characteristic cube strength of concrete at 28 days.
- Cement hydrates slowly over a long period so concrete gains its strength over a long time.
- Hydration of cement takes place only when the capillaries are saturated with water.
- Strength of concrete after 28 days = 1.0 f_{ck}
- Strength of concrete after 6 months = 1.2 f_{ck}

Age	*7 days*	*28 days*	*6 months*
Rel. strength	0.70	1.0	1.2

(f) Grades of Concrete

1. As per IS: 456-2000

(a) Nominal Mix Concrete
M 5, M 10, M 15, M 20.

(b) Plain Concrete
M 15, M 20, M 25.

(c) Reinforced Concrete
M 20, M 25, M 30, M 35, M 40.

2. Other Categorisation

(a) Ordinary Concrete
M 10, M 15, M 20.

(b) Standard Concrete
M 25, M 30, M 35, M 40, M 45, M 50, M 55.

(c) High strength concrete
M 60, M 65, M 70, M 75, M 80

(g) Compressive Strength of Concrete in a Structure

- The strength was found to decrease with increase in size of specimen reason being there is a great probability of presence of a weak element in large volume of concrete. Practically there is no decrease in strength with size of specimen greater than 450 mm.
  Strength of 450 mm cube = 0.85 times the strength of 150 mm cube.