

## UNIT-1 GENERAL FEATURES OF REINFORCED CONCRETE:

### 1.1 Introduction:

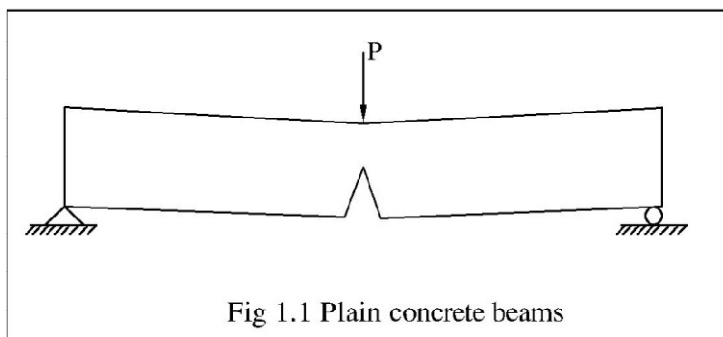
A structure refers to a system of connected parts used to support forces (loads). Buildings, bridges and towers are examples for structures in civil engineering. In buildings, structure consists of walls floors, roofs and foundation. In bridges, the structure consists of deck, supporting systems and foundations. In towers the structure consists of vertical, horizontal and diagonal members along with foundation.

A structure can be broadly classified as (i) sub structure and (ii) super structure. The portion of building below ground level is known as sub-structure and portion above the ground is called as super structure. Foundation is sub structure and plinth, walls, columns, floor slabs with or without beams, stairs, roof slabs with or without beams etc are super structure.

Many naturally occurring substances, such as clay, sand, wood, rocks natural fibers are used to construct buildings. Apart from this many manmade products are in use for building construction. Bricks, tiles, cement concrete, concrete blocks, plastic, steel & glass etc are manmade building materials.

Cement concrete is a composites building material made from combination of aggregates (coarse and fine) and a binder such as cement. The most common form of concrete consists of mineral aggregate (gravel & sand), Portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone like material. Recently a large number of additives known as concrete additives are also added to enhance the quality of concrete. Plasticizers, super plasticizers, accelerators, retarders, pazolonic materials, air entertaining agents, fibers, polymers and silica furies are the additives used in concrete. Hardened concrete has high compressive strength and low tensile strength. Concrete is generally strengthened using steel bars or rods known as rebars in tension zone. Such elements are “**reinforced concrete**” concrete can be moulded to any complex shape using suitable form work and it has high durability, better appearance, fire resistance and economical. For a strong, ductile and durable construction the reinforcement shall have high strength, high tensile strain and good bond to concrete and thermal compatibility. Building components like slab walls, beams, columns foundation & frames are constructed with reinforced concrete. Reinforced concreted can be in-situ concreted or precast concrete.

For understanding behavior of reinforced concrete, we shall consider a plain concrete beam subjected to external load as shown in Fig. 1.1. Tensile strength of concrete is approximately one-tenth of its compressive strength.



Hence use of plain concrete as a structural material is limited to situations where significant tensile stresses and strains do not develop as in solid or hollow concrete blocks, pedestal and in mass concrete dams. The steel bars are used in tension zone of the element to resist tension as shown in Fig 1.2. The tension caused by bending moment is chiefly resisted by the steel reinforcements, while concrete resists the compression. Such joint action is possible if relative slip between concrete and steel is prevented. This phenomena is called “bond”. This can be achieved by using deformed bars which has high bond strength at the steel-concrete interface. Rebars impart “ductility” to the structural element, i.e. RC elements has large deflection before it fails due to yielding of steel, thus it gives ample warning before its collapse.

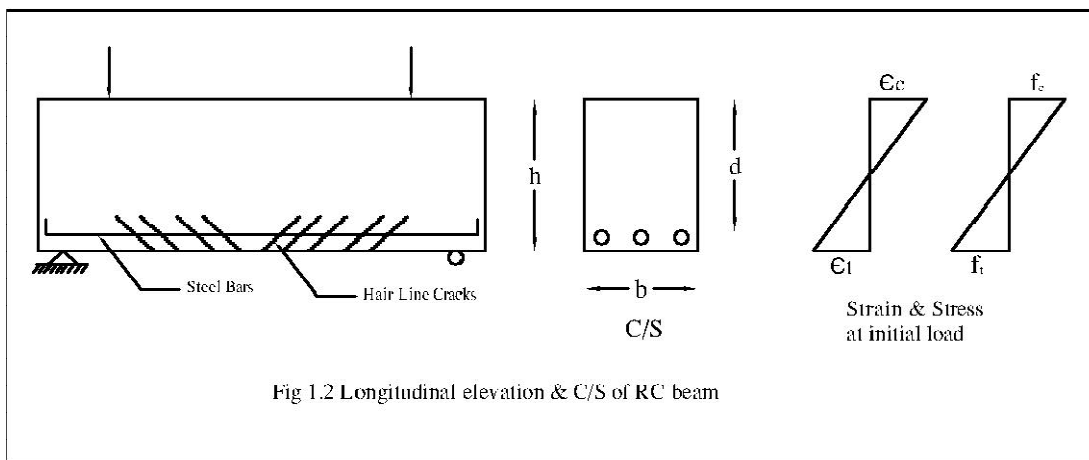


Fig 1.2 Longitudinal elevation & C/S of RC beam

## 1.2 Design Loads

For the analysis and design of structure, the forces are considered as the “Loads” on the structure. In a structure all components which are stationary, like wall, slab etc., exert forces due to gravity, which are called as “Dead Loads”. Moving bodies like furniture, humans etc exert forces due to gravity which are called as “Live Loads”. Dead loads and live loads are gravity forces which act vertically down ward. Wind load is basically a horizontal force due to wind pressure exerted on the structure. Earthquake load is primarily a horizontal pressure exerted due to movement of the soil on the foundation of a structure. Vertical earthquake force is about 5% to 10% of horizontal earthquake force. Fig. 1.3 illustrates the loads that are considered in analysis and design.

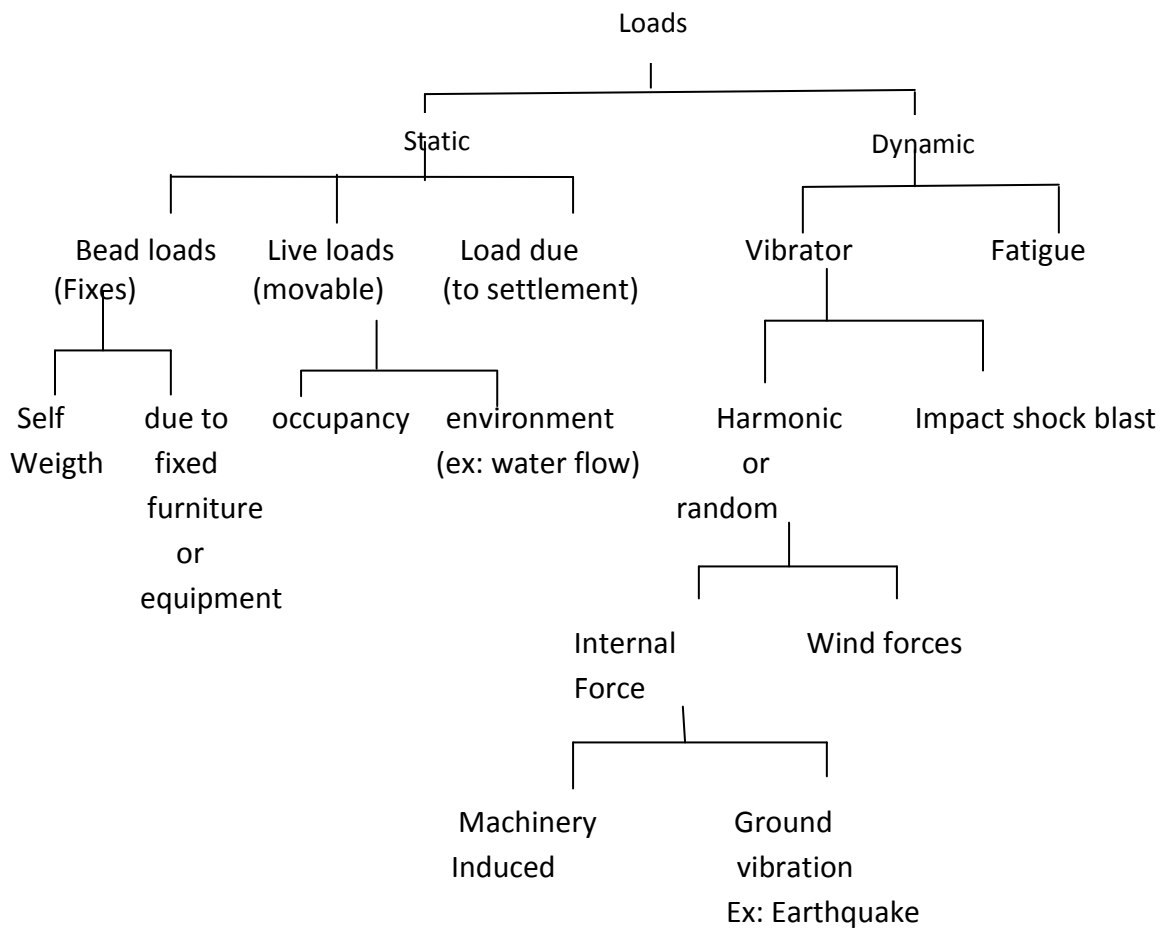


Fig 1.3 Types of loads on Structure

IS875 -1987 part 1 gives unit weight of different materials, Part – 2 of this code describes live load on floors and roof. Wind load to be considered is given in part 3 of the code. Details of earthquake load to be considered is described in 1893 – 2002 code and combination of loads is given in part 5 of IS875 – 1987.

### 1.3. Materials for Reinforced Concrete

#### **Concrete**

Concrete is a composite material consists essentially of

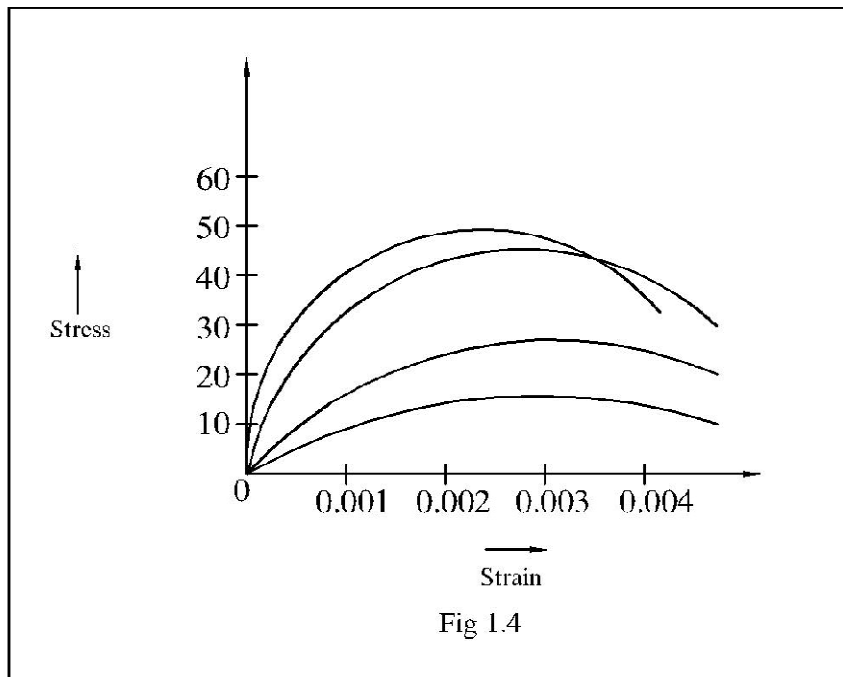
- a) A binding medium cement and water called cement paste
- b) Particles of a relatively inert filler called aggregate

The selection of the relative proportions of cement, water and aggregate is called “mix design” Basic requirement of a good concrete are workability, strength, durability and economy. Depending upon the intended use the cement may be OPC (33,43 & 53 Grade), Rapid hardening cements Portland slag, Portland pozzolona etc. High cement content give rise to increased shrinkage, creep and cracking. Minimum cement content is  $300\text{Kg/m}^3$  and maximum being  $450\text{Kg/m}^3$  as per Indian code. Mineral additives like fly ash , silica fume, rice husk ash, metakoline and ground granulated blast furnace slag may be used to reduce micro cracks . The aggregate used is primarily for the purpose of providing bulk to the concrete and constitutes 60 to 80 percent of finished product. Fine aggregates are used to increase the workability and uniformly of concrete mixture. Water used for mixing and curing shall be clean and free from oil, acids, alkalis, salts, sugar etc. The diverse requirements of mixability, stability, transportability place ability, mobility, compatibility of fresh concrete are collectively referred to as workability.

Compressive strength of concrete on 28<sup>th</sup> day after casting is considered as one of the measure of quality. At least 4 specimens of cubes should be tested for acceptance criteria.

#### *Grade of concrete*

Based on the compressive strength of concrete, they are designated with letter H followed by an integer number represented characteristic strength of concrete, measured using 150mm size cube. Characteristic strength is defined us the strength of material below which not more than 5% of test results are expected to full. The concrete grade M10, M15 and M20 are termed as ordinary concrete and those of M25 to M55 are termed as standard concrete and the concrete of grade 60 and above are termed as high strength concrete. The selection of minimum grade of concrete is dictated by durability considerations which are based on kind of environment to which the structure is exposed, though the minimum grade of concrete for reinforced concrete is specified as M20 under mild exposure conditions, it is advisable to adopt a higher grade. For moderate, severe, very severe and extreme exposure conditions, M25, M30, M35 & M40 grades respectively are recommended. Typical stress-strain curves of concrete is shown in Fig.1.4



### Reinforcing steel

Steel bars are often used in concrete to take care of tensile stresses. Often they are called as rebars, steel bar induces ductility to composite material i.e reinforced concrete steel is stronger than concrete in compression also. Plain mild steel bars or deformed bars are generally used. Due to poor bond strength plain bars are not used. High strength deformed bars generally cold twisted (CTD) are used in reinforced concrete. During beginning of 21st century, Thermo-mechanical treated (TMT) bars which has ribs on surface are used in reinforced concrete. Yield strength of steel bars are denoted as characteristic strength. Yield strength of mild steel is 250MPa, yield strength of CTD & TMT bars available in market has 415 MPa or 500 MPa or 550MPa. TMT bars have better elongation than CTD bars. Stress-strain curve of CTD bars or TMT bars do not have definite yield point, hence 0.2% proof stress is used as yield strength. Fig 1.5 shows stress strain curve of different steel grades. Steel grades are indicated by Fe followed by yield strength. In the drawings of RCC,  $\phi$  denotes MS bar and # denotes CTD or TMT bars

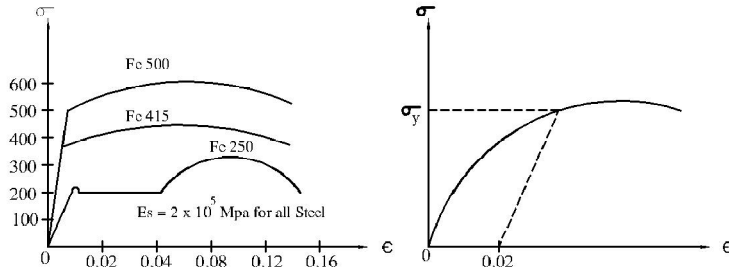


Fig 1-5 stress –strain curve

#### 1.4 Design codes and Hand books

A code is a set of technical specifications intended to control the design and construction. The code can be legally adopted to see that sound structure are designed and constructed code specifies acceptable methods of design and construction to produce safe and sound structures.

National building code have been formulated in different countries to lay down guidelines for the design and construction of structures. International building code has been published by international code council located in USA. National building code (NBC – 2005) published in India describes the specification and design procedure for buildings.

For designing reinforced concrete following codes of different countries are available

India – IS456 – 2000 – Plain and reinforced concrete code practice.

USA - ACI 318-2011 – Building code requirements for Structural concrete (American concrete institute)

UK - BS8110 –part1 – structural use of concrete –code of practice for design and construction. (British standard Institute)

Europe – EN 1992(Euro code 2) - Design of concrete structures

Canada – CAN/CSA – A23.3-04 - Design of concrete structures (Reaffirmed in 2010),

Australia – As 3600 -2001 – concrete structures.

Germany – Din 1045 – Design of concrete structures

Russia – SNIP

China - GB 50010 -2002 code for design of concrete structures to help the designers, each country has produced “handbook”. In India following hand books called special publication are available.

SP – 16-1980- Design Aid for Reinforced concrete to IS456-1978

SP – 23-1982- Hand book on concrete mixes

Sp – 24 -1983 – Explanatory hand book on IS456 – 1978

SP – 34-1987 - Hand book on concrete reinforcement and detailing.

### 1.5 Design Philosophies

Structural design is process of determining the configuration (form and proportion) of a structure subject to a load carrying performance requirement. Form of a structure describes the shape and relative arrangements of its components. The determination of an efficient form is basically a trial and error procedure.

In the beginning of 20<sup>th</sup> century (1900 to 1960) to late 50's of this century, members were proportioned so that stresses in concrete and steel resulting from service load were within the allowable stresses. Allowable stresses were specified by codes. This method of design is called “working stress method” (WSM). This method of design resulted in conservative sections and was not economical. This design principle satisfies the relation  $\frac{R}{FS} > L$ .

Where R is resistance of structural element, RS is factor of safety and L is applied external load.

In 1950's ultimate load method or load factor method was developed. In this method, using non linear stress – strain curve of concrete and steel, the resistance of the element is computed. The safety measure in the design is introduced by an appropriate choice of the load factor (ultimate load/working load). Different load factors are assigned for different loads. Following equations are used for finding ultimate load as per IS456 – 1964

$$U = 1.5 DL + 2.2 LL$$

$$U = 1.5 DL + 2.2LL \text{ to } 5WL \text{ or } 1.5 DL + 0.5LL + 2.2 WL$$

Here DL = Dead load, LL = Live load WL= wind load or earthquake load. The design principle should satisfy  $R \geq LF$  etc or  $R \geq U$ , Where, R= Resistance, LF= Load factor, L= load. Ultimate load method generally results in more slender section, but leads to larger deformation. Due to the disadvantage of larger deflection, this method was discontinued. To over come the disadvantages of working stress method and ultimate method, a probabilistic design concept called as “Limit state method, was developed during 1970's. IS456 -1978 recommended this method and is continued in 2000 version also. This method safe guards the risk of both collapse and unserviceability. Limits state method uses multiple safety factory format, which attempt to provide adequate safety at ultimate loads or well as a denote serviceability at

service loads by considering all limit states, The acceptable limit for safety and serviceability requirements before failure or collapse is termed as “Limit state” Two principal limit states are considered i.e 1. Limit state of collapse 2. Limit state of serviceability. The limit state of collapse include one or more of i) flexure, II) shear, III) torsion and IV) compression the limit state of collapse is expressed as  $\mu R > \sum X_i L_i$  Where,  $\mu$  and  $\lambda$  are partial safety factors, Here  $\mu < 1$  &  $\lambda > 1$ . The most important limit state considered in design are of deflection, other limit state of serviceability are crack and vibration. For deflection  $\delta_{max} \leq \frac{l}{\alpha}$  where  $\delta_{max}$  is maximum deflection,  $l = \text{span}$   $\alpha$  is an integer numbers. For over all deflection  $\alpha$  is 250 and for short term deflection  $\alpha = 350$ .

### 1.6 Partial safety factor

To account for the different conditions like for material strength, load etc. Different partial factors are used for material and load.  $M$  indicate safety factor for material &  $\gamma_f$  for load

$$\text{Design strength} = \frac{\text{Characteristic strength}}{\gamma_m}$$

$$\text{Design load} = \gamma_f \times \text{characteristic load}$$

As per clause 36.4.2 page 68 of IS 456,  $\gamma_m = 1.5$  for concrete and  $\gamma_m = 1.15$  for steel. Similarly clause 36.4.1 page 68 of code gives  $\gamma_f$  in table 18 for different values for different load combinations and different limit states.

### IS 456 – 2000 Recommendations

(i) Partial safety factors for materials to be multiplied with characteristic strength is given below.

#### Values of partial safety factor $\gamma_m$

Material	Limit state		
	Collapse	Deflection	Cracking
Concrete	1.5	1.0	1.3
Steel	1.15	1.0	1.0

$$\text{Design strength } f_m = \frac{f_{ck \text{ or } f_y}}{\gamma_m}$$



- (ii) Partial safety factors for loads to be multiplied with characteristic load is given below.

**Value of partial safety factors  $\gamma_f$**

Load combination	Ultimate limit state	Serviceability limit state
1) Dead load & live load	1.5(DL+LL)	DL+LL
2) Dead seismic/wind load	0.9DL+1.5(E2/WL)	DL + EQ/WL
a) Dead load contributes to Stability		
b) Dead load assists overturning	1.5(DL+E2/WL)	DL+EQ/wL
3) Dead, live load and Seismic/wind load	1.2(DL+LL+EQ/WL)	DL+0.7LL+0.8EQ/WL

DL-Dead load, LL- Live load WL- Wind load EQ- Earthquake load

- (iii) The code has suggested effective span to effective depth ratios as given below

**Basic effective span to effective depth ratio (l/d) basic**

Type of beam one /slab	Span $\leq$ 10m	Span>10m
1)Cantilever	7	Deflection should be calculated
2) Simply supported	20	(20 $\times$ 10)/span
3)continuous beam	26	(26 $\times$ 10)/span

The above values are to be modified for (i) the type and amount of tension steel (Fig 4 page 38 of T5456-2000)

- (ii) The amount of compression steel (Fig 5 page 39 of I5456-2000)
- (iv) The type of beam ie flanged beams etc (Fig 6 page 39 of I5456 – 2000).

For slabs spanning in two directions, the l/d ratio is given below.

For slabs spanning in two directions, the l/d ratio is given below

Type of slab	l/d for grade of steel	
	Fe250	Fe415
1) Simply supported	35	28
2) Continuous	40	32

### 1.7 Characteristic strength and loads

Limit state method is based on statistical concepts. Strength of materials and loads are highly variable in a range of values. The test in laboratory on compressive strength of concrete has indicated coefficient of variation of  $\pm 10\%$ . Hence in reinforced concrete construction, it is not practicable to specify a precise cube strength. Hence in limit state design uses the concept of “characteristic strength”  $f_{ck}$  indicates characteristic strength of concrete & by characteristic strength of steel. In general  $f_k$  indicates the characteristic strength of material.

$$\therefore f_k = f_m - 1.646 \sigma \rightarrow (2.6) \text{ here } f_m = \text{mean strength.}$$

Similarly “characteristic load” is that value of load which has an accepted probability of not being exceeded during the life span of structure. In practice the load specified by IS875 – 1987 is considered as characteristic load. Equation for characteristic load is

$$L_k = L_m + 1.64\sigma.$$