# Note Book

Date : 20 / /

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## Structural Design

### Plain cement concrete (PCC)

→ cement + sand + aggregate + water

→ High compressive strength & low tensile strength.

→ Direct tensile strength of concrete is about 10% of compressive strength

→ Flexural tensile strength is about 15% of compressive strength.

→ Modulus of elasticity of concrete $= 5700\sqrt{f_{ck}}$ (IS 456 : 1978)

$= 5000\sqrt{f_{ck}}$ (IS 456 : 2000)

Where; $f_{ck}$ = characteristic compressive strength of concrete.

→ Unit weight of PCC $= 24\ KN/m^3$.

Uses of Concrete. $M_5 - M_{10}$ → PCC work

$M_{20}$ & above → RCC work (IS456 : 2000)

$M_{30}$ & above → PSC work

### Reinforced cement concrete (RCC)

→ Concrete (PCC) + Rebar (steel)

→ High compressive & tensile strength.

→ Modulus of elasticity of steel $= 2 \times 10^5\ N/mm^2$

→ Unit weight of RCC $= 25\ KN/m^3$

→ Grade of concrete used in RCC $\geq M_{20}$.

→ Unit weight of steel $= \frac{D^2}{162}$ (Kg/m). where, D = Diaᵐ of bar in mm

### Grade of Concrete.

| Concrete grade | $M_{10}$ | $M_{15}$ | $M_{20}$ | $M_{25}$ |
|---|---|---|---|---|
| characteristic compressive strength | 10 | 15 | 20 | 25 |
| Ratio (C : FA : CA). | 1:3:6 | 1:2:4 | 1:1.5:3 | 1:1:2 |
| Water cement ratio (W/C) | 0.6 – 0.65 | 0.55 – 0.6 | 0.5 – 0.55 | 0.45 – 0.5 |

## Steel for Reinforcement

1. Mild Steel (Fe 250)
2. High yield Strength deformed (HYSD)

→ TOR Steel (Fe 415)

→ TMT Steel (Fe 500, Fe 550)

RCC The Composite material of Steel & Concrete acts as a Structural member & can resist tensile as well as compressive stresses very well.

| Working Stress Method | Limit State Method |
|---|---|
| Stress-strain behavior is linear. | → non-linear |
| → Also, known as elastic design. | → Also, known as plastic design. |
| → Stress based method. | → Strain based method. |
| → Materials follows hooke's law. | → Not follows hooke's law. |
| → Stress is not allowed to cross yield limit. | → Stress is allowed to cross yield limit. |
| → Safety factor is considered. | → partial safety factor is considered. |
| → Doesn't consider shrinkage, creep & long term effects. | → Considers the behavior of structure beyond yielding point. |
| → Traditional approach. | → More scientific approach. |

## Types of Reinforcement sections

① Balance section

→ Area of concrete (Ac) = Area of steel (Ast)

→ The crushing of concrete & yielding of steel occurs simultaneously.

→ The permissible stress in concrete & steel reach at same time.

→ $X = X_c$, Where $X$ & $X_c$ are actual & critical depth of neutral axis.

→ The failure of such beam is called balanced failure.

→ It is also known as critical or economical section

② under reinforced section

→ The amount of steel provided is less then balance section.

→ Area of Concrete ($A_c$) > Area of steel ($A_{st}$).

→ The yielding of steel occurs earlier then crushing of Concrete.

→ The permissible stress in steel reaches earlier then concrete

→ $x < x_c$, Actual depth of NA moves in upward direction.

→ The failure of such beam is called ductile failure.

→ It is also known as primary tension failure or tension failure.

③ over reinforced section

→ The amount of steel provided is greater then balance section

→ Area of concrete ($A_c$) < Area of steel ($A_{st}$)

→ The crushing of concrete occurs earlier then yielding of steel

→ The permissible stress in Concrete reaches earlier then steel

→ $x > x_c$, Actual depth of NA moves in downward direction.

→ The failure of such beam is called Brittle failure.

→ It is also known as primary Compression failure or compression failure

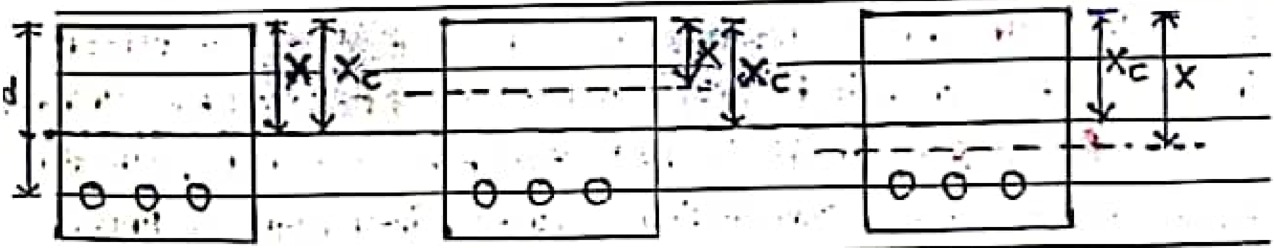
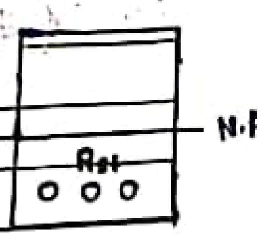



fig ①   fig ②   fig ③

Types of Reinforced section (Beam)

① singly Reinforced section

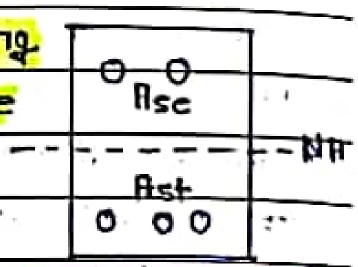



→ if the section is longitudinally reinforced along tension zone only is known as singly reinforced section.

→ In such section, the ultimate bending moment & tension carried by reinforcement, while compression is carried by the concrete.

## ② Doubly Reinforced section

If the section is longitudinally reinforced along tension zone as well as compression zone is known as doubly reinforced section.




→ The doubly reinforced section is provided to increase the moment capacity of section within limited dimension.

### Condition for DRS

→ If dimension of section (width & depth) is limited/Restricted.

→ If moment capacity of section is less then moment due to external loads. $M_{capacity} < M_{loading}$

→ If the section is subjected to heavy loading, eccentric loading, impact loading, dynamic loading, reversal loading.

## Shear & Bond of RC Sections

**Shear strength** The concrete has low resistance to shear.

→ Shear strength of concrete between tensile & compressive streng

→ That is way all shear failures are due to actual tension.

**Bond strength** The resistance of slipping of steel bar placed in concrete, when it is subjected to a force is called bond strengt

→ It occurs due to friction betn steel bar & concrete, adhesion between steel bar & surrounding concrete & interlocking of lugs.

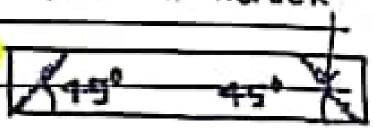
↳ IS 456 : 2000

(i) Bond strength of deformed bar is 60% more then plain bar.

(ii) For bars in compression, the value of bond stress for bars in tension shall be increased by 25%.

## Shear failure of RCC Beam

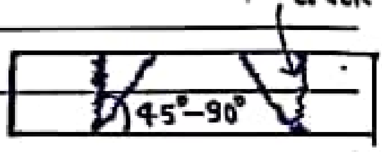
① Diagonal tension failure




→ occurs near to support where shear force is very large compare to bending moment.

→ The angle made by the failure is 45° to horizontal.

② Diagonal compression failure

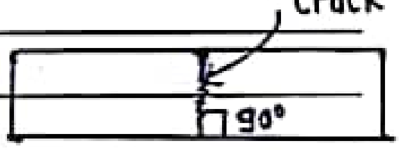



→ occurs between support & center.

→ Where shear force & bending moment are equal importance. (combined effect)

→ The angle made by the failure is 45–90° to horizontal.

③ Flexural tension failure




→ occurs at center (mid-span). Where BM is very large compare to shear force.

→ The angle made by the failure is 90° to horizontal.

## Types of shear reinforcement

Shear reinforcement provided in beam to resist diagonal tension & prevent diagonal tension failure.

→ Some minimum amount of shear reinforcement is provided to resist shrinkage stress & provide ductility to beam.

→ It provides by following types

① Vertical stirrups → more effective & normally used.

② Inclined stirrups

③ Longitudinal bars bent-up along with stirrups.

→ Horizontal component of shear force is resisted by main longitudinal bars of beam & vertical component of SF is resisted by vertical stirrups.

→ Common type of shear reinforcement is two-legged stirrups, compare to closed & open loop, with it's end anchored properly around longitudinal bar

→ Vertical stirrups placed perpendicular to the member axis.

→ Maximum shear stress in rectangular beam = 1.5 X Average stress
→ Maximum shear stress in Circular beam = 1.33 X Average stress

## Design of Shear Reinforcement

① **No shear reinforcement**
→ If factored shear force $(V_u) <$ 0.5 X shear capacity of section $(V_c$
→ Members of minor structural importance such as lintels.

② **Minimum shear reinforcement**
→ if nominal shear stress $(\tau_v) <$ design shear strength of concrete $(\tau_c$

③ **Shear reinforcement**
→ if $\tau_v > \tau_c$, shear reinforcement is designed in the form of
ⓐ Vertical stirrups ⓑ Inclined stirrups
ⓒ combined Vertical & inclined stirrups.

④ **Redesign of section**
→ if $\tau_v > \tau_{c,max}$, redesign the section.

Where:

$$\tau_v = \frac{V_u}{bd}$$

* Maximum shear stress $(\tau_{c,max}) = 0.36\sqrt{f_{ck}}$

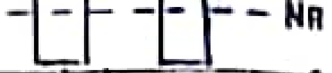
↳ **Design shear strength of concrete depends upon**
ⓐ Grade of concrete ⓑ % of longitudinal tensile reinforcement.
↳ **Maximum shear stress depends upon** : Grade of concrete.

**Maximum spacing of shear reinforcement.**
→ 0.75d or 300mm whichever is less for Vertical stirrups.
→ d or 300mm whichever is less for inclined stirrups at 45°.
Where; d = effective depth.

## Shear Stress Diagram

① Shear force diagram of a homogeneous beam is rectangular.
② Shear stress " " " " is parabolic having maximum at neutral axis.

③ Shear stress diagram reinforced concrete beam is, Shear stress = $\frac{SF}{LA \times \text{breadth of beam}}$




② Maximum shear stress in a rectangular beam is 1.5 times that of average shear stress.

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## Development Length ($L_d$)

It is the minimum length of bar which must be embedded in concrete beyond any section or overlap so that no slippage take place. It is denoted by $L_d$. → Depends on grade of concrete.

| | | | |
|---|---|---|---|
| $L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$ | (Tension) | $L_d = \frac{\phi \sigma_s}{5 \tau_{bd}}$ | (Compression) |

Where; $\phi$ = Diameter of bar

$\sigma_s$ = Stress in bar

$\tau_{bd}$ = Design bond stress

| Grade of concrete | M20 | M25 | M30 | M35 | M40 | |
|---|---|---|---|---|---|---|
| Design bond stress ($\tau_{bd}$) | 1.2 | 1.4 | 1.5 | 1.7 | 1.9 | N/mm² |

↳ Design bond stress value for plain bars in tension

→ Design bond stress for plain bar in compression, increased by 25%

→ " " " for deformed bar should be increased by 60%

## Types of steel

① Plain bar → mild steel → $f_y$ = 250 N/mm²

② Deformed bar → High yield strength deformed bar (HYSD steel)

→ TOR steel, $f_y$ = 415 N/mm²

→ TMT steel, $f_y$ = 500 N/mm² (Thermo mechanically treated)

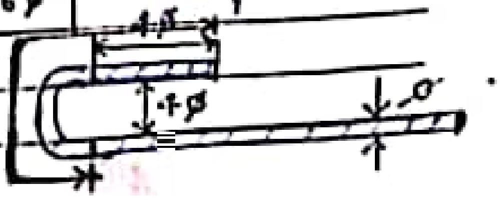
## # Anchorages Length ($L_o$)

The extra length of bar that should be provided at end to provide sufficient development length is known as anchorages length.


| Types of bend | 45° | 90° | 135° | 180° |
|---|---|---|---|---|
| Anchorages length | 4 $\phi$ | 8 $\phi$ | 12 $\phi$ | 16 $\phi$ |

Note : standard bend = 90° bend

Standard hook = 180° bend 16$\phi$




Note:- ① Dia of standard hook ≮ 4$\phi$

② minimum ...

## Cases of stirrup

| Types of bend | 90° | 135° | 180° |
|---|---|---|---|
| Anchorages length | $8\phi_t$ | $6\phi_t$ | $4\phi_t$ |

For seismic forces → 135° bend

## # Splicing/Lapping.

If the required length of steel bar is greater then available length of steel bar, then the bar need to be spliced to get full length.

Splicing Length

1. Compression member : $L_d$ or $24\phi$, whichever is greater.
2. Flexural member : $L_d$ or $30\phi$, whichever is greater.
3. Direct Tension : $2L_d$ or $30\phi$, whichever is greater.
4. St. length of lap in hook : $15\phi$ or 200 mm, whichever is greater.

Note : if diaⁿ of bar > 36 mm, no splicing

→ In this case either diaⁿ of bar decreased or welded.

→ if diaⁿ are unequal; Lap length based on minimum diaⁿ of bar.

## # Bundling of bars

| Bundling of bars | Development Length |
|---|---|
| ① Two bars are in contact | Increased by 10% |
| ② Three " " " " | " " 20% |
| ③ four or more " " " " | " " 33% |

## Analysis of Singly Reinforced Beam

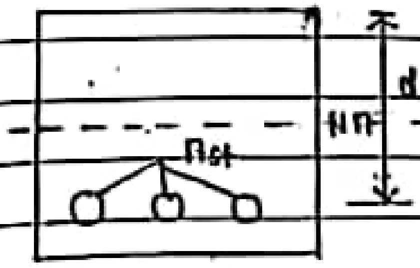



fig: RCC Beam

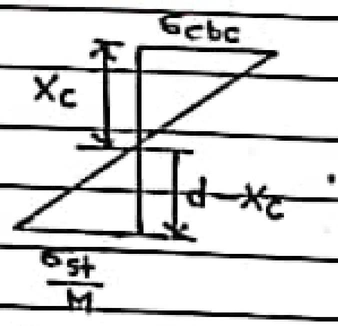



fig: Stress Diagram

Where; $x_c$ = Critical depth of N.A

$d$ = effective depth of beam

n.$A_{st}$ = Area of steel in tension.

$\sigma_{cbc}$ = permissible compressive bending stress in concrete

$\sigma_{st}$ = permissible tensile stress in steel.

$M$ = modular ratio = $\frac{280}{3\sigma_{cbc}}$

① Balanced section ∵ $x = x_c$

By similar triangle ; $\frac{\sigma_{cbc}}{x_c} = \frac{\sigma_{st}/m}{d - x_c}$ or, $\frac{\sigma_{cbc}}{x_c} = \frac{\sigma_{st}}{m(d-x_c)}$

∴ $\frac{M\sigma_{cbc}}{\sigma_{st}} = \frac{x_c}{d-x_c}$

→ if $x < x_c$, under-reinforced section.
→ if $x > x_c$, over-reinforced section.

IS 456-2000

## Permissible Stress in Concrete

$N/mm^2$

| Grade of Concrete | $\sigma_{cbc}$ $N/mm^2$ | Bond stress $\tau_{bd}$ $(N/mm^2)$ | modular ratio M | Design bond stress in limit state method |
|---|---|---|---|---|
| M10 | 3 | — | 31.11 | — |
| M15 | 5 | 0.6 | 18.67 | — |
| M20 | 7 | 0.8 | 13.33 | 1.2 |
| M25 | 8.5 | 0.9 | 10.98 | 1.4 |
| M30 | 10 | 1.0 | 9.33 | 1.5 |
| M35 | 11.5 | 1.1 | 8.12 | 1.7 |
| M40 | 13 | 1.2 | 7.18 | |
| M45 | 14.5 | 1.3 | 6.44 | 1.9 |
| M50 | 16 | 1.4 | 5.83 | |

## Permissible Stress in Reinforcement

| SN | Type of reinf. | Characteristic strength ($f_y$) | permissible stress ($\sigma_{st}$) |
|---|---|---|---|
| 1 | Mild steel bar | 250 $N/mm^2$ | 140 $N/mm^2$ ($d \le 20mm$) |
| | (Grade I) | | otherwise 130 $N/mm^2$ |
| 2. | HYSD Fe 415 | 415 $N/mm^2$ | 230 $N/mm^2$ |
| 3. | HYSD Fe 500 | 500 $N/mm^2$ | 275 $N/mm^2$ |

## RC section in Bending/

### Reinforcement

Plain cement concrete beam fail by developing cracks on tension side even under small load. this is because flexural tensile strength about 15%.(10−25%) of its compressive strength. to prevent this failure it is required to place steel bars on tension side. Steel bars take care of tensile stress.

→ :- Diameter of bar for different element

| | | |
|---|---|---|
| ① slab | 6−16mm(8mm) | |
| ② Beam | 10−25mm | Clear spacing between bar |
| ③ Column | 12−38mm | ① minimum horizontal spacing |
| ④ Distribution | 5−12mm | |

ⓐ Maximum diameter of bar, $\phi_{max}$
ⓑ Maximum size of aggregate + 5mm (whichever is greater)

② Minimum Vertical Spacing

ⓐ max^m dia^m of bar ⓑ $\frac{2}{3}$ x max^m. size of aggregate ⓒ 15mm

### Cover Block & Cover

Cover block is a rectangular piece of mortar used for maintaining required cover. the mortar for concrete block should be 1:1 to 1:2 to resist the compressive force exerted by steel as well as live load during the placing of steel.

→ Center to center spacing of cover block = 0.75m.

→ Purpose of cover block ⇒ provide cover to reinforcement.

Cover is a distance between outer face of steel & the nearest extreme fiber. Effective cover is a distance between centroid of steel & nearest extreme fiber.

| SN | Element | Cover |
|---|---|---|
| 1 | Slab | 15mm |
| 2 | Beam | 25 mm |
| 3 | Column (200X200) | 25 mm |
| 4 | Column (>200X200) | 40 mm |
| 5 | Distribution | 2ϕ or 25mm, whichever is greater. |
| 6 | End of reinf. | 2ϕ or 25 mm, whichever is greater. |
| 7 | Footing | 75 mm |
| 8 | Sea | 50mm plus above cover |

## Purpose of Cover

→ Good grip betn steel & Concrete → protect steel from corrosion.

→ Protect steel from acid, salt etc.

## Maximum size of Coarse Aggregate

→ ≯ $\frac{1}{4}$th of minimum thickness of member.

→ for most work, 20mm aggregate is suitable. (Beam, Column)

→ 40mm & larger size may be permitted. (foundation used)

→ for thin section, 10mm nominal maximum size. (slab, roof)

## Bar Bending Schedule

Bar bending schedule is a descriptive list containing details regarding the exact shape, size, dimension & diameter of each & every bar together with the weight & number of bar required for specific work.

## Assumptions of RC section in Bending

① At any C/s the plain section, remain plain before & after bending.

② Modulus of elasticity of steel & concrete is constant.

③ All the tensile stresses are taken up by the reinforcement alone & none by the concrete.

④ All the compressive stress are taken up by the concrete alone & non by the reinforcement.

⑤ The bond between concrete & steel is sufficient to resist tensile or compressive stresses.

Deep beam → $\frac{\text{effective span}}{\text{overall span}} \left(\frac{L}{D}\right) \leq 2$ & 2.5 for SSB & continuous beam.

→ Deep beams are designed based on bending moment.

Equivalent Area of steel Compression

$= m_s A_{sc} - A_{sc}$

$= A_{sc}(m_s - 1)$

$= A_{sc}(1.5m - 1)$

· Reinforcement in Beam (Design consideration)

① → maximum area tension reinforcement of beam $\not>$ 0.04bD

→ minimum " " " " $\not<$ 0.3% of cross sectional area of plain bar.

→ minimum tension reinforcement of beam $\not<$ 0.2% of cross sectional area of HYSD bar.

② → maximum area compression reinforcement of beam $\not>$ 0.04bD

③ → minimum area of tension reinforcement $\not<$ $A_s = \frac{0.85bd}{f_y}$

④ → side face reinforcement is provided if depth of beam exceed 750mm.

→ Total area of side face reinforcement shall be greater than 0.1% of web area & equally distributed on both face.

→ Spacing S $\not>$ 300mm or web thickness } whichever is lesser.

(5) In case of Cantilever beam/ slab, the main reinforcement is provided top face of beam.

## Maximum Deflection in Beam

(1) To Control the deflection the span to effective depth ratios for spans upto 10m should be as follw. (IS code : 2000)

| Cantilever | Simply supported | Continuous |
|---|---|---|
| 7 | 20 | 26 |

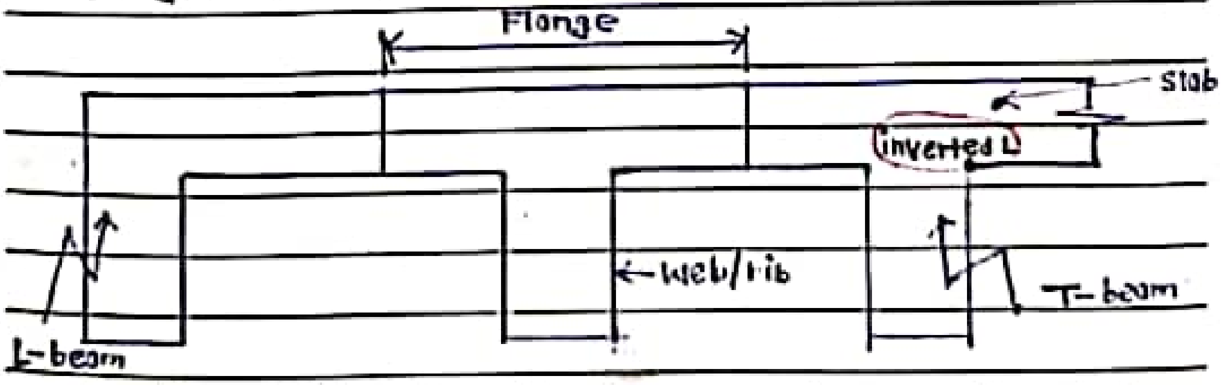
(2) for spans above 10m Values in m may be multiplied by 10/span in meter, except for Cantilever in which case deflection Calculations should be made.

(3) The deflection of beams can be decreased by increasing the depth of bear

## Flange Beams

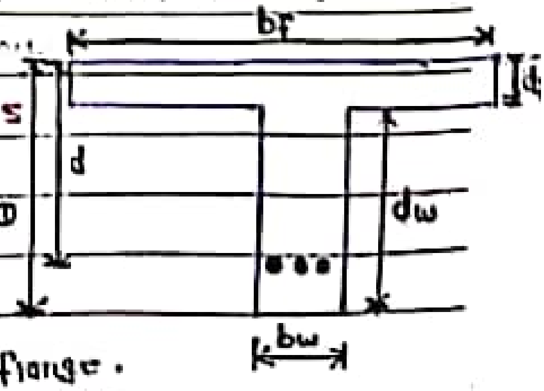
→ In RCC Construction, slabs & beams are cast monolithically. In such Construction, a portion of the slab act as flange of beam.

→ flange bems are of two types : T-beam & L-beam




→ Intermediate beams : T-beams → End beams : L-beams

## Terms used in flange beams




1) Breadth of flange (bf)

(a) $\frac{1}{3}^{rd}$ of effective span of T-beam

(b) Distance between center of ribs of adjacent beam.

(c) bw of rib plus 12t the thickness of flange.

: bf should not be less than ... of clear span.

② Thickness of flange ($D_f$)

→ Thickness of flange is equal to thickness or depth of slab.

③ Breadth of Web ($b_w$)

ⓐ 2.5 times the sum of diameter of bars

ⓑ minimum size 15 cm

ⓒ $\frac{1}{3}$rd of d but not less then 2t & more then $\frac{2}{3}$d.

④ Depth of rib (overall) D

ⓐ for light load → $\frac{1}{15 \text{ to } 20}$ of the span.

ⓑ for medium load → $\frac{1}{12 \text{ to } 15}$ of the span.

ⓒ for heavy load → $\frac{1}{12}$ of the span

## Other Beam / Elements

① Hidden beam / Conceal beam A beam which is concealed in slab. The max^m thickness should be thickness of depth of slab.

② Coupling beam It is a type of beam which connects two shear walls or any other elements of a structure that are used for withstanding lateral loads in combines.

③ Spacer bar When more then two layers of bar are required then these layers of bar are separated by placing a piece of bar along the breadth of beam, which is known as spacer bar.

→ Spacer bar is perpendicular to main bar of member.

④ Hanger bar In case of singly reinforced beam, at least two bars having diameter 12mm is provided in compression zone to support the shear reinforcement, which is known as hanger bar.

# Axially Loaded RC Column

→ RCC column is compression member. → Example: Column, strut, stanchi

## Types of Columns

① Based on slenderness ratio

* pedestral = $\frac{l_{eff}}{b} \leq 3$

ⓐ Short Column → $3 < \frac{l_{eff}}{b} \leq 12$

→ $10 < \frac{l_{eff}}{r_{min}} \leq 40$ → Crushing failure occurs.

ⓑ Long Column → $\frac{l_{eff}}{b} > 12$ → $\frac{l_{eff}}{r_{min}} > 40$

→ Buckling failure occurs.

ⓒ Intermediate Column → $\frac{l_{eff}}{b} \leq 30$ → $30 < \frac{l_{eff}}{r_{min}} \leq 120$

→ Crushing & buckling failure occurs

Where; $l_{eff}$ = Effective length of column

$b$ = least lateral dimension

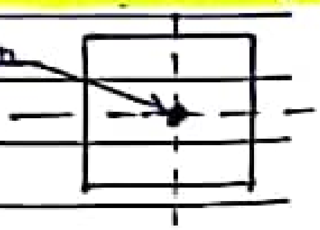
$r_{min}$ = least radius of gyration

Note: Reinforcement in pedestral = 0.15 % of gross-sectional area.

② Based on type of loading

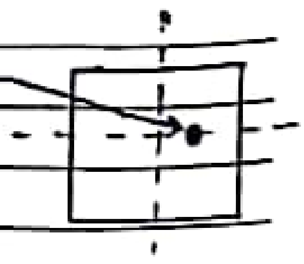
ⓐ Axially loaded Column → Vertical axial loads act on the center of gravity of the cross-section of column.

Example: interior column of multi-storey building with symmetrical loads from floor slabs from all sides.




ⓑ Column with uniaxial eccentric loading

→ Vertical load do not coincide with center of gravity of Column Cross-section. & load acts either on X or Y axis of the column cross-section.



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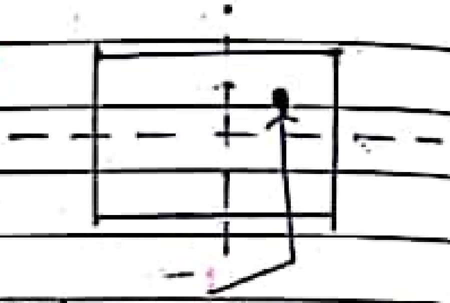
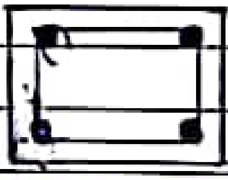
**Example** : Columns rigidly connected beam from one side only such as edge columns.

**(c) Column with biaxial eccentric loading**

→ Vertical load on the column is not coincide with center of gravity of cross-section & loads act on either certain distance along both in x & y direction.




**Example**: Corner columns with beams rigidly connected at right angles at the top of columns.



## ③ Based on types of reinforcement

**(a) Tied column**: This type of column is commonly construction from reinforced concrete. longitudinal reinforcement are confined within closely spaced tie reinforcement.

**(b) Spiral column**: It is also construction from reinforced concrete. in this type of column, longitudional bar are confined within closely spaced & continuously wound spiral reinforcement.

**(c) Composite column**: When the longitudinal reinforcement is in the form of structural steel section or pipe with or without longitudinal bars. this type of column have high strength with fairly small cross-section.

## ④ Based on construction material

① Reinforced concrete ② Steel ③ timber ④ brick ⑤ block ⑥ stone

## ⑤ Based on Shape

① Square column
② Rectangular column
③ Circular column
④ Hexagonal column
⑤ T-shaped column
⑥ L-shaped column.

## Codal provision / Design specification / Design Consideration of column

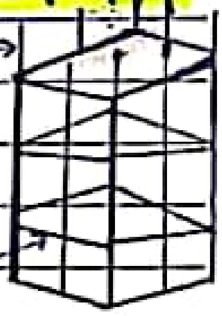
① minimum diameter of longitudinal bar = 12mm

② minimum number of longitudinal bar : provide at lest one bar at each corner.
→ for square & rectangular = 4
→ for circular = 6
→ for octagonal = 8

③ Percentage of steel:
→ minimum % of reinforcement = 0.8% cross sectional area
→ maximum % reinforcement = 4% for practical purpose
= 6% for theoritical purpose.

④ Clear cover:
→ for 200mm x 200mm column = 25 mm
→ for column size > 200mm = 40mm

⑤ maximum spacing of longitudinal bars = 300mm.




## Design Consideration of lateral ties (transverse reinforcement)

① Diameter of lateral ties ($\phi_t$) = $\frac{\phi_{Largest\ of\ longitudinal\ bar}}{4}$ or 6mm
→ whichever is greater.

② spacing of lateral ties (pitch) = least lateral dimension of column
= $16 \times \phi_{min}$
= $48 \times \phi_t$ (whichever is less)
= 300mm

③ maximum diameter of ties ≯ 12mm

→ The purpose of lateral ties is to avoid the buckling of longitudinal bars.

→ The richer the concrete, the more economical is the design of column.

## Core section or kernal of column section

Centrally located portion of column in which the load must act so as to produce only compressive stress but not produce tensile stress is called core section.

| Section | Core |
|---|---|
| 1. Square (B x B) | B/3 |
| 2. Rectangular (B x D) | B/3, D/3 |
| 3. Circular (Dia. D) | D/4 |

## Load Carrying Capacity of Column.

① Load Carrying Capacity of short Column $P = \sigma_{cc} A_c + \sigma_{sc} A_{sc}$

② Load Carrying capacity of helical stirrups around the longitudinal steel bars will be increased by 5%.

$P = 1.05 \times (\sigma_{cc} A_c + \sigma_{sc} A_{sc})$

Where: $\sigma_{cc}$ = permissible stress in concrete in Compression

$A_c$ = Area of Concrete.

$\sigma_{sc}$ = permissible stress in steel in compression.

$A_{sc}$ = Area of Steel in Column.

③ Load Carrying Capacity of long Column $P = C_r \times (\sigma_{cc} A_c + \sigma_{sc} A_{sc})$

Where: $C_r$ = Reduction factor $= 1.25 - \frac{l_{eff}}{48b} = 1.25 - \frac{l_{eff}}{160 r_{min}}$

## Slab

Slab is two dimensional or planer element. Which thickness is very small as compared to its length & width.

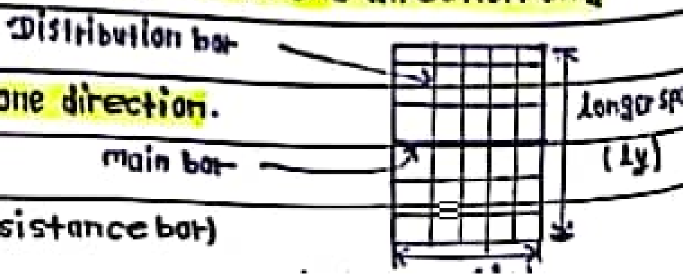
## Types of Slab

① One way slab

The slab rests on two side, either beam or wall in sides.

→ the deflection of slab is considered in one direction only.

→ $\frac{l_y}{l_x} > 2$




→ one way slab bending in one direction.

→ main bar is provided on shorter side. (moment resistance bar)

→ Distribution bars are provided on longer side. (Temperature & shrinkage resistance bar)

② Two way slab

The slab rest on either beam or wall in four sides.

→ The deflection of slab is considered in both direction.

→ $\frac{l_y}{l_x} \leq 2.$

→ main bar or reinforcement provided on both direction.

→ two way slab bending in two direction.

## Vertical deflection control criteria

$\frac{\text{Span}}{\text{overall depth}}$ = 30 (one way simply supported slab)

= 30 ( " " Continuous slab)

= 35 ( Two way simply supported slab)

= 40 ( " " Continuous slab)

= 12 ( Cantilever slab)

Note: Cantilever slab is always one way slab.

## Design Consideration for slab / specification / Codal provisio

① Clear cover → ⌀ diameter of bar or 15mm.

② minimum percentage of reinforcement

= 0·15 % of gross area (for mild steel used)

= 0·12 % of gross area (for deformed bar)

③ Maximum spacing of bars:

ⓐ for main bar → 3x effective depth of slab (3d) or 300mm } Whichever is less

ⓑ Distribution bar → 5d or 450mm (Whichever less)

④ Curtailment of bar

→ Curtailment of alternate bar at simply supported slab at a distance

= $\frac{\text{Shorter Span}}{7}$

⑤ minimum overall depth of slab = 100mm

⑥ max$^m$ diameter of main steel bar = $\frac{1}{8}$th of overall depth.

⑦ Cover of end of bar = 2∅ or 25mm whichever is greater.

⑧ minimum clear spacing between bar.

→ Nominal maximum size of coarse aggregate + 5mm

→ max$^m$ diameter of bar, $\phi_{max}$ (whichever greater)

## Torsional Reinforcement (Corner reinforcement)

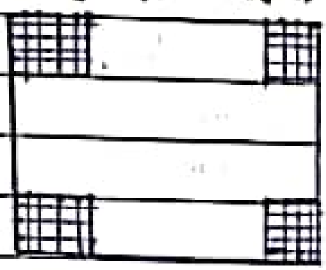
→ provided at simply supported discontinuous edge. (four edges)

→ length of torsional bar = $\frac{1}{5}$ of shorter span.

→ provided in mesh form.

→ Square mesh → Two layer (Top & bottom)

→ Area of torsional reinforcement = 0.75 × maximum area of slab.

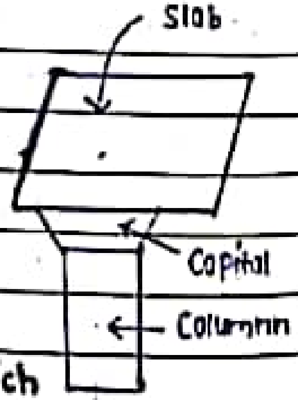


## Flat slab

→ minimum depth of slab = 125 mm (5")

→ directly rests on Column. → no Beam.

→ Column head / capital : Enlarge portion of Column in which slab rests.




Drop pannel : Thickened part of slab in which rest on Column.

## Ribbed slab

A reinforced concrete slab with equally spaced rib parallel to sides, having a waffle appearance from below, is called ribbed slab. → lighter & stiffer → provide on longer span → good vibration control capacity → high load carrying capacity → less no. of column required.

→ Used on laboratories & hospitals etc.

# Design steps of Slab

## 1 Design of one-way slab

Basic Value

(a) Check for ratio of spans : $\frac{l_y}{l_x} > 2$ (one way slab)

(b) Determine the depth of slab

→ By deflection criteria.

$\frac{l}{d} \leq$ Basic Value $\times F_1 \times F_2 \times F_3$

Where: $F_1 > 1.25$

$F_2$ & $F_3$ close to unity.

| | l/d ratio |
|---|---|
| Cantilever | 7 |
| Simply supported | 20 |
| Continuous | 26 |

(c) find the factored moment $M_u$ for 1m width of slab.

(d) Determine $M_{u,lim}$ for 1m width of slab.

(e) spacing of main bars must be calculated.

$$S = \frac{\frac{\pi \phi^2}{4}}{A_{st}} \times 1000$$

(f) Check for shear : Design shear $(\tau_v) = \frac{V_u}{b \times d}$

→ $K_s$ depend on slab thickness.

→ Design strength of concrete $= K_s \tau_c$

→ if $\tau_v > \tau_c$, slab thickness is increased & redesigned.

(g) Check for deflection : $\frac{l}{d} \leq$ Basic Value $\times F_1 \times F_2 \times F_3$

(h) Distribution steel

→ minimum 0.15 % of total cross-section for mild steel.

→ " 0.12 % " " " " " deformed bar.

## 2 Design of two way slab

(a) Check for ratio of spans : $\frac{l_y}{l_x} \leq 2$ (two way slab)

(b) Determine the depth of slab.

→ if span < 3.5 m & live load < 3 kN/m² ∴ $\frac{l_x}{d}$ ratio is follows.

| | Fe 250 | Fe 415/Fe 500 |
|---|---|---|
| Simply supported | 35 | 28 |
| Continuous | 40 | 32 |

→ if shorter span is grater then 3.5 m or live load > 3 kN/m²

→ $l_x/d \leq$ Basic Value $\times F_1 \times F_2 \times F_3$

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(c) Find effective length $l_x$ & $l_y$ as obtained from 456 : 2000

(d) Calculate design moments using coefficients as per condition (table 26 of IS 456 : 2000)

$M_x^+ = \alpha_x^+ \times W_u \times l_x^2$ $\quad$ $M_x^- = \alpha_x^- \times W_u \times l_x^2$

$M_y^+ = \alpha_y^+ \times W_u \times l_x^2$ $\quad$ $M_y^- = \alpha_y^- \times W_u \times l_x^2$

Where: $M_x$ & $M_y$ = design moments along x & y direction.

→ +ve sign indicates sagging moment at mid-span

→ −ve sign indicates hogging moment in top face of slab at support locations.

(e) Calculate design shear force : $V_u = W_u \times \frac{r^4}{1+r^4} \times \frac{l_x}{2}$

Where, $r = \frac{l_y}{l_x}$

(f) Design reinforcement in both directions.

$$M_u = 0.87 \times f_y \times A_{st} \times d \times \left(1 - \frac{A_{st} f_y}{Bd\, f_{ck}}\right)$$

(g) Check for shear : $\tau_v = \frac{V_u}{b \times d}$

→ $\tau_v < K_s \tau_c$, where : $K_s$ = factor depend on slab thickness obtained from Clause 40.2 in IS 456 : 2000

→ Shear reinforcement is avoided in slab so if $\tau_v > \tau_c$, the slab thickness is increased & redesigned.

(h) Check for deflection : $l/d$ provided ≤ Basic value $\times F_1 \times F_2 \times F_3$