RRB-JE 2024

Railway Recruitment Board

Junior Engineer Examination

Civil Engineering

Design of Concrete Structures

Well Illustrated **Theory** *with*

Solved Examples and **Practice Questions**

MADE EASY PUBLICATIONS

Design of Concrete Structures

Contents

Chapter 01

Basic Design Concepts

1.1 Introduction

Concrete is one of the most common building material used for constructive civil engineering structures and is essential in the infrastructure development of any nation. Concrete is used in the construction of various types of structures which include buildings, bridges, piers, chimneys, pavements, dams, hydraulic structures, conveying pipes, liquid retaining tanks/structures, assembly halls, auditorium, swimming pools, bunkers etc. and the list goes on.

1.2 Types of Concrete

1.2.1 Plain Concrete

Concrete can be defined as a mass which is made from any cementing material and consists of sand, gravel and water. Mixing of such naturally occurring materials along with a cementing material result in a partial solid mass that can be molded in any shape and form, when wet, and which becomes hard on drying. Concrete is being used as a building material probably from the last 150 years.

Concrete is a highly successful building material and has gained wide popularity because of the following reasons:

1. Concrete is highly durable even under hostile environmental conditions.
2. It can be easily casted into any shape and size.
3. It is relatively cheaper and widely available.

The most important property of concrete is its compression resisting ability i.e. compressive strength, which supersedes any other building material. At present we have concrete grades ranging from 5 MPa to 100 MPa.

The major drawback of concrete is that it cannot resist significant tension. The tensile strength of concrete is about 10% of its compressive strength. Thus, the use of plain concrete as a building material is limited to places where tensile stresses/strains never develop. For example pedestals, mass concreting in dams etc.

1.2.2 Reinforced Concrete

Concrete has gained so much importance and popularity because of the development of **reinforced concrete**. Introducing the reinforcing bars in concrete makes the concrete an excellent composite building material which can resist significant amount of tensile stresses/strains also. Construction of load bearing building elements like beams, slabs etc. is made possible due to the reinforced concrete only. Steel bars embedded in the tension zone of concrete make it able to take tension.

In reinforced concrete, strain compatibility is assumed to exist i.e. there exists a perfect bond between the concrete and steel bars so that strain in concrete is equal to the strain in steel at the interface of concrete and steel.

Moreover, since the failure of concrete is brittle in nature which takes place without giving any warning, introduction of steel in concrete makes it a ductile material which gives sufficient warning before collapse.

Now tensile stresses occur either directly (e.g. direct tension, flexural tension) or indirectly (e.g. shear which causes tension along the diagonal planes). Temperature and shrinkage effects may also induce tensile stresses. At all such locations, steel is invariably provided which is in fact inevitable, that passes across the tensile cracks. Insufficient steel causes propagation of cracks which can lead to complete failure.

Embedding reinforcing bars in compression zone of concrete increases the compressive strength of member (e.g. In columns, doubly reinforced beams etc.).

1.2.3 Prestressed Concrete

Development of prestressed concrete took place along with the reinforced concrete. It is a high strength concrete with high tensile wires embedded in concrete and tensioned before the application of actual working load. While doing so, the concrete can be compressed to such an extent that when the structure is actually loaded, there is almost no tension developed in the beam section. Prestressed concrete is frequently used where, even a hair line crack is not admissible like, high pressure vessels, pipes, water tanks etc. and at locations which are subjected to fatigue loading like long span bridges or rail sleepers etc.

1.3 Importance of Design Codes in the Design of Structures

Different countries have formulated their own codes for laying down the guidelines for the design and construction of structures. These codes came into picture after a collaborative effort of highly experienced structural engineers, construction engineers, academicians and other eminent fellows of respective areas. These codes are revised periodically based on current research and trends (e.g. IS 456: 1978 and IS 456: 2000). Codes serve the following objectives/purposes:

1. They ensure structural stability/safety by specifying certain minimum design requirements.
2. They make the task of a designer rather simple by making available results in the form of tables and charts.
3. They ensure a consistency in procedures adopted by the various designers in the country.
4. They protect the designer against structural failures that are caused by improper site construction practices i.e. codes have legal sanctity and one can have a stand on the basis of these design codes.

Basic Indian Standard Codes for Structural Design

Some of the basic Indian Standard codes for reinforced concrete published by the BIS (Bureau of Indian Standards) are:

1. IS 456 : 2000 Plain and reinforced concrete-Code of practice.
2. IS 875 : 1987 (Part-I to V) Code of practice for design loads.
3. IS 1893 : 2002 Criteria for earthquake resistant design of structures.
4. IS 13920 : 1993 Ductile detailing of reinforced concrete structures subjected to seismic forces.
5. IS 1343 : 2012 Pre stressed concrete design
6. IS 3370 : 2009 Liquid retaining structure
7. IS 10262 Concrete mix design
8. IS 1642 Fire protection

1.4 Hardened Concrete

After final setting time (10 hr) from mixing concrete is assumed to be hard, from final setting time concrete starts gaining strength up to very long time (1 to 5 years).

1.4.1. Compressive Strength

(a) Compressive strength of cube: It is the compressive strength of cube of size 150 mm, subjected to uniaxial compression after 28 days from day of casting.

(b) Characteristics compressive strength of cube: It is the strength below which not more than 5% of the test results are expected to fail.

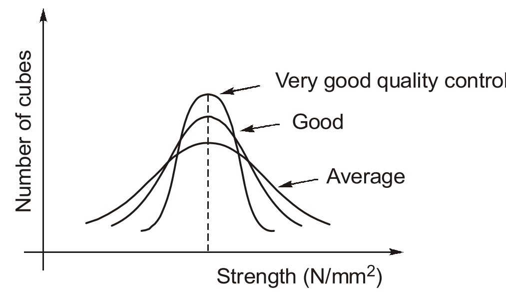


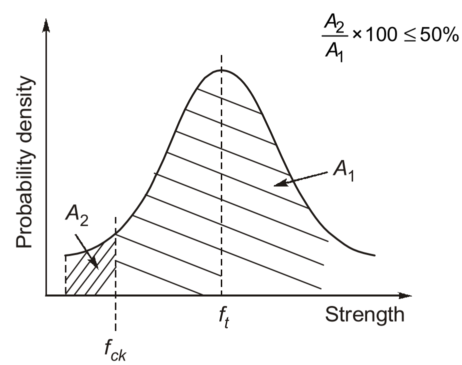
Fig. *Influence of quality control on the frequency distribution of concrete strength*

NOTE: Experimentally, it is found that probability distribution of concrete strength (for a particular concrete mix as found out by compressive strength tests in laboratory on a large number of specimens follow normal/ Gaussian distribution.

$f_t = f_{ck} + ks$

$k = 1.65$ (for 5% of definition)

s = Standard deviation that depends on grade of concrete



As per IS : 456-2000, clause 9.2.4.2
Assumed standard deviation

Grade of Concrete	Assumed Standard Deviation (N/mm^2)
M10, M15	3.5
M20, M25	4.0
M30, M35, M40, M45, M50	5.0

f_t = Target mean strength

for 0% of definition; $k = \infty$

for 50% of definition; $k = 0$

Example-1.1 If the characteristics strength of concrete f_{ck} is defined as the strength below which not more than 50% of the test result are expected to fail, the expression for f_{ck} in terms of mean strength f_t and the standard deviation 's' would be

(a) $f_t - 0.1645s$ (b) $f_t - 1.645s$
(c) f_t (d) $f_t + 1.645s$

Solution: (c)

We know that, $f_t = f_{ck} + ks$

for 50% of definition, $k = 0$

$\therefore$ $f_t = f_{ck}$

Example-1.2 Uniaxial compressive test, results of 100 cubes are listed below in increasing order. What is characteristics strength of concrete 26, 26.5, 27, 27, 28.5, 29, 29.5, 30, ..., 44.5

Solution:

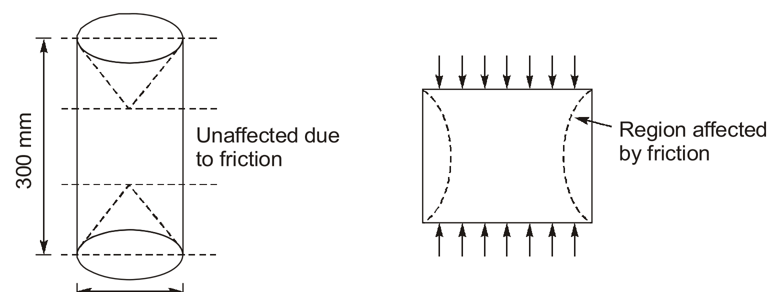
As per definition, characteristics strength should be 29 N/mm^2 since f_{ck} is designated in multiple of 5. So, f_{ck} should be either 25 or 30, in this case 7 samples (7%) are below 30 N/mm^2 so, 30 cannot be characteristics strength now, 25 is the characteristics strength of this concrete because zero sample (0% < 5%) is below 25 N/mm^2

$$\therefore \quad f_{ck} = 25 \text{ N/mm}^2$$

(c) Characteristics strength of concrete: It is obtained by dividing characteristics compressive strength of cube by a factor 1.5 to account for variation in loading condition (other than uniaxial compression) and variation in shape of concrete (other than cube of 150 mm).

(d) Characteristics strength of cylinder: Uniaxial compressive strength of concrete can be determined by using different types of shapes of specimen (cube, cylinder, prism).

- Cylinder gives more appropriate result for uniaxial compressive strength because effect of friction between machine plate and ends of specimen is least.
- Middle portion of cylinder remain unaffected of friction.

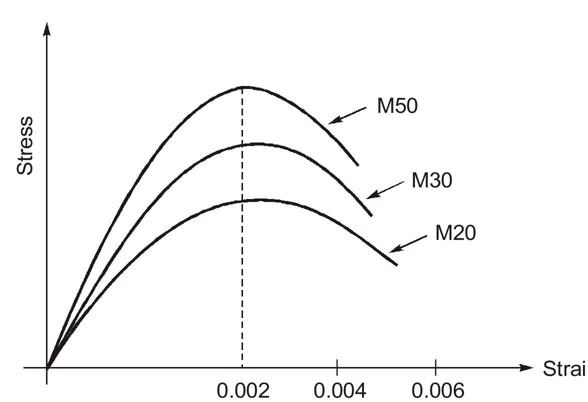


$(f_{ck})_{cube} = 1.25\ (f_{ck})_{cylinder}$

NOTE: In general, compressive strength of cube is used for characteristics strength of concrete for conversation purpose.

(e) Stress-strain diagram of concrete under uniaxial compression:

- Stress-strain diagram is non-linear.
- Maximum stress is corresponding to 0.002 strain (approximately).
- Ultimate strain lies between 0.004 to 0.006.
- Brittleness increases with increase in grade of concrete.
- Modulus of elasticity increases with increase in grade of concrete.
- Falling portion of stress-strain curve is obtained by controlled strain machine.



1.4.2 Grade of Concrete

Grade of concrete are based on characteristics strength. As per IS code (Amendment No. 4) the various grades of concrete are

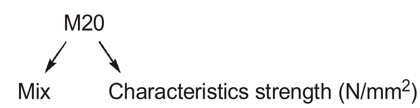
M10
M15 } Ordinary grade
M20

M25-M60] - Standard grade

M65-M100] - High strength concrete

where, M represents mix and number represents grade which is characteristics strength of 150 mm cube at 28 days.

Ex:



NOTE

- IS 456 : 2000 is not applicable to grade above M-60 (Amendment No. 4, May 2013)
- IS 456 : 2000 recommends the minimum grade as M-20 for reinforced concrete.
- Minimum grade of RCC and PCC used, depends on the exposure condition.

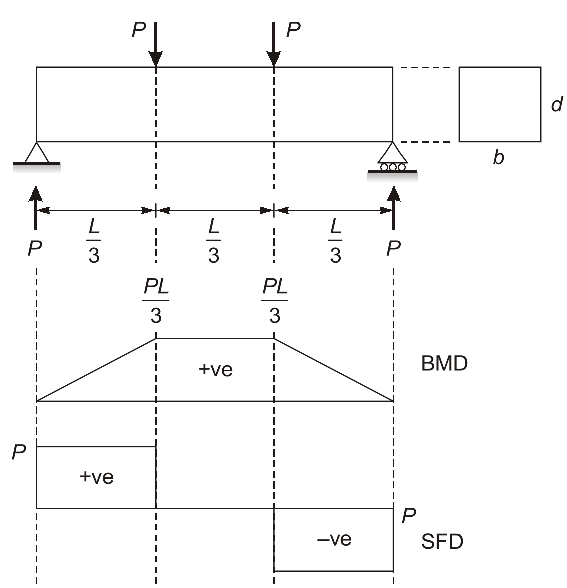
Exposure Condition	Minimum Grade (RCC)	Minimum Grade (PCC)
Mild	M20	–
Moderate	M25	M15
Severe	M30	M20
Very Severe	M35	M20
Extreme	M40	M25

1.4.3 Tensile Strength of Concrete

It is approximately 7 to 15% of compressive strength and stress-strain diagram is almost linear. Since, tensile strength of concrete is ignored in design so, it has vary less importance however it may be used to calculate cracking width and cracking moment.

(i) Direct tension test: Practically it is difficult to perform direct tension test due to stress concentration and non-homogeneity of material.

(ii) Flexure test:



Flexural formula, $$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

$$\frac{\left(\frac{PL}{3}\right)}{\left(\frac{bd^3}{12}\right)} = \frac{f_{cr}}{\left(\frac{d}{2}\right)}$$

$$f_{cr} = ?$$

- Third point loading is applied for pure bending condition.
- Value of P is increased from 0 to value corresponding to which first crack develops.
- Corresponding to cracking load, bending moment is calculated in central portion and tensile strength is calculated as shown above.
- IS : 456 provides a standard formula for flexure tensile strength/modulus of rupture as shown above:
- IS : 456 provides a standard formula for flexure tensile strength/modulus of rupture as shown below:

$$f_{cr} = 0.7\sqrt{f_{ck}}$$
$$\downarrow \quad \downarrow$$
$$\text{N/mm}^2 = \text{N/mm}^2$$

(iii) Cylinder split test/splitting tensile strength of concrete: Owing to limitations of direct tensile strengthtest of concrete, cylinder splitting test is performed which gives more uniform results. In this test, a standard plain concrete cylinder (as used in compression test) is loaded on its sides along a diameter. Failure occurs by splitting of the cylinder along the plane of loading. This type of loading produces a uniform tensile stress across the plane of loading.

The splitting tensile strength (f_{ct}) is obtained as:

$$f_{ct} = \frac{2P}{\pi dL}$$

Where, P is the maximum load applied at failure, d is the diameter of the cylinder specimen, L is the length of the cylinder specimen.

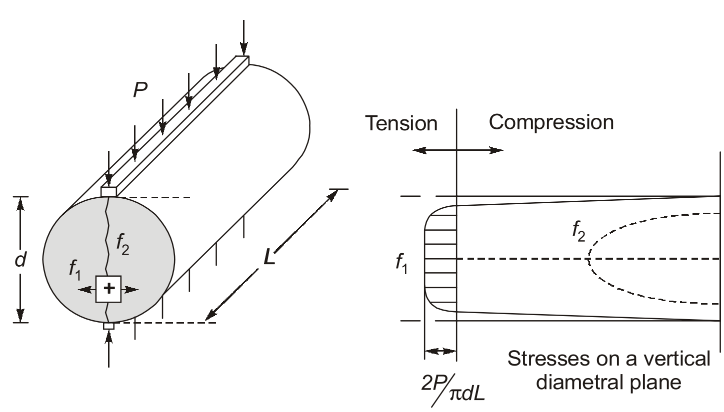


***Fig.** Cylinder splitting test for tensile strength*

Remember

IS 456: 2000 does not provide any empirical formula for splitting tensile strength (f_{ct}) as it does for modulus of rupture of concrete (f_{cr}). For normal density concrete, the **splitting tensile strength is about 2/3rd of the modulus of rupture of concrete**.

Example-1.3 Calculate cracking moment of plain cement concrete section of size 200 × 300 mm of M30 concrete.

Solution:

$$f_{cr} = 0.7\sqrt{f_{ck}} = 0.7\sqrt{30} = 3.834 \text{ N/mm}^2$$

$$\therefore \quad \frac{M_{cr}}{\left(\frac{bd^3}{12}\right)} = \frac{f_{cr}}{\left(\frac{d}{2}\right)}$$

$$M_{cr} = 3.834 \text{ N/mm}^2 \times \frac{200 \times (300)^2}{6} \text{ mm}^3$$

$$= 11502000 \text{ N-mm} = 11.50 \text{ kN-m}$$

1.4.4 Creep of Concrete

Creep of concrete is covered in more detail in forth coming chapters. At present, it is worth to note that creep of concrete is having the following ill effects on concrete structures:

1. It increases the deflections of certain concrete elements like beams and slabs.
2. It increases the deflection of very long / slender columns.
3. It slowly transfers the load from concrete to reinforcing steel over a period of time.
4. It causes loss of prestress in prestressed concrete members.

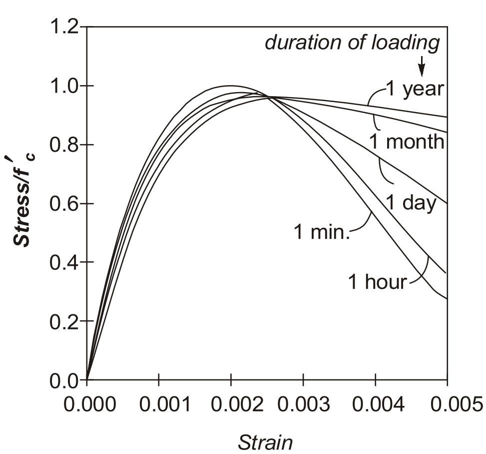


Fig. *Influence of duration of loading (strain-controlled) on the stress-strain curve of concrete*

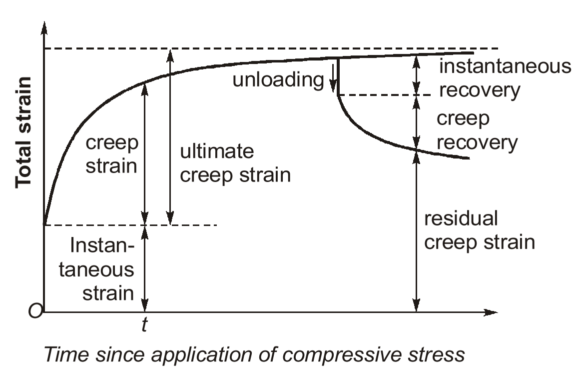


Fig. *Typical strain-time curve for concrete in uniaxial compression*

Following factors influence the creep of concrete:

1. High cement content increases the creep of concrete.
2. High water-cement ratio increases creep of concrete.
3. Creep increases when aggregate content is low.
4. It increases when air entrainment is high in concrete.
5. Low relative humidity increases creep.

6. Small size/thickness of members show large amount of creep.
7. Early loading of concrete members increases creep.
8. Long term sustained loading increases creep of concrete.

Long term sustained loading on concrete at a constant stress results in creep strains and a decrease in the compressive strength of concrete.

Creep Coefficient for Design

- As long as stress in concrete does not exceed one-third of its characteristics strength, creep may be assured to be proportional to stress.

$$\theta = \text{Creep coefficient} = \frac{\text{Ultimate creep strain}}{\text{Instantaneous elastic strain}}$$

Age of Loading	Creep Coefficient (θ)
7 Days	2.2
28 Days	1.6
1 Year	1.1

- Intermediate value of creep coefficient may be interpolarated by assuming that the creep coefficient decreases linearly with the log of time (in days). Thus, creep coefficient for age of loading at 15 days

$$\theta_{15} = 1.6 + \frac{0.6[\log_{10} 28 - \log_{10} 15]}{[\log_{10} 28 - \log_{10} 7]}$$

i.e. $$\theta = C - \theta_0 \cdot \log t$$

Effect of creep can be reduced by:

(i) Using high strength concrete.
(ii) Delaying the application of finishes, partition walls etc.
(iii) Adding reinforcement.
(iv) Steam curing under pressure.

1.4.5 Shrinkage of Concrete

Concrete is having shrinkage property due to presence of cement.

- Concrete undergoes volume changes as it changes phase from plastic to solid and this process is called shrinkage.
- Shrinkage is usually expressed as a linear strain (mm/mm).
- Unlike creep, shrinkage strains are independent of the stress condition of the concrete.
- Shrinkage is reversible to a greater extent.
- The total shrinkage of a concrete depends upon the constituents of concrete, size of member and environmental conditions etc.
- For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and to a lesser extent by the cement content.
- Shrinkage has detrimental effects on the serviceability and durability of concrete. Shrinkage has been divided into five types as per different mechanisms:

  (a) Chemical shrinkage (b) Autogenous shrinkage (c) Plastic shrinkage
  (d) Drying shrinkage (e) Carbonation shrinkage

(a) Chemical shrinkage:

- This is due to the chemical reactions in concrete.
- In the plastic phase the chemical shrinkage results in overall reduction of specimen volume and at a later stage it creates pores within the mix structures.

(b) Autogenous shrinkage: It is a volume reduction of the concrete with no moisture transfer with the outer environment.

- It is mainly due to self-desiccation of cement resulting in rise in capillary suction pressure.

NOTE: Chemical shrinkage induces internal voids and autogenous shrinkage results in element shortening.

(c) Plastic shrinkage:

- This induce cracking on the top surface due to shortening of the concrete as sufficient tensile strength has not been developed in concrete.
- It is a short term process.

(d) Drying shrinkage: It is the contraction of a hardened concrete due to loss of water from concrete pores.

- It is similar to autogenous shrinkage as both occurs due to loss of water. However, in drying shrinkage the water is transferred to the outside and in autogenous shrinkage the water is transferred within the pore structure.
- Drying shrinkage is a long term process.

(e) Carbonation shrinkage: It is the result of reaction between calcium hydroxide $Ca(OH)_2$ present in the concrete and carbondioxide in atmosphere with the existence of moisture.

- Carbondioxide (CO_2) and moisture form carbonic acid (H_2CO_3)

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$$

- The above reaction lower the pH in concrete and results in corrosions of reinforcement.
- The rate of carbonation shrinkage is low.
- A constant value of shrinkage strain is considered while designing RCC structure.

$$\varepsilon_s = 0.0003 = 3 \times 10^{-4} \simeq 0.03\%$$

1.4.6 Durability

Exposure Conditions	Description	Minimum grade of concrete	Minimum cement content	Minimum nominal cover	Maximum W/C ratio
Mild	Protected from rainfall	*M20	*300 kg/m^3	*20 mm	*0.55
Moderate	• Exposed to normal rain • Permanently submerged in normal water	M25	300 kg/m^3	30 mm	0.55
Severe	• Coastal area • Exposed to heavy rain • Footing in non-aggressive soil • Alternate drying and wetting in normal water • Permanently submerged in sea water	M30	320 kg/m^3	**45 mm	0.45
Very severe	• Exposed to sea spray • Footing in aggressive soil	M35	340 kg/m^3	50 mm	0.45
Extreme	• Tidal zone • Subjected to aggressive chemicals	M40	360 kg/m^3	***75 mm	0.40

* → It can be reduced to 15 mm when bar dia is 12 mm or less.
** → It can be reduced to 40 mm for grade M35 or above.

$$\text{Load Factor} = \frac{\text{Ultimate or design load}}{\text{Working or service load}}$$

This concept of load factor makes it possible to assign different factors of safety (in terms of load factors) to different types of loads (like dead loads, live loads, seismic loads, wind loads, snow loads etc.) and can be suitably combined; which was a major drawback in the WSM of design.

Limitations of ULM of design

1. The major drawback of this method is that, one cannot say with 100% assurance that if a structure performs well at ultimate loads (**strength**), the same structure will perform its function satisfactorily at service loads also (**serviceability**).
2. Another drawback of this method is that, the assumed nonlinear stress strain behavior of concrete and steel is relevant only if nonlinear analysis is performed on the structure. But nonlinear analysis of structures is too cumbersome to be done for routine type of structures.

For assessing the distribution of stresses at ultimate loads, we use the stress distribution at service loads magnified by the load factor, but this approach is NOT correct owing to the fact that as the loading is increased from the service load level to the ultimate load level, significant inelastic and nonlinear behavior of materials comes in with considerable stress redistribution.

1.11.3 The Limit State Method (LSM) of Design

The earlier design methods includes the working stress method (WSM) and the ultimate load method (ULM) of design. **WSM is based on service loads conditions** alone whereas the **ULM is based on ultimate load conditions** alone. However, LSM takes into account the safety at ultimate load and serviceability at service loads. LSM employs different safety factors at ultimate loads and service loads. These multiple safety factors are based on probabilistic approach with separate approaches for each type of failure, type of materials and types of loads.

Limit State: Limit state is the state of 'about to collapse' or 'impending failure', beyond which, the structure is not of any practical use i.e. either the structure collapses or becomes unserviceable. In LSM, two types of limit states are defined which are:

1. **Limit state of collapse**: This limit state deals with the strength of the structure in terms of collapse, overturning, sliding, buckling etc.

   Various limit states of collapse are:

   - Flexure
   - Compression
   - Shear
   - Torsion

2. **Limit state of serviceability**: This limit state deals with the deformation of the structure to such an extent that the structure becomes unserviceable due to excessive deflection, cracks, vibration, leakage etc.

   Various limit states of serviceability are:

   - Deflection
   - Excessive vibrations
   - Corrosion
   - Cracking (Do not consider the tensile strength of concrete)

1.12 Necessity of Designing Reinforced Concrete Structures

The principal aim of structural design is that the structures should perform its intended function *safely* at ultimate loads within their life time and also *serviceable* at service or working loads.

The term '**safety'** includes the following parameters:

1. Reserve strength of the material of the structure.
2. Limited or permissible deformation(s) in the structure.
3. Durability of the structure in the long run.

Thus, **safety** implies that the possibility of the failure of the structure (partial or complete failure) is very low even at **ultimate loads** considering appropriate factor of safety.

Serviceability implies that the structure should perform its intended function very well at **working loads.** It includes deflection, vibration, crack widths, durability, permeability, acoustics, thermal insulation etc.

Thus, the basic objectives to fulfil serviceability criteria can be summarized as:

1. Properly designed structures should perform its intended function at service loads quite satisfactorily.
2. Structure should bear all the loads and should deform within the permissible limits.
3. The structures should be durable enough against the adverse environmental conditions.
4. The designed structure must adequately resist the probable hazardous effects of structural misuse and fire.

Remember

Increasing the **factor of safety** in the design of structures increases the safety and serviceability of the structure but at the same time it increases the cost of structure also. Here comes the role of **economy** in the design of structures. While considering the overall economy of a structure, the increased cost associated with the increased factor of safety must be properly weighed against the possibility of structural failure.

1.12.1 Objectives of Structural Design

The rational design of a structure must satisfy the following requirements:

1. **Stability:** The structure must be stable enough to resist the failure of structure in terms of overturning, sliding, buckling of the structure or parts thereof under the severe action of loads viz. both permanent (dead load) and temporary (superimposed live load etc.).
2. **Strength:** The structure must be able to carry safely the stresses induced by the severe most possible combination of loads acting on the structure.
3. **Serviceability:** The structure must perform its intended function i.e. it must be serviceable. This implies that the deflections, vibrations, crack-widths, permeability to water etc. are within the permissible limits.
4. **Aesthetics:** The structure must be in harmony with the surroundings and should look pleasing. It is purely an architectural consideration.
5. **Economy:** At last, economy plays the most important role in structural design. The cost of the structure and its associated facilities must not be so gargantuan that it may dictate the overall functional requirement of the structure.

1.13 Major Reasons of Structure Failure

There are so many reasons for a building failure. By the term '**failure**', it implies failure in terms of either **collapse or serviceability or both**. Some of the major reasons of structure failure are as follows:

Failure during construction or soon after	Failure after a long time of construction
Design fault/significant shift from actual design	Collapse/failure of primary load carrying member by accident or otherwise
Poor detailing	Change in use of the structure leading to over loading
Inferior quality of materials	Factors which are beyond human control like fire, earthquake, blast etc.
Inferior construction quality	Lack of proper repair and maintenance
Substandard formwork and/or scaffolding	Exposure to adverse environment which was not envisaged in design

1.14 Major Challenges for a Structural Designer

In order to design a structure economically , a structural designer faces the following challenges:

1. Analysing a structure on the basis of **highly simplified structural analysis theories** which are far from actual material (steel, concrete) behavior.
2. Construction of structure by the unorganized sector of construction workers and there always exists a possibility of human error.
3. Structure subjected to a completely unpredictable natural environment.

STUDENT'S ASSIGNMENTS

Q.1 A reinforced concrete structures has to be constructed along sea coast. The minimum grade of concrete to be used as per IS 456 : 2000 is

(a) M15 (b) M20
(c) M25 (d) M30

[GATE-2008]

Q.2 The characteristics strength of concrete is defined as that compressive strength below which not more than

(a) 10% of result fail (b) 5% of result fail
(c) 2% of result fail (d) None of above

[GATE-1999]

Q.3 The cylinder strength of the concrete is less than the cube strength because of

(a) The difference in the shape of the cross-section of the specimens.
(b) The difference in the slenderness ratio of the specimens.
(c) The frictional between the concrete specimens and the steel plate of the testing machine.
(d) The cubes are tested without capping but the cylinders are tested with capping.

[GATE-1997]

Q.4 The flexural strength of M30 concrete as per IS 456 : 2000 is ________.

(a) 3.83 MPa (b) 5.47 MPa
(c) 21.43 MPa (d) 30.0 MPa

[GATE-2005]

Q.5 In a random sampling procedure for cube strength of concrete, one sample consist of X number of specimens. These specimens are tested at 28 days and average strength of these X specimens is considered as test result of the sample, provided the individual variation in the strength of specimens is not more than ±Y percent of the average strength. The value of X and Y as per IS 456 : 2000 are

(a) 4 and 10 respectively
(b) 3 and 10 respectively
(c) 4 and 15 respectively
(d) 3 and 15 respectively

[GATE-2005]

Q.6 The modulus of rupture of concrete in terms of its characteristics cube compressive strength (f_{ck}) in MPa according to IS 456 : 2000 is

(a) $5000\ f_{ck}$ (b) $0.7\ f_{ck}$
(c) $5000\sqrt{f_{ck}}$ (d) $0.7\sqrt{f_{ck}}$

[GATE-2009]

Q.7 The modulus of elasticity, $E = 5000\sqrt{f_{ck}}$ where f_{ck} is the characteristics compressive strength of concrete, specified in IS 456 : 2000 is based on

(a) Tangent modulus
(b) Initial tangent modulus
(c) Secant modulus
(d) Chord modulus

[GATE-2014]

Q.8 The target mean strength f_{cm} for concrete mix design obtained from the characteristics strength f_{ck} and standard deviation σ, as defined in IS 456 : 2000 is

(a) f_{ck} + 1.35σ (b) f_{ck} + 1.45σ
(c) f_{ck} + 1.55σ (d) f_{ck} + 1.65σ
[GATE-2014]

Q.9 Limit state of serviceability of prestressed concrete sections should satisfy
(a) cracking deflection and maximum compression
(b) cracking only
(c) deflection and cracking
(d) deflection and maximum compression

Q.10 Mild steel used in RCC structures conforms to
(a) IS : 432 (b) IS : 1566
(c) IS : 1786 (d) IS : 2062

Q.11 The value of ultimate creep coefficient for concrete
(a) increases with age of loading
(b) decreases with age of loading
(c) remains constant
(d) is taken as 0.0003

Q.12 The cover to reinforcement in a RC beam shall not be less than
(i) 25 mm
(ii) diameter of the bar (φ)
(iii) spacing between the bars
(iv) 5 mm
Which of the above statement(s) is/are true?
(a) (i) and (ii) (b) (i) only
(c) (ii) only (d) (i) and (iii)

Q.13 Minimum grade of concrete that can be used in structures as per IS 456: 2000 is
(a) M15 (b) M20
(c) M25 (d) M30

Q.14 Which of the following reinforced concrete design philosophy do not distinguish between the different load cases?
(a) Limit State Method
(b) Working Stress Method
(c) Ultimate Load Method
(d) All of the above

Q.15 The number of concrete cube samples required to be taken for 35 m^3 of concreting work as per IS 456 : 2000 is:
(a) 1 (b) 2
(c) 3 (d) 4

Q.16 Which of the following curve is NOT covered by **IS 456 : 2000?**
(a) Stress strain curve of concrete in tension.
(b) Stress strain curve for mild steel.
(c) Stress strain curve of concrete in compression.
(d) Stress strain curve for cold worked steel.

Q.17 Flexure strength of concrete is determined as
(a) modulus of rigidity
(b) modulus of rupture
(c) modulus of plasticity
(d) modulus of elasticity

Q.18 Why are steel reinforcing rods used in concrete beams
(a) to make it carry compression
(b) to make it carry tension
(c) to make it carry tension as well as compression
(d) none of these

Q.19 As per IS 456 : 2000, in absence of test data approximate value of total shrinkage strain for design may be taken as
(a) 0.004 (b) 0.001
(c) 0.002 (d) 0.0003

Q.20 Characteristics strength of concrete measured at
(a) 14 days (b) 28 days
(c) 91 days (d) 7 days

ANSWER KEY // STUDENT'S ASSIGNMENTS

1. (d)	**2.** (b)	**3.** (c)	**4.** (a)	**5.** (d)
6. (d)	**7.** (c)	**8.** (d)	**9.** (c)	**10.** (b)
11. (b)	**12.** (a)	**13.** (b)	**14.** (b)	**15.** (d)
16. (a)	**17.** (b)	**18.** (b)	**19.** (d)	**20.** (b)

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