INTRODUCTIONON

Basic Code for Design:

IS 456: 2000 - Plain and reinforced concrete - code of practice (IVth revision)

IS 875 (Part I - 5): 1987 : Code of practice for design loads (other than earthquake) for buildings and structures (2nd revision)

Part 1 : Dead loads

Part 2 : Imposed (lives) loads

Part 3 : Wind loads

Part 4 : Snow loads

Part 5 : Special loads and load combinations

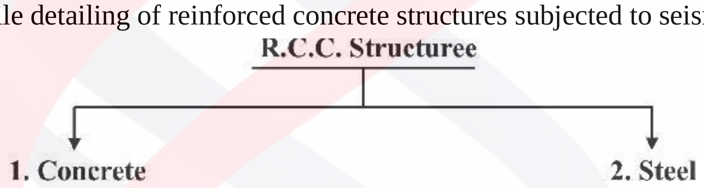
IS1893 : 2002 - Criteria for earthquake resistant design of structures (4th revision)

SP 16 : 1980 - Design aids(for reinforced concrete) to IS 456 : 1978

SP 34 : 1987 - Handbook on concrete reinforcement and detailing

SP 23 : 1982 - Design of concrete mixes

IS 13920 : 1993 - Ductile detailing of reinforced concrete structures subjected to seismic forces.



1. **Concrete :**
   - Mixture of cement, sand (fine aggregate), coarse aggregate and water.

   Main characteristics of concrete:
   - Durability under hostile environment.
   - Can be mound into variety of shapes
   - Relative economy and easy availability
   - Compression bearing capacity
   - Shows versatility
2. **Cement:**Various types of cement and tests on cements are dealt in detail in "**Building materials**"
   - **Aggregate :** Fine aggregate <4.75 mm. ; e.g. sand
     Coarse aggregate > 4.75 mm. ; e.g - Gravel and crushed rock
   - Generally, a maximum nominal size of 20mm is found to be satisfactory in RC structure elements.

(i) <u>Exposure conditions of concrete:</u>

Table: Exposure conditions and requirements for RC work with normal aggregate (20 mm nominal size)

Exposure e Category	Description	Min. grade	Min. cover (mm)
Mild	Protected against weather or aggressive conditions, except if located in coastal area	M 20	20*
Moderate	Sheltered from severe rain or freezing whilst wet, or Exposed to condensation and rain, or Continuously under water, or In contact with or buried under non-aggressive soil or ground water, or Sheltered from saturated 'salt air' in coastal area	M 25	30
Severe	Exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation, or Completely immersed in sea water, or Exposed to coastal environment	M 30	45**
Very Severe	Exposed to sea water spray, corrosive fumes or severe freezing whilst wet, or In contact with or buried under aggressive sub-soil or ground water	M 35	50
Extreme	Members in tidal zone, or Members in direct contact with liquid/solid aggressive chemicals	M 40	75

1. **Compressive Strength of CConcrete:**
   - Compressive strength off c concrete is measured by standard tests on concreet te cube or cylinder specimen.
   - The grade of concrete iss de designated in terms of M10, M15, M20, M25, ettcc., where 'M' denotes 'mix' and 10, 15, 20, 25 etc. de. denotes the characteristic compressive strength **ORR** characteristic strength of the mix at 28 days expreesssed in N/mm^2.
   - **Characteristic strengthh** is defined as the strength of material below whi icch not more than 5% of the test results are expected d tto fall.

2. ***g.,*** let the characteristic compreessive strength of concrete be M 20. This means, , iif we perform 100 tests on cube specimen, then 95 cubes or or m more will show their compressive strength moree than 20 MPa.
   It is denoted by 'f_{ck}'
   Mean compressive strength (f_{cm}))aat 28 days:

28-

$f_{cm} = f_{ck} \quad 1.65\sigma$

Where, σ = standard deviation

- When the 'standard test cubes' of 150mm size is used to find the 28 days compressive strength of concrete, it is referred as **cube strength (f_c)** of concrete. While in some countries (such as USA),'standard test cylinders' of 150mm diameter and 300mm high are used to find the compressive strength of concrete, and it is referred as **cylinder strength (f'_c)** the cylinder strength is found to be invariably lower than the cube strength for the same grade of concrete.
- **<u>Influence of size of Test Specimen</u>:**

Compressive strength of concrete depends on height/width ratio and cross-sectional dimensions of the test specimen.

- A standard cylinder specimen size is: of 150mm in diameter and height/diameter =2.0

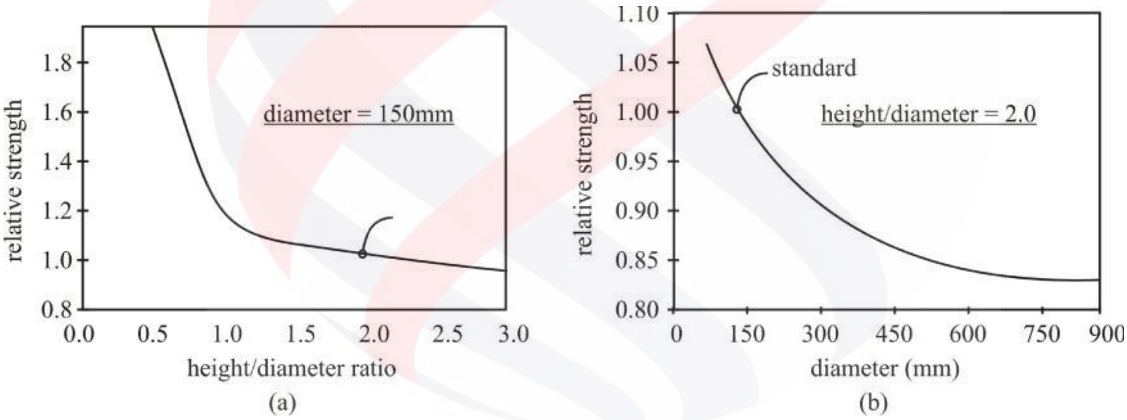
It height/diameter = 0.5, strength increases by 80% with diameter =150mm

Similarly, if height/diameter =2.0, with diameter=900mm, strength decreases by 17%

- End friction restrains the specimen from failure. In case of cube specimen, the end friction acts on the whole length, but in the case of cylinder, end friction acts only up to height of 0.85 times diameter of cylinder, so its compressive strength is lower

Cube (f_c) strength ≈ 1.25 × cylinder strength (f_c')

Where, $f_c' = 0.8\ f_{ck}$; where f_{ck} is characteristic cube strength.



2. Modules of Elasticity and Poisson's ratio :

Types of Modulus:

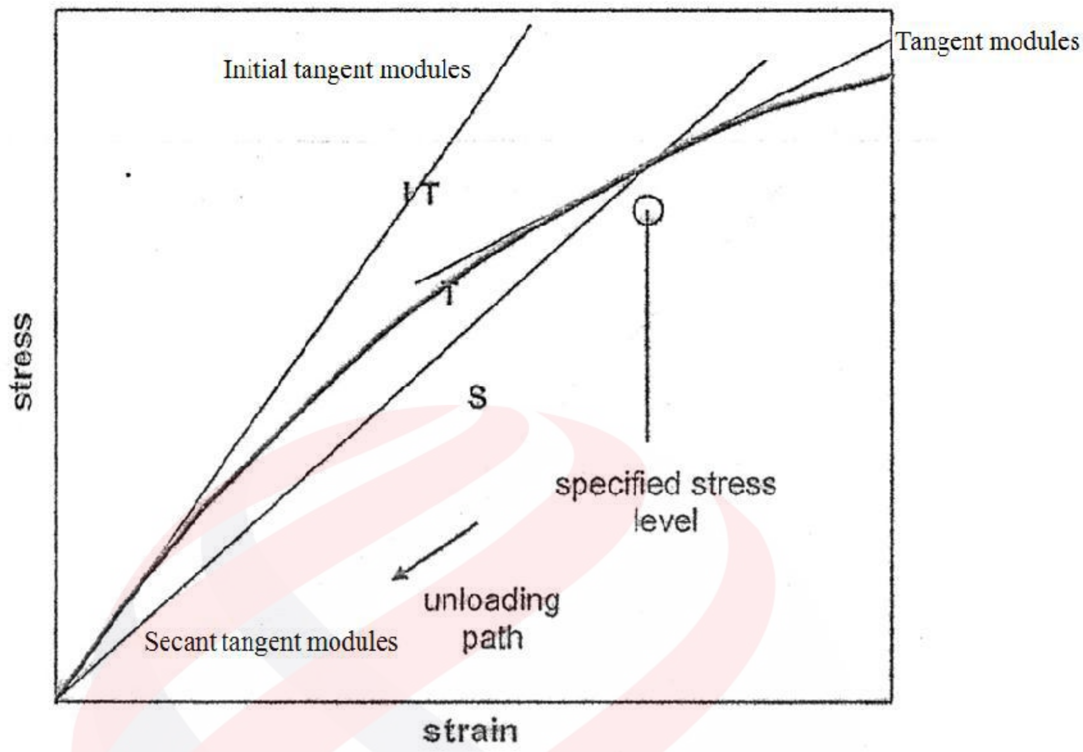
1. Initial tangent modulus: Slope of stress strain curve at origin.

- This value is considered by IS 456

2. Tangent Modulus: Slope of tangent of any point on the curve.

3. Secant Modulus: Slope of line joining any point on curve to origin.

4. Long term modules of elasticity



- Initial tangent modulus, $\boxed{E_c = 5000\sqrt{f_{ck}}}$ (According to IS:456-2000)

  OR (Short or term static modulus of elasticity)

However, earlier version of IS 456 had recommended $E_c = 5700\sqrt{f_{ck}}$, which is found to over-estimate the elastic modulus.

- Poisson's ratio varies between 0.1-0.2 ; for design purpose a value of about 0.2 is taken.

4. Modulus of rupture or flexural strength (f_{cr}):

$$\text{Modulus of rupture } (f_{cr}) = \frac{M}{Z}$$

where, M = bending moment
Z = section modulus

$$\boxed{f_{cr} = 0.7\sqrt{f_{ck}}}$$

5. Splitting Tensile Strength :

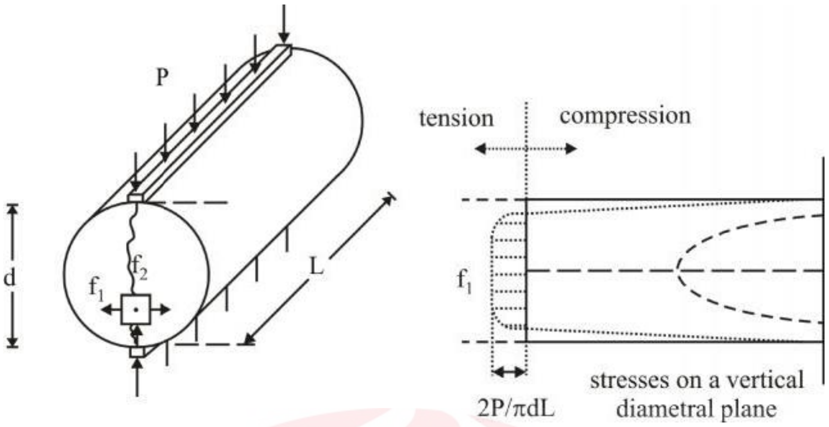


Figure: Cylinder splitting test for tensile strength

- Cylinder splitting test is performed to find splitting tensile strength of concrete In this test, a standard plain concrete cylinder (of 150mm diameter and 300mm height) is loaded in compression on its side along a diametric plane and failure occurs by the splitting of the cylinder along the loaded plane.

$\therefore$ Splitting tensile strength $f_{ct} = \dfrac{2P}{\pi dL}$

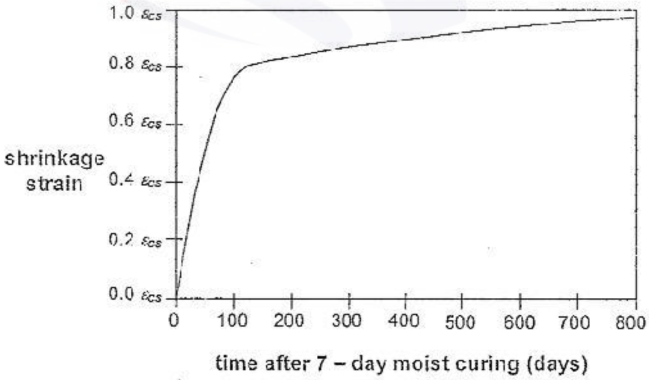
Where P = Maximum applied load d = Diameter L = Length

Generally, $f_{ct} \approx 0.6 f_{cr}$

6. Shrinkage:

- Shrinkage is the time dependent deformation, generally compressive in nature
- The factors on which the total shrinkage of concrete depends are:-
  (*i*) Constituents of concrete
  (*ii*) Size of member
  (*iii*) Environmental condition
- The total shrinkage, however, is mostly influenced by the total amount of water present in the concrete at the time of mixing for a given humidity and temperature.

The approximate value of total shrinkage strain for design is taken as 0.0003 in the absence of test data.



7. Creep:

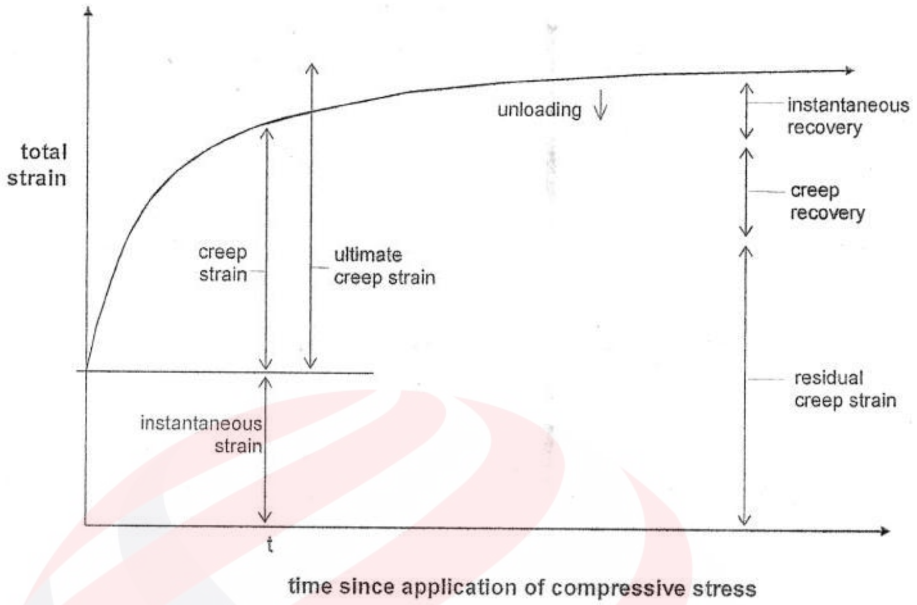


Figure: Typical strain-time curve for concrete in uniaxial compression

It is also a time dependent deformationof concrete usually under compressive stress. Factors affecting creep of concrete is:

- Properties of concrete
- W/C ratio
- Age of concrete at first loading
- Magnitude of stress and its duration
- Surface volume ratio of member

Creep of concrete results in following detrimental results in reinforced concrete structure:

(i) Increased deflection of beams and slabs
(ii) Increased deflection of slender columns
(iii) Loss of pre-stress in pre-stressed concrete

$$\text{Creep coeficient} = \theta = \frac{\varepsilon_{cr}}{\varepsilon_c}$$

Where, ε_{cr} =short term strain at the age of loading at a stress value of ‘f_c’.

ε_{cr} =Ultimate creep strain

Age of loading	Creep coefficient ( )
7 Days	2.2
28 Days	1.6
1 year	1.1

Also, total strain, $\boxed{\varepsilon = \varepsilon_{cr} + \varepsilon_c}$

- **Effective Modulus of concrete (E_{ce}):**

  Long term modulus of elasticity (E_{ce}),

  $\boxed{E_{ce} = \frac{E_c}{1+\theta}}$ Where, E_c = Short term elastic Modulus

Coefficient of thermal expansion:

The co-efficient of thermal expansion depends on nature of cement, aggregate, the relative humidity and the size of section.

Stress-strain curve for concrete:

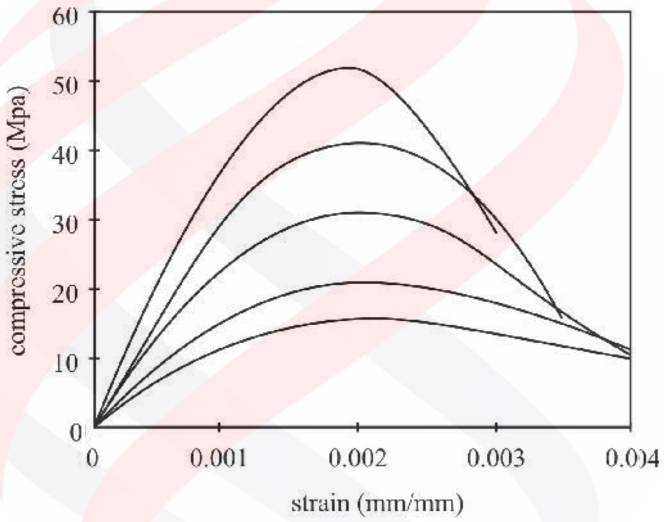


Figure: Typical stress-strain curves of concrete in compression

The curves are approximately linear in the very initial phase of loading and the non-linearity begins to gain significant when the stress level exceeds about one-third to one-half of the maximum

The maximum stress is reached at a strain approximately equal to 0.002 and beyond this point, an increase in strain is accompanied by a decrease in stress.

The higher the concrete grade, the steeper is the initial portion of stress-strain curve, the sharper the peak of the curve and a lesser the failure strain.
For low-strength grade, the curve has a relatively flat top and a high failure strain.

At a stress- level about 70-90% of the maximum stress internal cracks are initiated in the mortar throughout the concrete mass, roughly parallel to the direction the applied loading.

Permissible stresses in concrete

As per IS: 456-2000

1. Direct tensile stress:

Table : Permissible Direct Tensile Stress

Grade of concrete	M 10	M 15	M 20	M 25	M 30	M 35	M 40
Tensile stress N/mm^2	1.2	2.0	2.8	3.2	3.6	4.0	4.4

2. Compressive stress and bond stress:

Table: Permissible Stresses in Concrete (IS: 456-2000)

Grade of concrete	Permissible stress in compression (N/mm^2)		Permissible stress in Bond (Average) for plain bars in tention (N/mm^2) τ_{bd}
	Bending (σ_{cbc})	Direct (σ_{cc})	
M 10	3.0	2.5	_
M 15	5.0	4.0	0.6
M 20	7.0	5.0	0.8
M 25	8.5	6.0	0.9
M 30	10.0	8.0	1.0
M 35	11.5	9.0	1.1
M 40	13.0	10.0	1.2
M 45	14.5	11.0	1.3
M 50	16.0	12.0	1.4

3. Shear stress:

Table: Permissible Shear Stress In concrete (IS : 456-2000)

$\frac{100A_s}{bd}$	**Permissible shear stress in concrete $^{2}{}_{c}$, N/mm^2 for grades of concrete**					
	M 15	**M 20**	**M 25**	**M 30**	**M 35**	**M 40 and above**
≤ 0.15	0.18	0.18	0.19	0.20	0.20	0.20
0.25	0.22	0.22	0.23	0.23	0.23	0.23
0.50	0.29	0.30	0.31	0.31	0.31	0.32
0.75	0.34	0.35	0.36	0.37	0.37	0.38
1.00	0.37	0.39	0.40	0.41	0.42	0.42
1.25	0.40	0.42	0.44	0.45	0.45	0.46
1.50	0.42	0.45	0.46	0.48	0.49	0.49
1.75	0.44	0.47	0.49	0.50	0.52	0.52
2.00	0.44	0.49	0.51	0.53	0.54	0.55
2.25	0.44	0.51	0.53	0.55	0.56	0.57
2.50	0.44	0.51	0.55	0.57	0.58	0.60
2.75	0.44	0.51	0.56	0.58	0.60	0.62
3.00 and above	0.44	0.51	0.57	0.60	0.62	0.63

4. Modular ratio:

Modular ratio, $\boxed{m = \frac{280}{3\sigma_{cbc}}}$ (value considered by IS code)

Where, σ_{cbc} = Permissible compressive stress due to bending in concrete (N/mm^2)

Note: This value partially takes into account long term effect such as creep.

- This is the ratio of young modulus of steel and modulus of elasticity of concrete.

Table : Modular Ratio

Grade of concrete	M 10	M 15	M 20	M 25	M 30	M 35	M 40
Modular ration m	31 (31.11)	19 (18.67)	13 (13.33)	11 (10.98)	9 (9.33)	8 (8.11)	7 (7.18)

5. Increase of permissible stress:

- Due to wind (or earthquake) and temperature effects, the above stresses (Direct tensile stress compressive stress, bond stress, and shear stress are increased by $33\frac{1}{3}\%$)
- Wind and seismic forces are not considered to act simultaneously