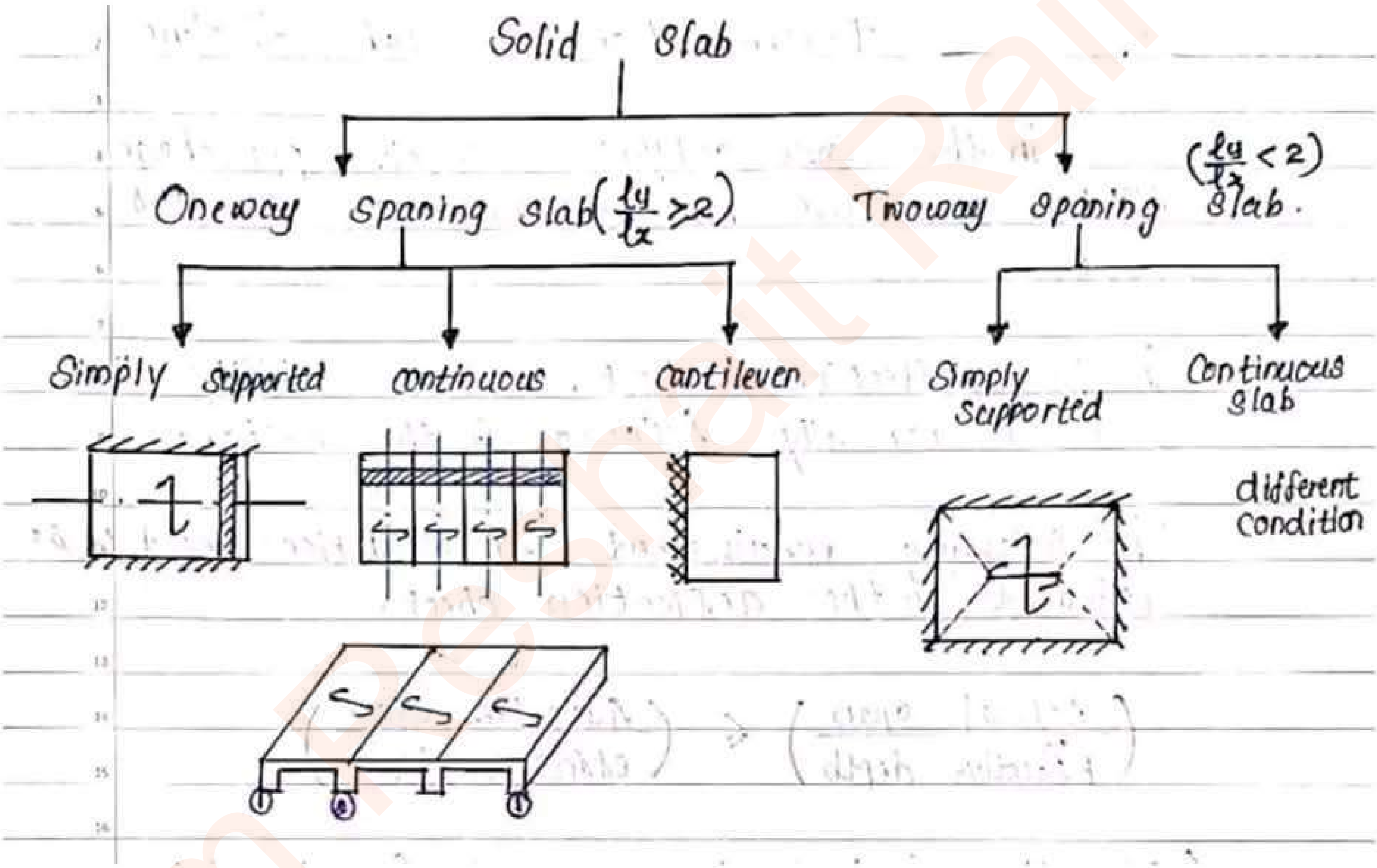
# Design of Floor Slab

# Floor slab

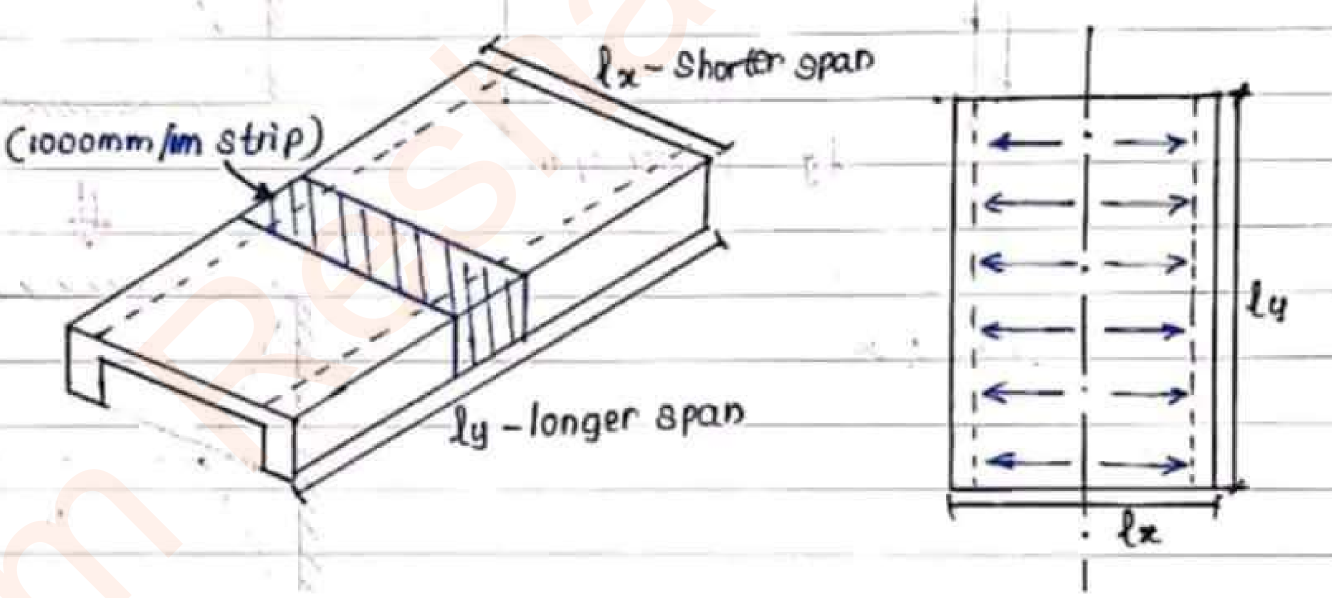

Solid Slab
Oneway spaning slab($\frac{ly}{lx} > 2$)
Twoway spaning slab. ($\frac{ly}{lx} < 2$)
Simply supported
continuous
cantilever
Simply supported
Continuous slab
different condition

# One way spanning slab…..

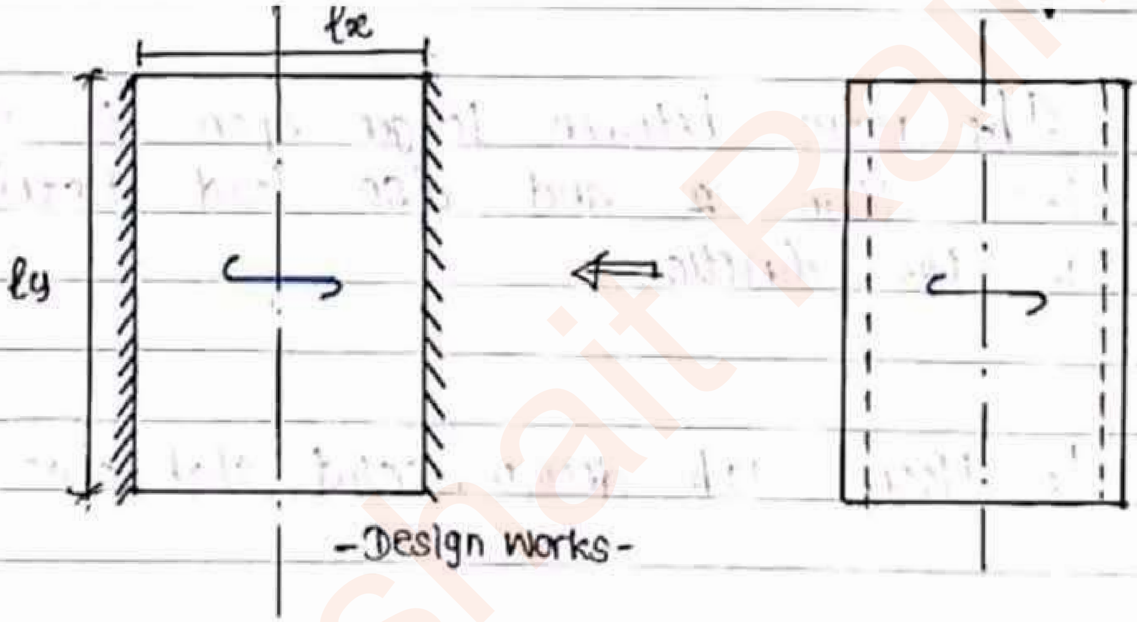
## Design Of Floor Slabs

Basically slab can be categorize in to two types which are given below;

01. One way slab



# One way spanning slab…..




-Design works-

$\frac{ly}{lx} \geq 2$ Oneway span slap

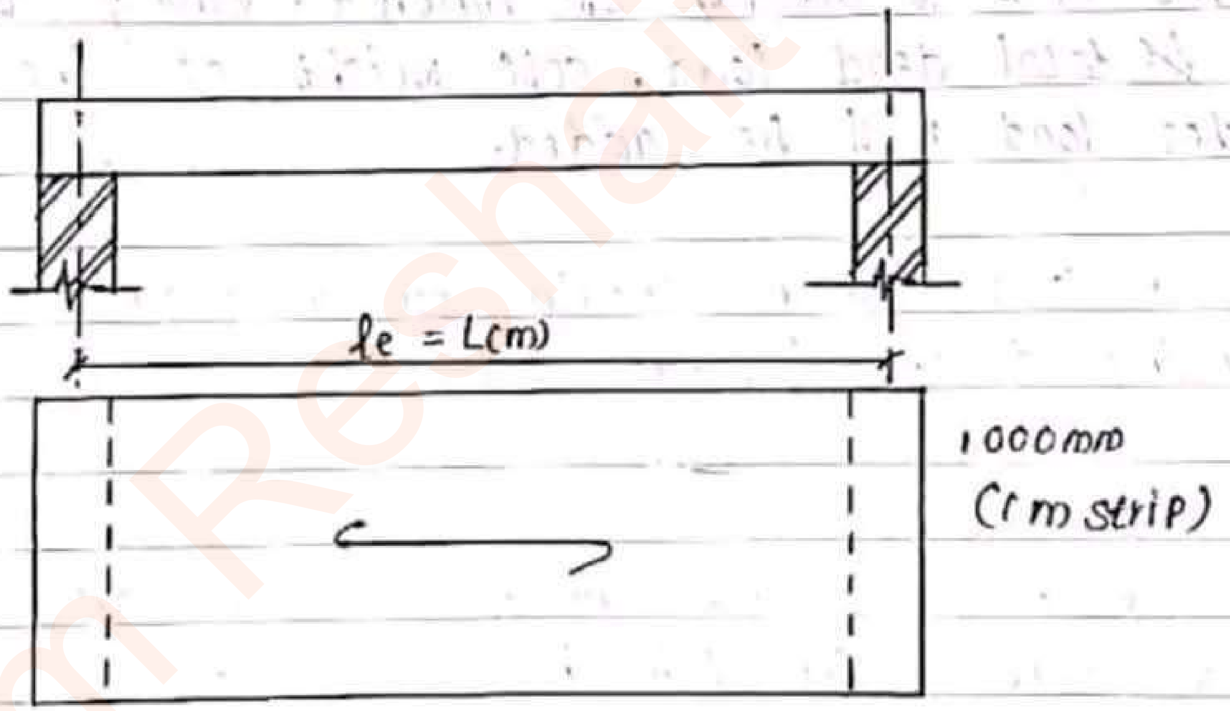
The ratio between longer span (ly) and shoter span(lx) is greater than or equal to 2 and also load distribution should be in one direction.

# One way spanning slab….

1. One way spanning slab –

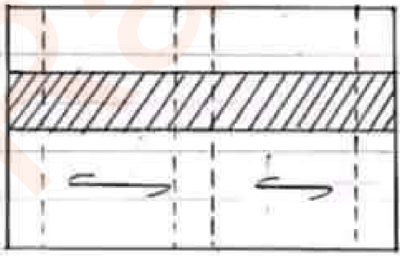
In this type there are 3 different conditions are there. Such as;

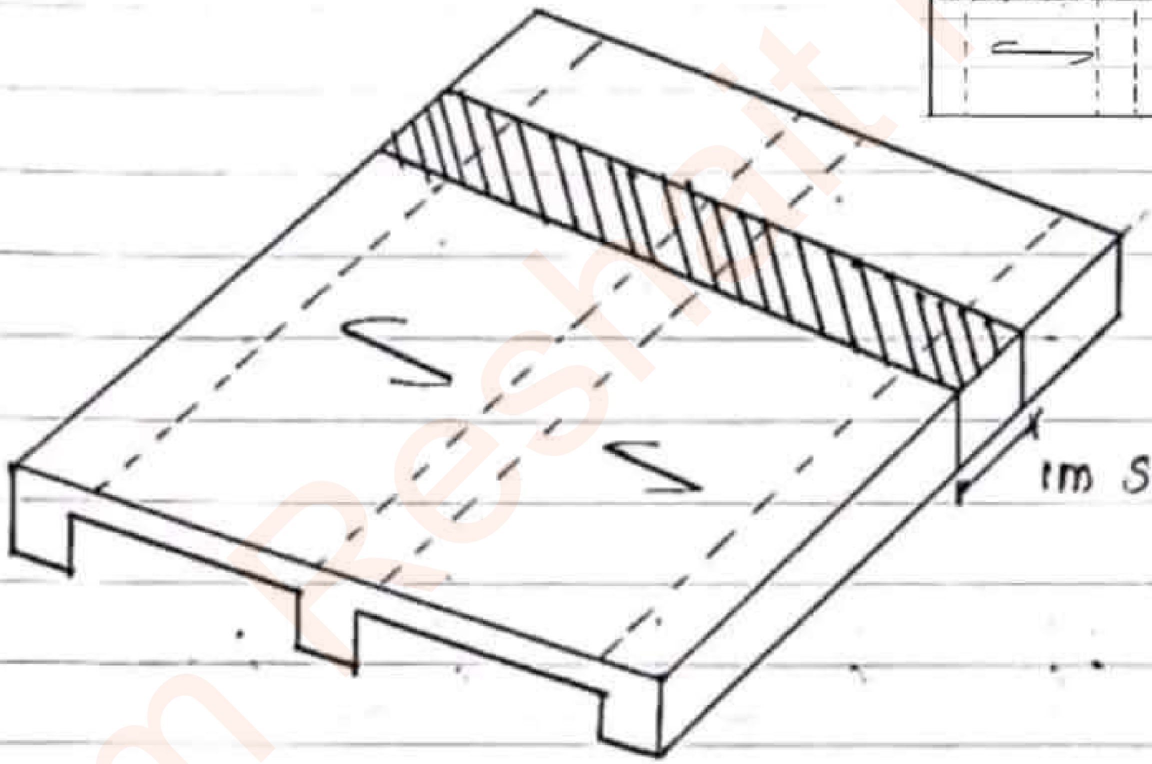
01. Simply supported Slab



# One way spanning slab....

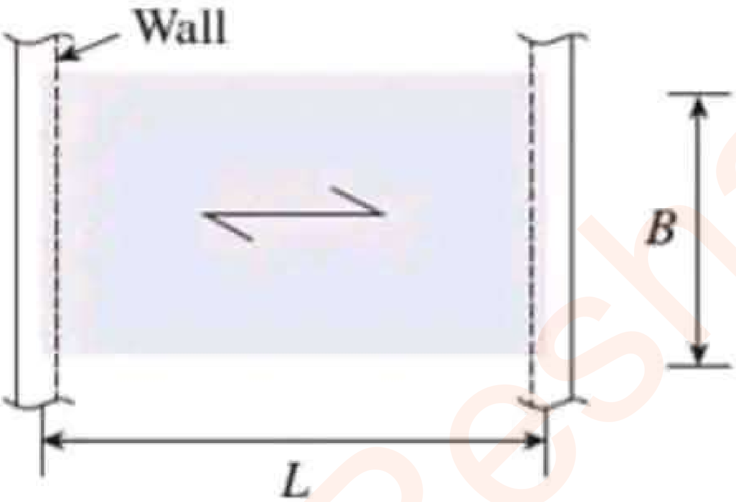
02. Continuous one way slab.



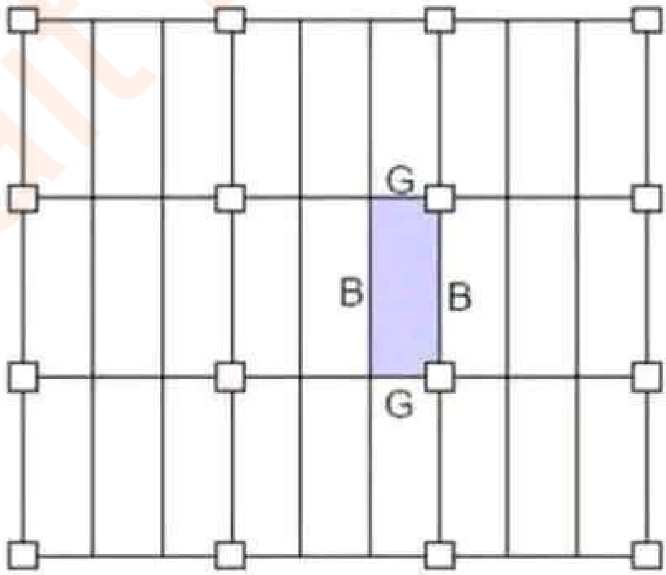



# One way spanning slab

One-way slabs, supported by parallel walls or beams, bend in only one direction and transfer their loads to the two opposite support walls or beams. The ratio between longer span to shorter span is equal or greater than two.

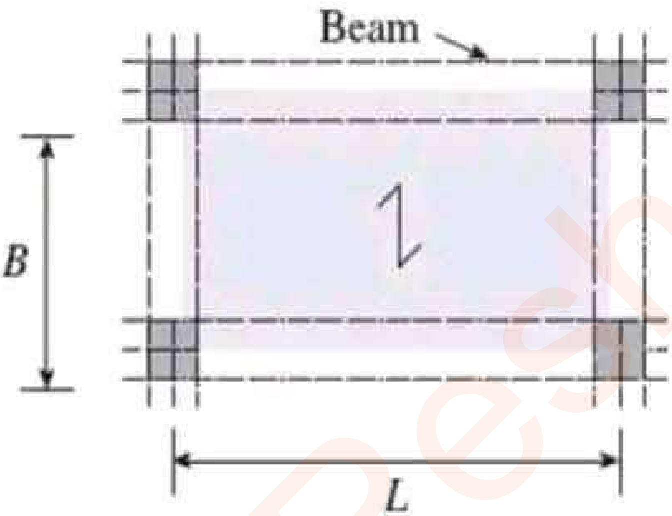


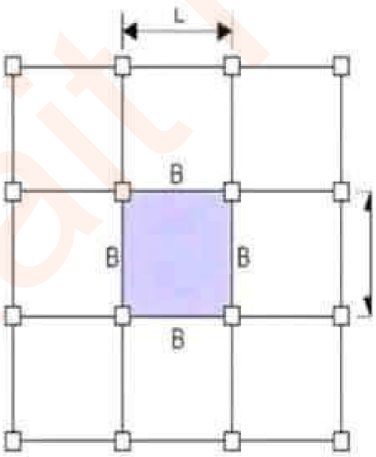

(a)

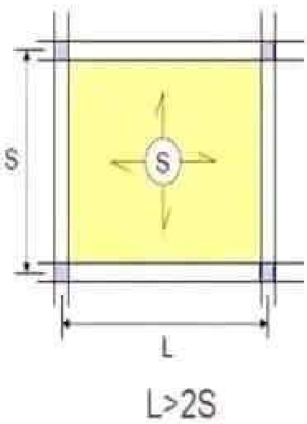


# One way spanning slab…..

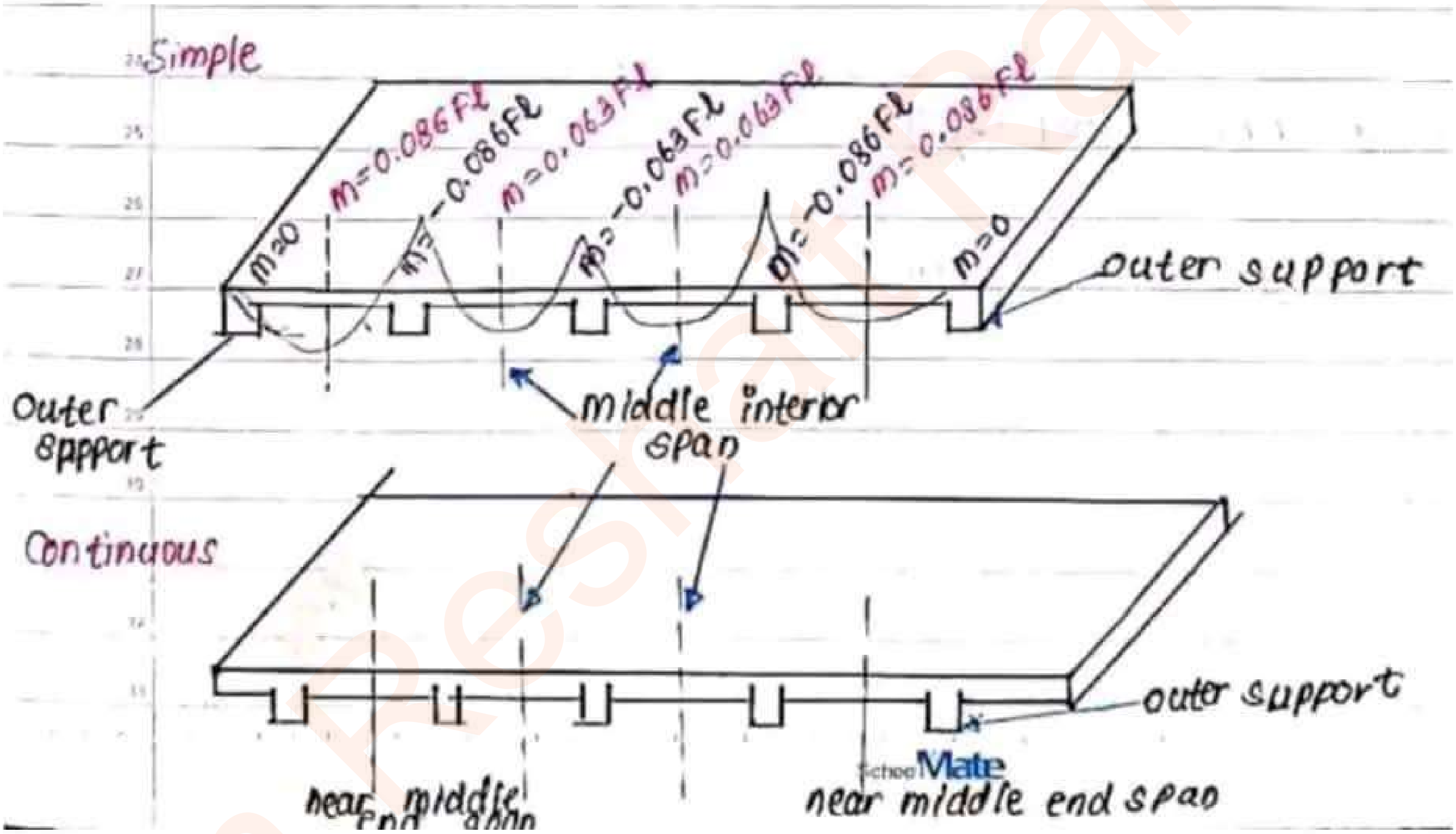
Even when a rectangular slab is supported on all the four edges, the slab may be considered as a one-way slab if the length-to-breadth (L/B) ratio of the slab is equal to or greater than two.



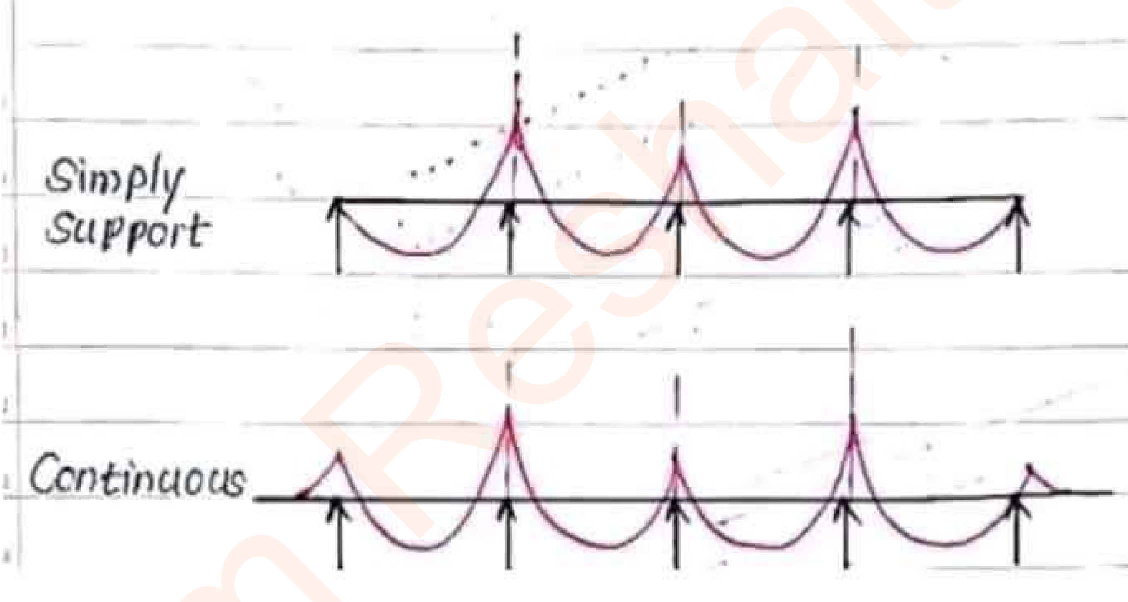



# Continuous One way spanning slab



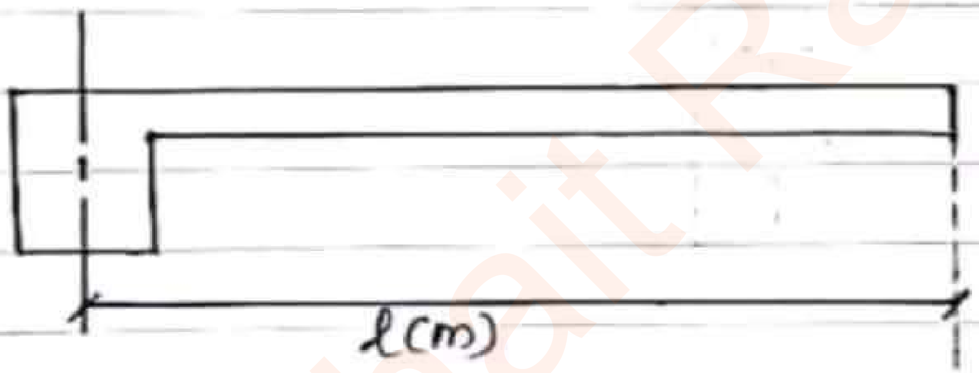
# Continuous One way spanning slab

For one way spanning continous slab the design bending moment and shear force can be determine from table 3.12 (ultimate Bending Moment & Shear forces in one way spanning slab, BS 8110 part 01 1997)



# Cantilever slab

a3. Cantilever slab

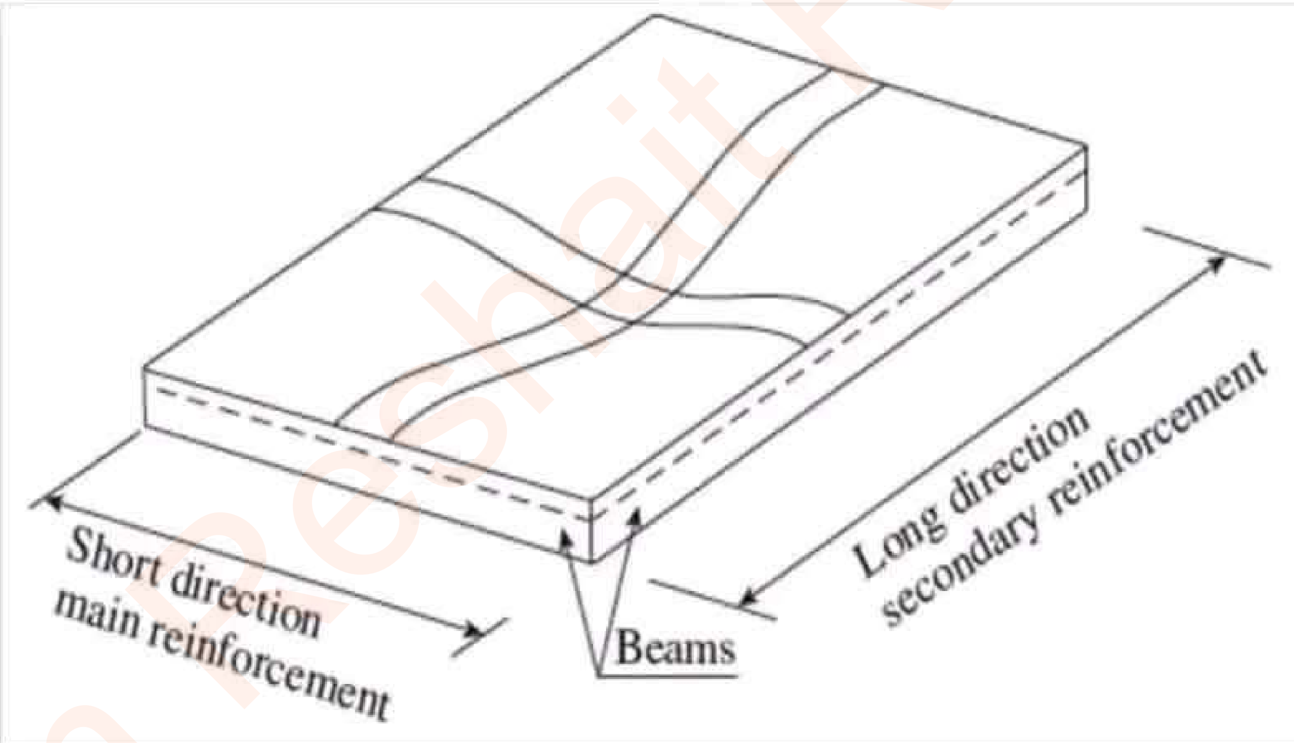



Design BM $= wl.(l/2)$

$M_{design} = \dfrac{wl^2}{2}$ kNm

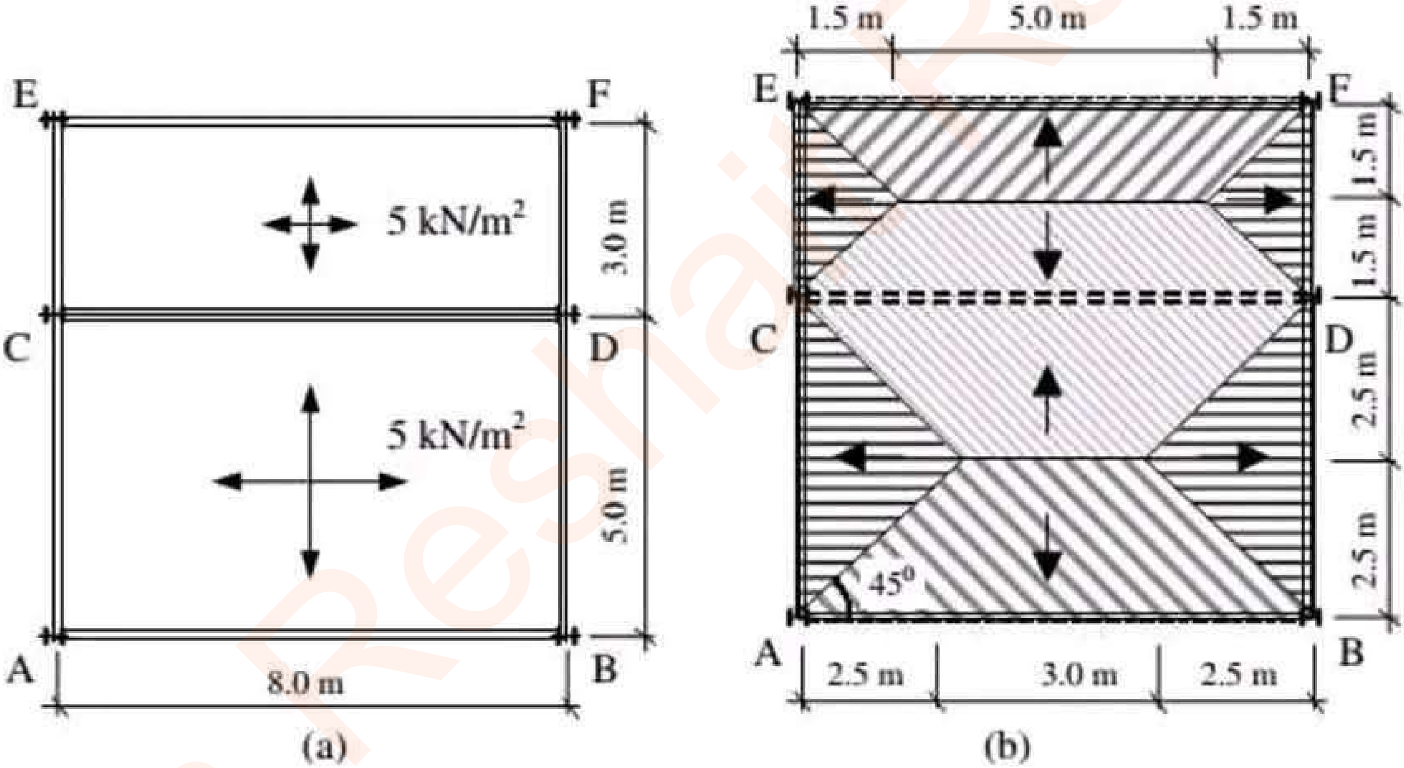
# Two way spanning slab

Two-way slabs are designed to transfer their loads to all the four support walls. When the ratio of long side to short side of a slab is less than two, it is called two-way slab



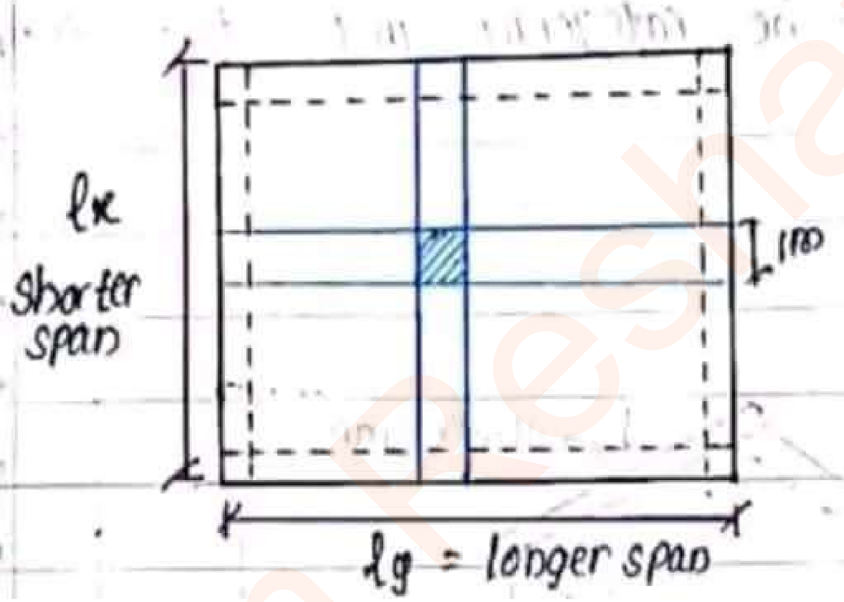
# Two way spanning slab.....

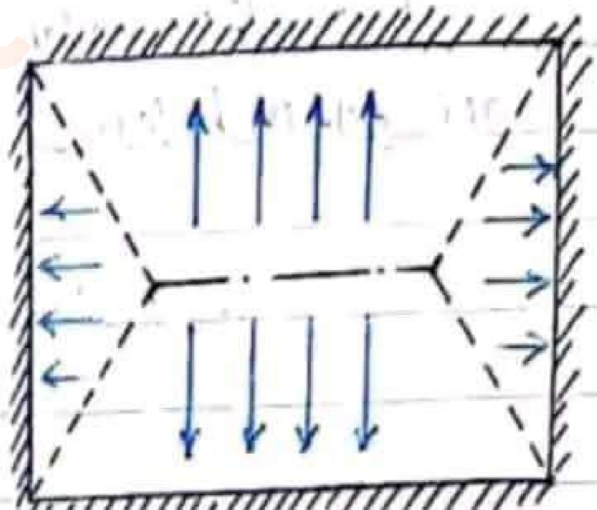
In all four sides slab load is distributed. And also the main concept is that the ratio between longer span to shorter span ratio is less than two.



# Two way spanning slab

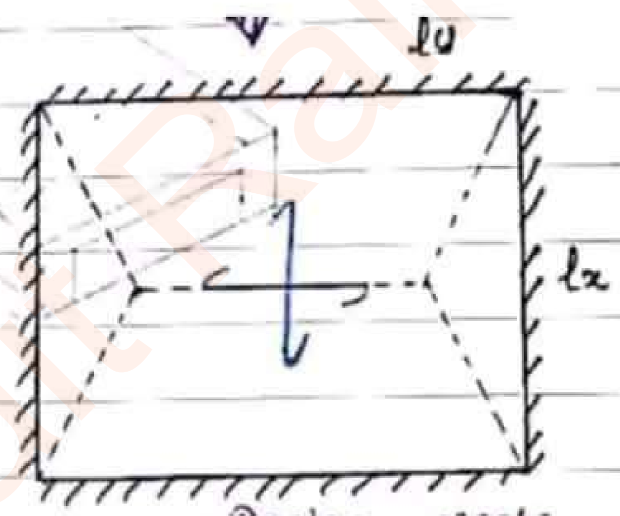
02. Two Way slab



# Two way spanning slab

$\frac{ly}{lx} < 2$




-Design works-

The ratio between longer span to shorter span is less than 2 and also load distribution should be in two direction.

# Two way spanning slab

In design application, there are two types of two way spanning slab can be design.

1. Simply supported two way spanning slab.

Normally in the design works there are some formulas (design formulas), equations, figures and close no should be mension in the reference column after that calculations will be executed in the description column & finally a result should be written in the output column.

In this type of two way spanning slab there is no any supporting moments in the edges but it carries mid span moments.

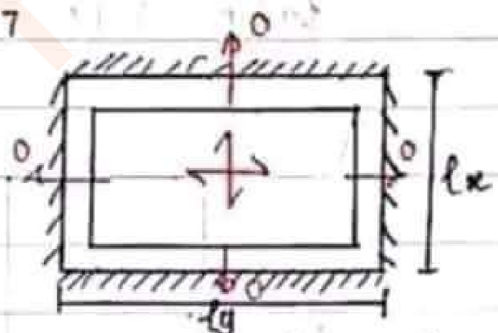
# Two way spanning slab

$m_{sx} = a_{sx} n l_x^2$

$m_{sy} = a_{sy} n l_x^2$ which is denorted in equation no 10 & equation no. 11 under close 3.5.3.3 - simply supported slab BS 8110 - 1997

$M_{sx} = \alpha_{sx} n l_x^2$ equation 10

$M_{sy} = \alpha_{sy} n l_x^2$ equation 11

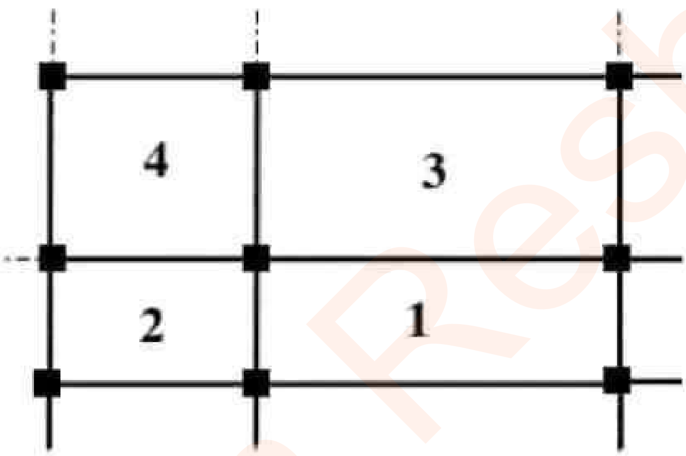


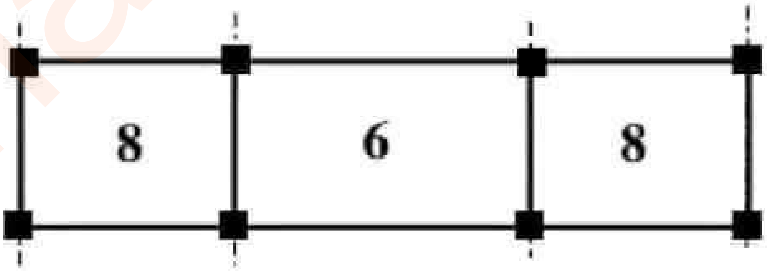

Where ; $\alpha_{sx}$ & $\alpha_{sy}$ - Moment coefficient shown in table 3.13 or else, which can be calculated from equation 12 and equation 13

$$\alpha_{sx} = \frac{(l_y/l_x)^4}{8\{1+(l_y/l_x)^4\}} \qquad \alpha_{sy} = \frac{(l_y/l_x)^2}{8\{1+(l_y/l_x)^4\}}$$

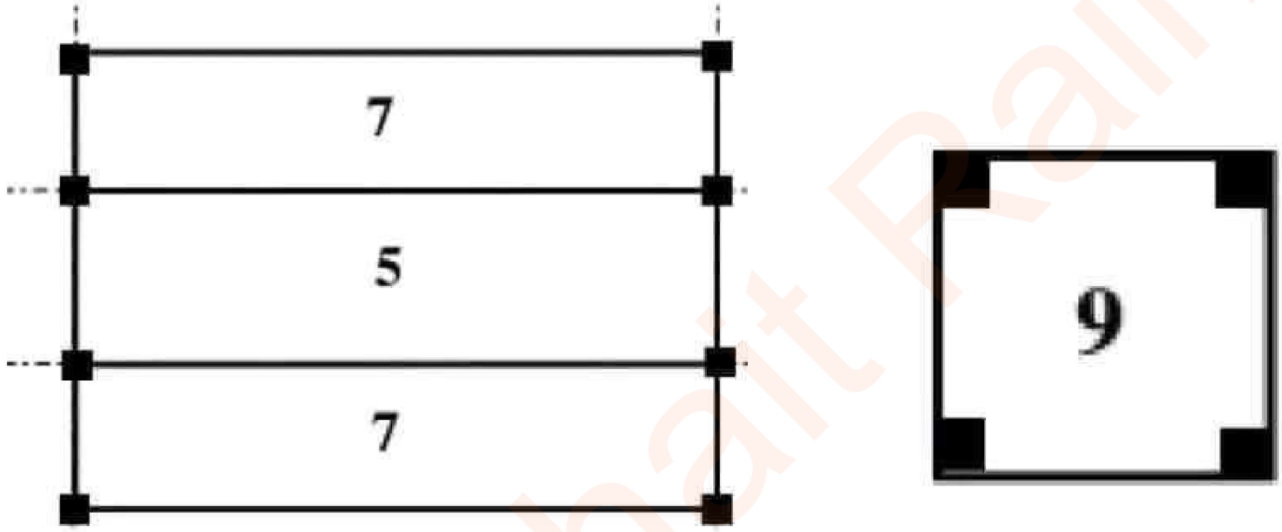
# Restrained slab

- When slabs are supported on all four sides, they effectively span in two directions provided that the longer side is no greater than twice the shorter side
- The magnitude of the bending moment in each direction is dependent on the ratio of the two spans, and the support conditions
- There are nine different types of support condition to be considered which relate to the particular support/restraint provided on each edge of individual slabs; these are illustrated in Figure below



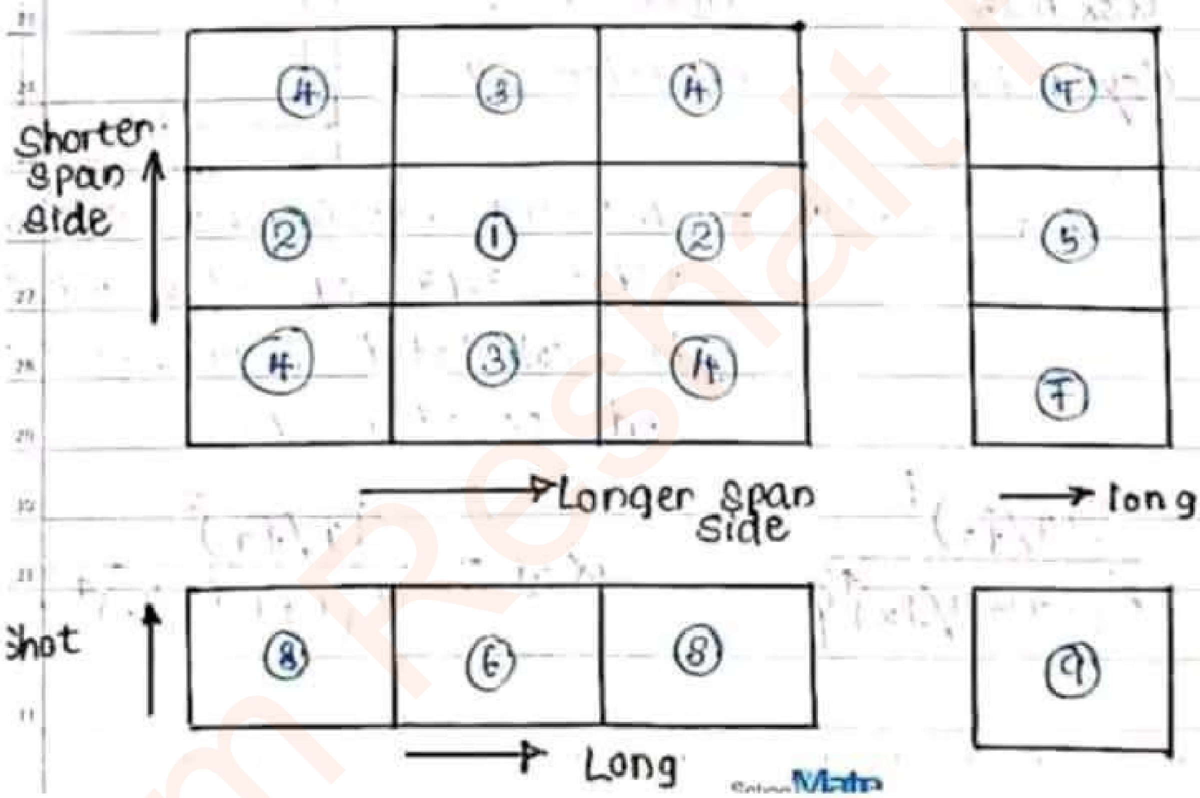
# Restrained slab




**Type 1** *Interior panel*
**Type 2** *One short edge discontinuous*
**Type 3** *One long edge discontinuous*
**Type 4** *Two adjacent edges discontinuous*
**Type 5** *Two short edges discontinuous*
**Type 6** *Two long edges discontinuous*
**Type 7** *Three edges discontinuous (one long edge continuous)*
**Type 8** *Three edges discontinuous (one short edge continuous)*
**Type 9** *Four edges discontinuous*

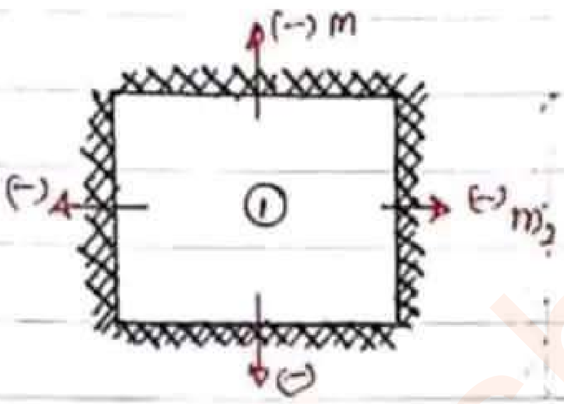
# Restrained slab

The restrain slab for different condition regarding table 3.14 is shown in the figures below.



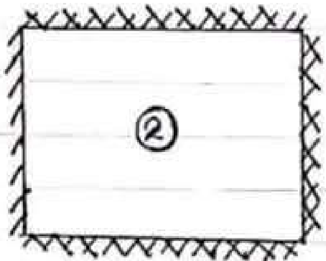
# Restrained two way slab

① Interior Panel



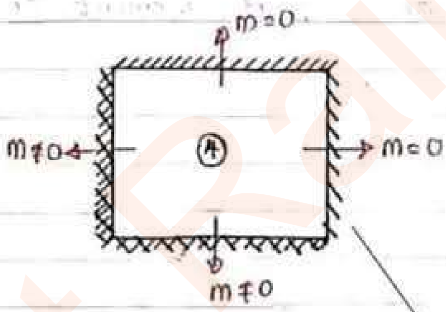

In this interior panel all 4 edges or supports are continuous support therefore it carries negative moment on the support and positive moment in the mid span in both side.

② One short edge is discontinuous



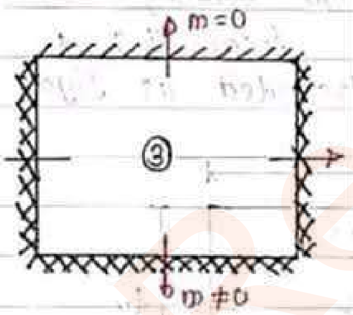

In this case one short edge is discontinuous and other 3 edges are continuous.

④ Two adjusent edges are discontinous



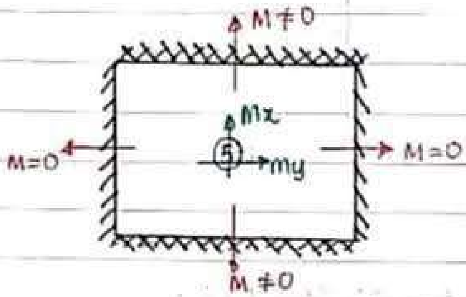

One shorter edge and one longer edge are discontinuous. Therefore this is called as 'two afecent edges are discontinuous'

③ One long edge is discontinuous

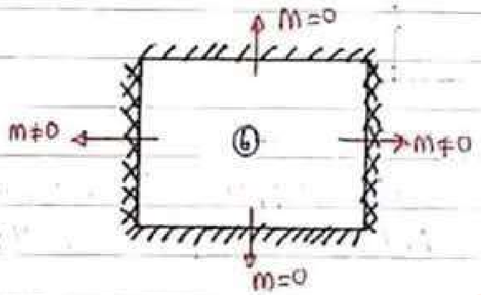



One long edge is discontinuous therefore other 3 sides will carry negative bending moment on the support.

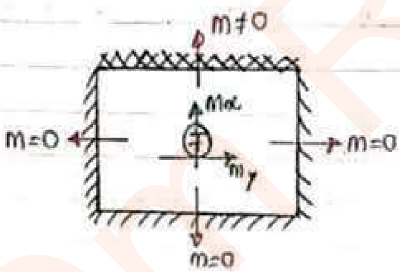
⑤ - Two short edges are discontinous



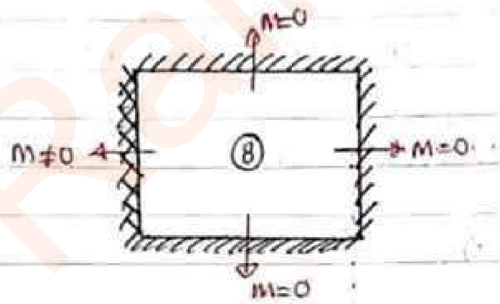

⑥ Two long edges are discontinous



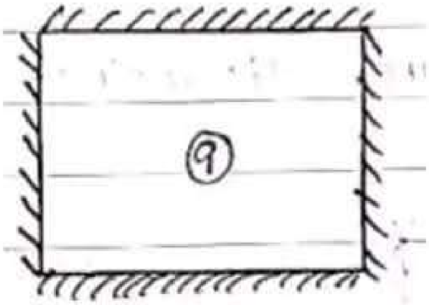

⑦ - Three edges are discontinuous, one long edge is continuous




⑧ - Three edges are discontinuous, One short edge is continuous.



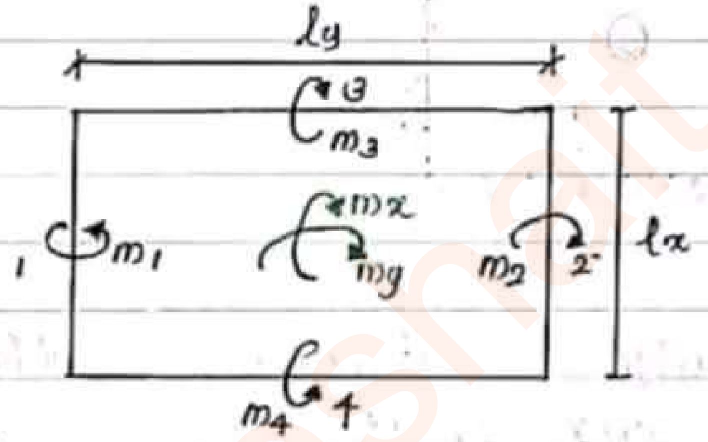

⑨ - Four edges are discontinuous.




In the restrain slab supports are restrain. Therefore there is a connection between support & slab

# Two way spanning Restrained slab

To determine the design Bending moment moment coefficient are taken from T 3.14 and moments in the panel can be illustrated as figure 3.8




$M_x$ & $M_y$ are mid span moment alone the longer span & shorter span. (Sagging Bending moment)
$m_1$, $m_2$, $m_3$ & $M_4$ are support moment or hogging Bending moment.

# Two way spanning Restrained slab

In restrain slab where the corners are prevented from lifting and provision for tortion, the Max$^{m}$ design Bending Moment for this case are illustrated in equation 14 & equation 15 under clause 3.5.3.4 - Restrain slab, BS 8110 - 1997

$$M_{sx} = \beta_{sx}\, n\, l_x^2 \qquad \text{equation } 14$$

$$M_{sy} = \beta_{sy}\, n\, l_x^2 \qquad \text{equation } 15$$

Moment coefficient $\beta_{sx}$ & $\beta_{sy}$ can be determine from table 3.14

# Bending moment Co-efficient : Table 3.14

| Type of panel and moments considered | Short span coefficients, $\beta_{sx}$ | | | | | | | | Long span coefficients, $\beta_{sy}$ for all values of $l_y/l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| | Values of $l_y/l_x$ | | | | | | | | |
| | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.75 | 2.0 | |
| **Interior panels** | | | | | | | | | |
| Negative moment at continuous edge | 0.031 | 0.037 | 0.042 | 0.046 | 0.050 | 0.053 | 0.059 | 0.063 | 0.032 |
| Positive moment at mid-span | 0.024 | 0.028 | 0.032 | 0.035 | 0.037 | 0.040 | 0.044 | 0.048 | 0.024 |
| **One short edge discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.039 | 0.044 | 0.048 | 0.052 | 0.055 | 0.058 | 0.063 | 0.067 | 0.037 |
| Positive moment at mid-span | 0.029 | 0.033 | 0.036 | 0.039 | 0.041 | 0.043 | 0.047 | 0.050 | 0.028 |
| **One long edge discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.039 | 0.049 | 0.056 | 0.062 | 0.068 | 0.073 | 0.082 | 0.089 | 0.037 |
| Positive moment at mid-span | 0.030 | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.062 | 0.067 | 0.028 |
| **Two adjacent edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.047 | 0.056 | 0.063 | 0.069 | 0.074 | 0.078 | 0.087 | 0.093 | 0.045 |
| Positive moment at mid-span | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.059 | 0.065 | 0.070 | 0.034 |

# Bending moment Co-efficient

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Two short edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.046 | 0.050 | 0.054 | 0.057 | 0.060 | 0.062 | 0.067 | 0.070 | — |
| Positive moment at mid-span | 0.034 | 0.038 | 0.040 | 0.043 | 0.045 | 0.047 | 0.050 | 0.053 | 0.034 |
| **Two long edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | — | — | — | — | — | — | — | — | 0.045 |
| Positive moment at mid-span | 0.034 | 0.046 | 0.056 | 0.065 | 0.072 | 0.078 | 0.091 | 0.100 | 0.034 |
| **Three edges discontinuous (one long edge continuous)** | | | | | | | | | |
| Negative moment at continuous edge | 0.057 | 0.065 | 0.071 | 0.076 | 0.081 | 0.084 | 0.092 | 0.098 | — |
| Positive moment at mid-span | 0.043 | 0.048 | 0.053 | 0.057 | 0.060 | 0.063 | 0.069 | 0.074 | 0.044 |
| **Three edges discontinuous (one short edge continuous)** | | | | | | | | | |
| Negative moment at continuous edge | — | — | — | — | — | — | — | — | 0.058 |
| Positive moment at mid-span | 0.042 | 0.054 | 0.063 | 0.071 | 0.078 | 0.084 | 0.096 | 0.105 | 0.044 |
| **Four edges discontinuous** | | | | | | | | | |
| Positive moment at mid-span | 0.055 | 0.065 | 0.074 | 0.081 | 0.087 | 0.092 | 0.103 | 0.111 | 0.056 |

# Determining the slab thickness

In this case deddlection check approchage will be considered in determination of slab thickness.

In the deflection check, survise ability limit state is normally followed in the design.

The following requeirements or conditions need to be satisfied in the deflection check.

$$\left(\frac{\text{Actual span}}{\text{Effective depth}}\right) \leq \left(\frac{\text{Allowable span}}{\text{effective depth}}\right)$$

# Determining the slab thickness

$\left(\frac{\text{Allowable span}}{\text{Effective depth}}\right)$ can be determined from the following relationship.

$$\frac{\text{Allowable span}}{\text{effective depth}} = \frac{\text{Basic span}}{\text{effective depth}} \times \text{Modification factor for tension r/f} \times \text{Modification factor for compression r/f}$$

$$\frac{\text{Allowable span}}{\text{effective depth}} = a_1 \times a_2 \times a_3$$

$a_1$ — Table 3.9; $a_2$ — Table 3.10; $a_3$ — Table 3.11

BS 8110, 1997 part 01

**Table 3.9 — Basic span/effective depth ratio for rectangular or flanged beams**

| Support conditions | Rectangular section | Flanged beams with $\frac{b_w}{b} \leq 0.3$ |
|---|---|---|
| Cantilever | 7 | 5.6 |
| Simply supported | 20 | 16.0 |
| Continuous | 26 | 20.8 |

# Modification factor for tension R/F

**Table 3.10 — Modification factor for tension reinforcement**

| Service stress | | $M/bd^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **0.50** | **0.75** | **1.00** | **1.50** | **2.00** | **3.00** | **4.00** | **5.00** | **6.00** |
| | 100 | 2.00 | 2.00 | 2.00 | 1.86 | 1.63 | 1.36 | 1.19 | 1.08 | 1.01 |
| | 150 | 2.00 | 2.00 | 1.98 | 1.69 | 1.49 | 1.25 | 1.11 | 1.01 | 0.94 |
| ($f_y$ = 250) | 167 | 2.00 | 2.00 | 1.91 | 1.63 | 1.44 | 1.21 | 1.08 | 0.99 | 0.92 |
| | 200 | 2.00 | 1.95 | 1.76 | 1.51 | 1.35 | 1.14 | 1.02 | 0.94 | 0.88 |
| | 250 | 1.90 | 1.70 | 1.55 | 1.34 | 1.20 | 1.04 | 0.94 | 0.87 | 0.82 |
| | 300 | 1.60 | 1.44 | 1.33 | 1.16 | 1.06 | 0.93 | 0.85 | 0.80 | 0.76 |
| ($f_y$ = 460) | 307 | 1.56 | 1.41 | 1.30 | 1.14 | 1.04 | 0.91 | 0.84 | 0.79 | 0.76 |

NOTE 1 The values in the table derive from the equation:

$$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0 \qquad \text{equation 7}$$

where

$M$ is the design ultimate moment at the centre of the span or, for a cantilever, at the support.

NOTE 2 The design service stress in the tension reinforcement in a member may be estimated from the equation:

$$f_s = \frac{2 f_y A_{s\,req}}{3 A_{s\,prov}} \times \frac{1}{\beta_b} \qquad \text{equation 8}$$

NOTE 3 For a continuous beam, if the percentage of redistribution is not known but the design ultimate moment at mid-span is obviously the same as or greater than the elastic ultimate moment, the stress $f_s$ in this table may be taken as $2/3 f_y$.

# Modification factor for Compression R/F

**Table 3.11 — Modification factor for compression reinforcement**

| $100\frac{A'_{s,prov}}{bd}$ | Factor |
|---|---|
| 0.00 | 1.00 |
| 0.15 | 1.05 |
| 0.25 | 1.08 |
| 0.35 | 1.10 |
| 0.50 | 1.14 |
| 0.75 | 1.20 |
| 1.0 | 1.25 |
| 1.5 | 1.33 |
| 2.0 | 1.40 |
| 2.5 | 1.45 |
| ≥3.0 | 1.50 |

NOTE 1 The values in this table are derived from the following equation:

Modification factor for compression reinforcement = $1 + \frac{100A'_{s,prov}}{bd} / \left(3 + \frac{100A'_{s,prov}}{bd}\right) \leq 1.5$ equation 9

NOTE 2 The area of compression reinforcement $A$ used in this table may include all bars in the compression zone, even those not effectively tied with links.

# Determination of Design Load

Design load can be estimated from Table 2.1 - load combination and values of $\gamma_f$ (load factor) in the ultimate limit state

Design load (Q) = (1.4) Dead load + (1.6) Imposed load

$$\boxed{Q = (1.4\ G_K) + (1.6\ Q_k)}$$

To estimate the dead load of the slab 1m strip of slab is normally considered after that self weight of the slab should be calculated with the help of thickness of the slab & density of concrete. Finally to calculate the ~~gk~~ total dead load, self weight of the slab and finishes load will be added.

# Determination of Design Load

**Table 2.1 — Load combinations and values of $\gamma_f$ for the ultimate limit state**

| Load combination | Load type | | | | | |
|---|---|---|---|---|---|---|
| | Dead | | Imposed | | Earth[a] and water[b] pressure | Wind |
| | Adverse | Beneficial | Adverse | Beneficial | | |
| 1. Dead and imposed (and earth and water pressure) | 1.4 | 1.0 | 1.6 | 0 | 1.2[c]<br>1.0[d] | — |
| 2. Dead and wind (and earth and water pressure) | 1.4 | 1.0 | — | — | 1.2[c]<br>1.0[d] | 1.4 |
| 3. Dead and imposed and wind (and earth and water pressure) | 1.2 | 1.2 | 1.2 | 1.2 | 1.2[c]<br>1.0[d] | 1.2 |

[a] The earth pressure is that obtained from BS 8002 including an appropriate mobilisation factor. The more onerous of the two factored conditions should be taken.

[b] The value of 1.2 may be used where the maximum credible level of the water can be clearly defined. If this is not feasible, a factor of 1.4 should be used.

[c] Unplanned excavation in accordance with BS 8002, **3.2.2.2** not included in the calculation.

[d] Unplanned excavation in accordance with BS 8002, **3.2.2.2** included in the calculation.

# Brick wall load on floor slab

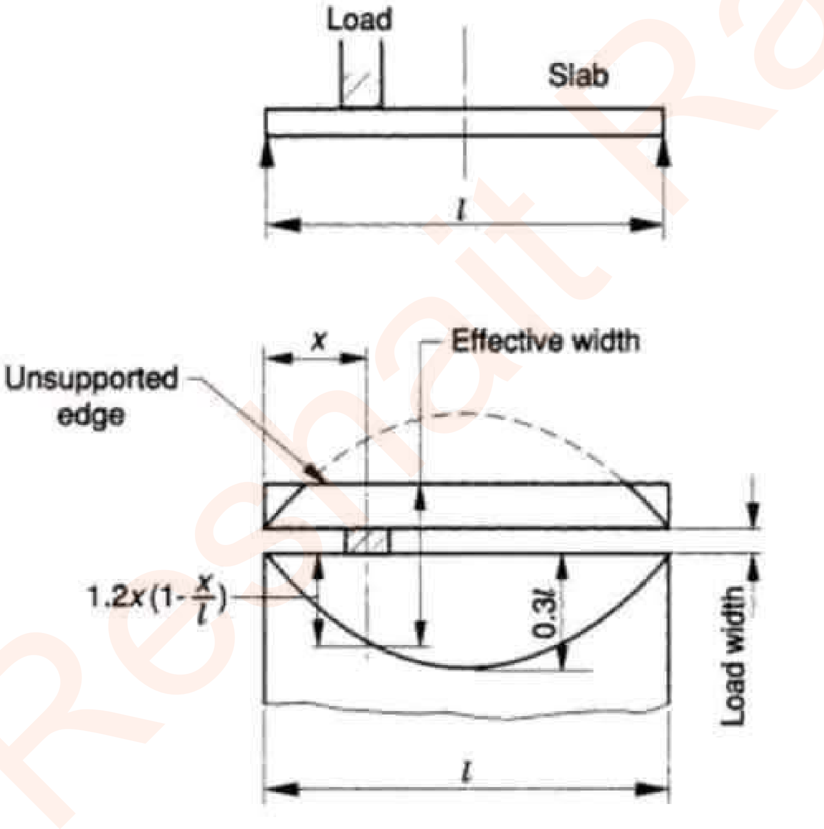
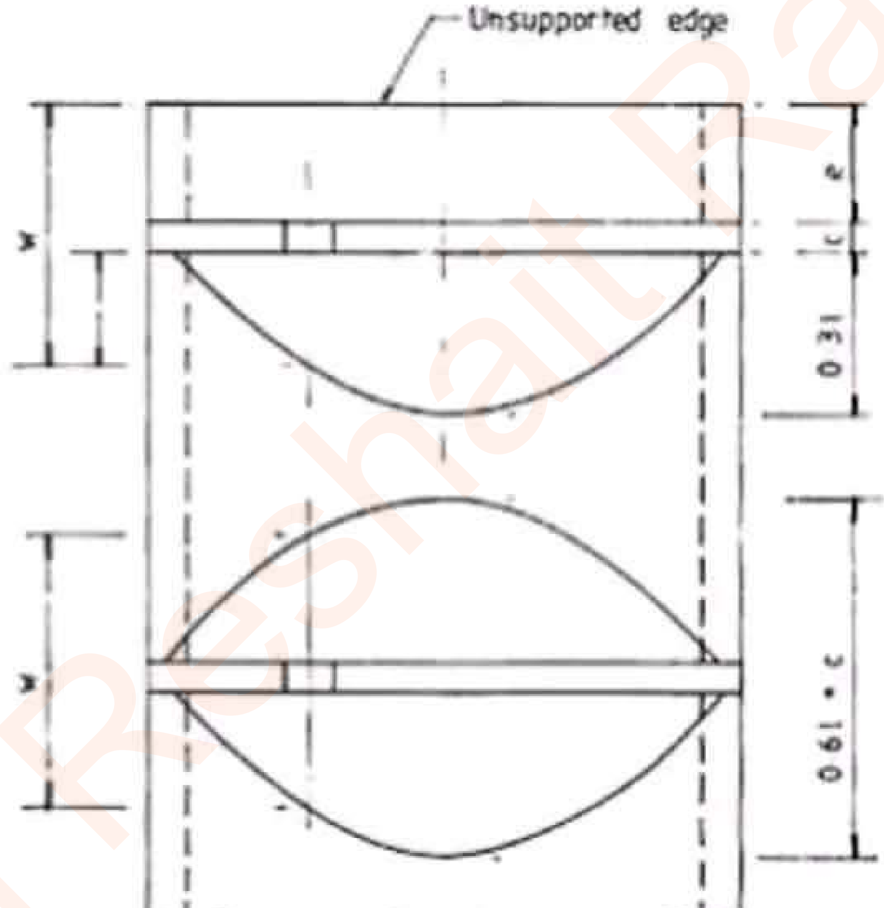
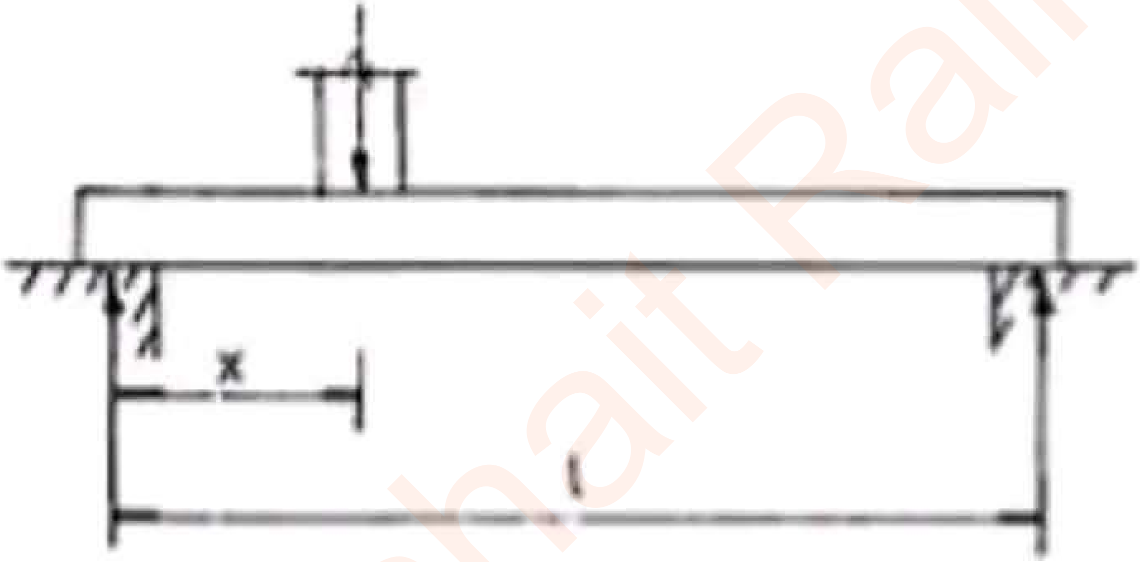



**Figure 3.6 — Effective width of solid slab carrying a concentrated load near an unsupported edge**

# Concentrated load on solid slab



# Concentrated load on solid slab




Load near edge of slab

$$w = c + 2.4x(1 - x/l)$$
$$\ngtr e + c + 1.2x(1 - x/l)$$

Load in interior of slab

$$w = c + 2.4x(1 - x/l)$$

# Concentrated load on solid slab

BS8110: Part 1 specifies in clause 3.5.2.2 that, for a slab simply supported on two edges carrying a concentrated load, the effective width of slab resisting the load may be taken as

$w$=width of load+$2.4x(1-x/l)$

where $x$ is the distance of the load from the nearer support and $l$ is the span of the slab. If the load is near an unsupported edge the effective width should not exceed

1. $w$ as defined above or
2. $0.5w$+distance of the centre of the load from the unsupported edge

The minimum area of main reinforcement is given in Table 3.27 of the code. For rectangular sections and solid slabs this is

| | |
|---|---|
| Mild steel | $f_y$=250 N/mm$^2$, $100A_s/A_c$=0.24 |
| High yield steel | $f_y$=460 N/mm$^2$, $100A_s/A_c$=0.13 |

where $A_s$ is the minimum area of reinforcement and $A_c$ is the total area of concrete.

# General idea about clear cover

## Clear cover?

The concrete cover is the distance between the surface of the reinforcement closest to the nearest concrete surface

## Nominal Cover?

- Nominal cover is the design depth of concrete cover to all steel reinforcement, including links.
- It is the dimension used in design and indicated on the drawings
- The actual cover to all reinforcement should never be less than the nominal cover minus 5 mm

# General idea about clear cover

- The nominal cover should

i. be in accordance with the recommendations for bar size and aggregate size for concrete cast against uneven surfaces
ii. protect the steel against corrosion
iii. protect the steel against fire
iv. allow for surface treatments such as bush hammering

**Bar Size?**

The nominal cover to all steel should be such that the resulting cover to a main bar should not be less than the size of the main

# General idea about clear cover

**Nominal maximum size of aggregate?**

- Nominal covers should be not less than the nominal maximum size of the aggregate.
- The nominal maximum size of coarse aggregate should not normally be greater than one-quarter of the minimum thickness of the concrete section or element
- For most work, 20 mm aggregate is suitable. Larger sizes should be permitted where there are no restrictions to the flow of concrete into sections

# Classification of exposure conditions (Table 3.2, BS8110, 1997, Part - 01)

| Environment | Exposure conditions |
|---|---|
| Mild | Concrete surfaces protected against weather or aggressive conditions |
| Moderate | Exposed concrete surfaces but sheltered from severe rain or freezing whilst wet<br>Concrete surfaces continuously under non-aggressive water<br>Concrete in contact with non-aggressive soil (see sulfate class 1 of Table 7a in BS 5328-1:1997)<br>Concrete subject to condensation |
| Severe | Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing or severe condensation |
| Very severe | Concrete surfaces occasionally exposed to sea water spray or de-icing salts (directly or indirectly)<br>Concrete surfaces exposed to corrosive fumes or severe freezing conditions whilst wet |
| Most severe | Concrete surfaces frequently exposed to sea water spray or de-icing salts (directly or indirectly)<br>Concrete in sea water tidal zone down to 1 m below lowest low water |
| Abrasive[a] | Concrete surfaces exposed to abrasive action, e.g. machinery, metal tyred vehicles or water carrying solids |

NOTE 1 For aggressive soil and water conditions see **5.3.4** of BS 5328-1:1997.
NOTE 2 For marine conditions see also BS 6349.

[a] For flooring see BS 8204.

# Nominal cover to all reinforcement (including links) to meet durability requirements (Table 3.3, BS 8110, 1997)

**Table 3.3 — Nominal cover to all reinforcement (including links) to meet durability requirements** (see NOTE 1)

| **Conditions of exposure** (see **3.3.4**) | **Nominal cover** Dimensions in millimetres | | | | |
|---|---|---|---|---|---|
| Mild | 25 | 20 | 20[a] | 20[a] | 20[a] |
| Moderate | — | 35 | 30 | 25 | 20 |
| Severe | — | — | 40 | 30 | 25 |
| Very severe | — | — | 50[b] | 40[b] | 30 |
| Most severe | — | — | — | — | 50 |
| Abrasive | — | — | — | See NOTE 3 | See NOTE 3 |
| Maximum free water/cement ratio | 0.65 | 0.60 | 0.55 | 0.50 | 0.45 |
| Minimum cement content ($kg/m^3$) | 275 | 300 | 325 | 350 | 400 |
| Lowest grade of concrete | C30 | C35 | C40 | C45 | C50 |

NOTE 1 This table relates to normal-weight aggregate of 20 mm nominal size. Adjustments to minimum cement contents for aggregates other than 20 mm nominal maximum size are detailed in Table 8 of BS 5328-1:1997.

NOTE 2 Use of sulfate resisting cement conforming to BS 4027. These cements have lower resistance to chloride ion migration. If they are used in reinforced concrete in very severe or most severe exposure conditions, the covers in Table 3.3 should be increased by 10 mm.

NOTE 3 Cover should be not less than the nominal value corresponding to the relevant environmental category plus any allowance for loss of cover due to abrasion.

[a] These covers may be reduced to 15 mm provided that the nominal maximum size of aggregate does not exceed 15 mm.

[b] Where concrete is subject to freezing whilst wet, air-entrainment should be used (see **5.3.3** of BS 5328-1:1997) and the strength grade may be reduced by 5.

# Nominal cover to all reinforcement (including links) to meet specified periods of fire resistance (Table 3.4, BS 8110, 1997)

| Fire resistance h | Nominal cover | | | | | | |
|---|---|---|---|---|---|---|---|
| | Beams[a] | | Floors | | Ribs | | Columns[a] mm |
| | Simply supported mm | Continuous mm | Simply supported mm | Continuous mm | Simply supported mm | Continuous mm | |
| 0.5 | 20[b] | 20[b] | 20[b] | 20[b] | 20[b] | 20[b] | 20[b] |
| 1 | 20[b] | 20[b] | 20 | 20 | 20 | 20[b] | 20[b] |
| 1.5 | 20 | 20[b] | 25 | 20 | 35 | 20 | 20 |
| 2 | 40 | 30 | 35 | 25 | 45 | 35 | 25 |
| 3 | 60 | 40 | 45 | 35 | 55 | 45 | 25 |
| 4 | 70 | 50 | 55 | 45 | 65 | 55 | 25 |

NOTE 1 The nominal covers given relate specifically to the minimum member dimensions given in Figure 3.2. Guidance on increased covers necessary if smaller members are used is given in section **4** of BS 8110-2:1985.

NOTE 2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (see section **4** of BS 8110-2:1985).

[a] For the purposes of assessing a nominal cover for beams and columns, the cover to main bars which would have been obtained from Tables 4.2 and 4.3 of BS 8110-2:1985 has been reduced by a notional allowance for stirrups of 10 mm to cover the range 8 mm to 12 mm (see also **3.3.6**).

[b] These covers may be reduced to 15 mm provided that the nominal maximum size of aggregate does not exceed 15 mm (see **3.3.1.3**).

# Design formula

$K'$ = 0.156 where redistribution does not exceed 10 % (this implies a limitation of the neutral axis depth to $d/2$); or

$K'$ = $0.402(\beta_b - 0.4) - 0.18(\beta_b - 0.4)^2$ where redistribution exceeds 10 %;

and $K = M/bd^2 f_{cu}$.

If $K \leq K'$, compression reinforcement is not required and:

$$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)}\right\}$$

but not greater than $0.95d$.

$x = (d - z)/0.45$

$A_s = M/0.95 f_y z$

If $K > K'$, compression reinforcement is required and:

$$z = d\left\{0.5 + \sqrt{\left(0.25 - \frac{K'}{0.9}\right)}\right\}$$

$x = (d - z)/0.45$

$A_s' = (K - K') f_{cu} b d^2 / 0.95 f_y (d - d')$

$A_s = (K' f_{cu} b d^2 / 0.95 f_y z + A_s'$

# Reynold's Hand book



## Reinforcement: metric bar data

| Cross-sectional areas of bars at specific spacings — Bar spacing in millimetres (non-preferred spacings shown in italics) | Bar size in millimetres | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 16 | 20 | 25 | 32 | 40 | 50 |
| 75 | 376 | 670 | 1047 | 1507 | 2680 | 4188 | 6544 | — | — | — |
| *80* | *353* | *628* | *981* | *1413* | *2513* | *3926* | *6135* | — | — | — |
| *90* | *314* | *558* | *872* | *1256* | *2234* | *3490* | *5454* | — | — | — |
| 100 | 282 | 502 | 785 | 1130 | 2010 | 3141 | 4908 | 8042 | — | — |
| *110* | *257* | *456* | *713* | *1028* | *1827* | *2855* | *4462* | *7311* | — | — |
| *120* | *235* | *418* | *654* | *942* | *1675* | *2617* | *4090* | *6702* | *10471* | — |
| 125 | 226 | 402 | 628 | 904 | 1608 | 2513 | 3926 | 6433 | 10053 | — |
| *130* | *217* | *386* | *604* | *869* | *1546* | *2416* | *3775* | *6186* | *9666* | — |
| *140* | *201* | *359* | *560* | *807* | *1436* | *2243* | *3506* | *5744* | *8975* | — |
| 150 | 188 | 335 | 523 | 753 | 1340 | 2094 | 3272 | 5361 | 8377 | 13090 |
| *160* | *176* | *314* | *490* | *706* | *1256* | *1963* | *3067* | *5026* | *7853* | *12272* |
| 175 | 161 | 287 | 448 | 646 | 1148 | 1795 | 2804 | 4595 | 7180 | 11220 |
| *180* | *157* | *279* | *436* | *628* | *1117* | *1745* | *2727* | *4468* | *6981* | *10908* |
| 200 | 141 | 251 | 392 | 565 | 1005 | 1570 | 2454 | 4021 | 6283 | 9817 |
| *220* | *128* | *228* | *356* | *514* | *913* | *1427* | *2231* | *3655* | *5711* | *8925* |
| 225 | 125 | 223 | 349 | 502 | 893 | 1396 | 2181 | 3574 | 5585 | 8727 |
| *240* | *117* | *209* | *327* | *471* | *837* | *1308* | *2045* | *3351* | *5235* | *8181* |
| 250 | 113 | 201 | 314 | 452 | 804 | 1256 | 1963 | 3216 | 5026 | 7854 |
| 275 | 102 | 182 | 285 | 411 | 731 | 1142 | 1784 | 2924 | 4569 | 7140 |
| 300 | 94 | 167 | 261 | 376 | 670 | 1047 | 1636 | 2680 | 4188 | 6545 |

# Minimum Reinforcement

The main moment steel spans between supports and over the interior supports of continuous slabs as shown in Fig. 8.1. The slab sections are designed as rectangular beam sections 1 m wide and the charts given in section 4.4.7 for singly reinforced beams can be used.

The minimum area of main reinforcement is given in Table 3.27 of the code. For rectangular sections and solid slabs this is

| | |
|---|---|
| Mild steel | $f_y$=250 N/mm$^2$, $100A_s/A_c$=0.24 |
| High yield steel | $f_y$=460 N/mm$^2$, $100A_s/A_c$=0.13 |

where $A_s$ is the minimum area of reinforcement and $A_c$ is the total area of concrete.

# Minimum Reinforcement

**Table 3.25 — Minimum percentages of reinforcement**

| Situation | Definition of percentage | Minimum percentage | |
|---|---|---|---|
| | | $f_y$ = 250 N/mm² % | $f_y$ = 460 N/mm² % |
| *Tension reinforcement* | | | |
| Sections subjected mainly to pure tension | $100A_s/A_c$ | 0.8 | 0.45 |
| Sections subjected to flexure: | | | |
| a) flanged beams, web in tension: | | | |
| 1) $b_w/b < 0.4$ | $100A_s/b_wh$ | 0.32 | 0.18 |
| 2) $b_w/b \geqslant 0.4$ | $100A_s/b_wh$ | 0.24 | 0.13 |
| b) flanged beams, flange in tension: | | | |
| 1) T-beam | $100A_s/b_wh$ | 0.48 | 0.26 |
| 2) L-beam | $100A_s/b_wh$ | 0.36 | 0.20 |
| c) rectangular section (in solid slabs this minimum should be provided in both directions) | $100A_s/A_c$ | 0.24 | 0.13 |
| *Compression reinforcement* (where such reinforcement is required for the ultimate limit state) | | | |
| General rule | $100A_{sc}/A_{cc}$ | 0.4 | 0.4 |
| Simplified rules for particular cases: | | | |
| a) rectangular column or wall | $100A_{sc}/A_c$ | 0.4 | 0.4 |
| b) flanged beam: | | | |
| 1) flange in compression | $100A_{sc}/bh_f$ | 0.4 | 0.4 |
| 2) web in compression | $100A_{sc}/b_wh$ | 0.2 | 0.2 |
| c) rectangular beam | $100A_{sc}/A_c$ | 0.2 | 0.2 |
| *Transverse reinforcement in flanges or flanged beams* (provided over full effective flange width near top surface to resist horizontal shear) | $100A_{st}/h_fl$ | 0.15 | 0.15 |

# Shear check in Slab

Under normal loads shear stresses are not critical and shear reinforcement is not required. Shear reinforcement is provided in heavily loaded thick slabs but should not be used in slabs less than 200 mm thick. The shear resistance is checked in accordance with BS8110: Part 1, section 3.5.5.

**Table 3.16 — Form and area of shear reinforcement in solid slabs**

| Value of $v$ N/mm$^2$ | Form of shear reinforcement to be provided | Area of shear reinforcement to be provided |
| --- | --- | --- |
| $v < v_c$ | None required | None |
| $v_c < v < (v_c + 0.4)$ | Minimum links in areas where $v > v_c$ | $A_{sv} \geq 0.4bs_v/0.95f_{yv}$ |
| $(v_c + 0.4) < v < 0.8\sqrt{f_{cu}}$ or 5 N/mm$^2$ | Links and/or bent-up bars in any combination (but the spacing between links or bent-up bars need not be less than $d$) | Where links only provided: $A_{sv} \geq bs_v(v - v_c)/0.95f_{yv}$ Where bent-up bars only provided: $A_{sb} \geq bs_b(v - v_c)/\{0.95f_{yv}(\cos\alpha + \sin\alpha \times \cot\beta)\}$ (see **3.4.5.7**) |
| NOTE 1 It is difficult to bend and fix shear reinforcement so that its effectiveness can be assured in slabs less than 200 mm deep. It is therefore not advisable to use shear reinforcement in such slabs. NOTE 2 The enhancement in design shear strength close to supports described in **3.4.5.8**, **3.4.5.9** and **3.4.5.10** may also be applied to solid slabs. | | |

# Shear check in Slab

The shear stress is given by

$$v = V/bd$$

where $V$ is the shear force due to ultimate loads. If $v$ is less than the value of $v_c$ given in Table 3.9 in the code no shear reinforcement is required. Enhancement in design shear strength close to supports can be taken into account. This was discussed in section 5.1.2. The form and area of shear reinforcement in solid slabs is set out in Table 3.17 in the code. The design is similar to that set out for beams in section 5.1.3.

The shear resistance at the end support which is integral with the edge beam where the slab has been taken as simply supported in the analysis depends on the detailing. The following procedures are specified in clause 3.12.10.3 of the code:

1. If the tension bars are anchored 12 diameters past the centreline of the support the shear resistance is based on the bottom bars;
2. If the tension bars are stopped at the line of effective support, the shear resistance is based on the top bars.

Note that top bars of area one-half the mid-span steel are required to control cracking.

# Shear check in Slab

### 3.5.5.2 *Shear stresses*

The design shear stress $v$ at any cross-section should be calculated from equation 21:

$$v = \frac{V}{bd} \qquad \text{equation 21}$$

In no case should $v$ exceed $0.8\sqrt{f_{cu}}$ or 5 N/mm$^2$, whichever is the lesser, whatever shear reinforcement is provided.

### 3.5.5.3 *Shear reinforcement*

Recommendations for shear reinforcement in solid slabs are given in Table 3.16.

$A_{sv}$ area of shear links in a zone.

$A_{sb}$ area of bent-up bars in a zone.

$b$ breadth of slab under consideration.

$d$ effective depth or average effective depth of a slab.

$f_{yv}$ characteristic strength of the shear reinforcement which should not be taken as greater than 460 N/mm$^2$.

$v$ nominal design shear stress.

$v_c$ design ultimate shear stress obtained from Table 3.8.

$V$ shear force due to design ultimate loads or the design ultimate value of a concentrated load.

$\alpha$ angle between the shear reinforcement and the plane of the slab

$s_b$ spacing of bent-up bars (see Figure 3.4).

$s_v$ spacing of links.

# Deflection check in Slab

The check for deflection is a very important consideration in slab design and usually controls the slab depth. The deflection of slabs is discussed in BS8110: Part 1, section 3.5.7.

In normal cases a strip of slab 1 m wide is checked against span-to-effective depth ratios including the modification for tension reinforcement set out in section 3.4.6 of the code. Only the tension steel at the centre of the span is taken into account.

**3.4.6.3** ***Span/effective depth ratio for a rectangular or flanged beam***

The basic span/effective depth ratios for beams are given in Table 3.9. These are based on limiting the total deflection to span/250 and this should normally ensure that the part of the deflection occurring after construction of finishes and partitions will be limited to span/500 or 20 mm, whichever is the lesser, for spans up to 10 m. For values of $b_w/b$ greater than 0.3, linear interpolation between the values given in Table 3.9 for rectangular sections and for flanged beams with $b_w/b$ of 0.3 may be used.

**Table 3.9 — Basic span/effective depth ratio for rectangular or flanged beams**

| Support conditions | Rectangular section | Flanged beams with $\frac{b_w}{b} \leq 0.3$ |
|---|---|---|
| Cantilever | 7 | 5.6 |
| Simply supported | 20 | 16.0 |
| Continuous | 26 | 20.8 |

# Crack control in Slab

To control cracking in slabs, maximum values for clear spacing between bars are set out in BS8110: Part 1, clause 3.12.11.2.7. The clause states that in no case should the clear spacing exceed the lesser of three times the effective depth or 750 mm. No further check is needed for slabs in normal cases

1. if grade 250 steel is used and the slab depth is not greater than 250 mm or
2. if grade 460 is used and the slab depth is not greater than 200 mm or
3. if the amount of steel, $100A_s/bd$, is less than 0.3%

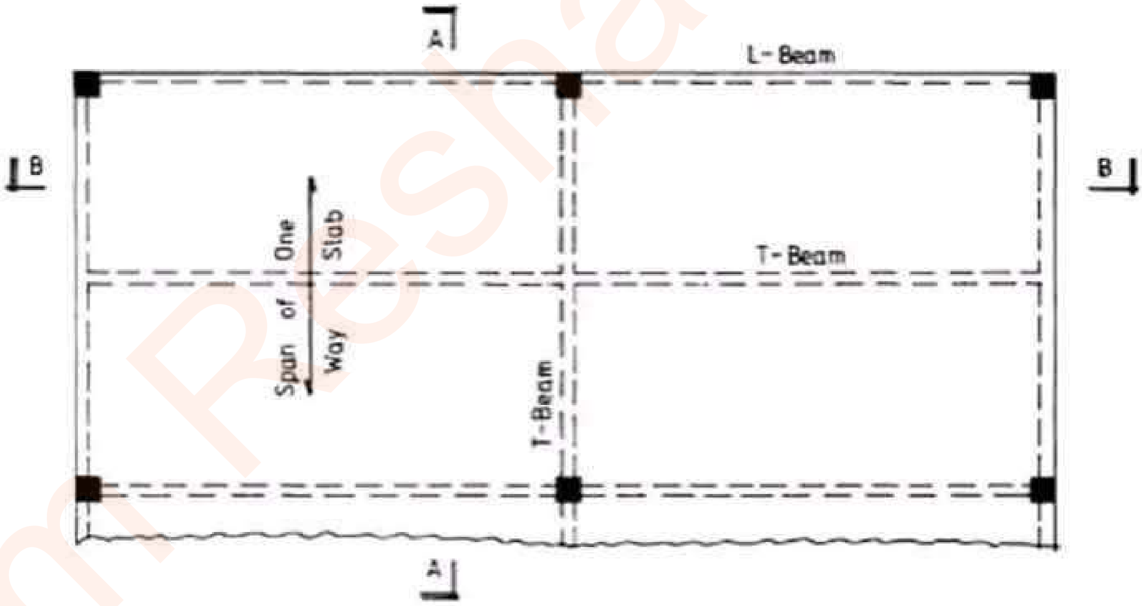
### 3.4.7 Crack control in beams

Flexural cracking may be controlled by use of the rules of **3.12.11.2** (maximum distance between bars in tension). If greater spacings are required (e.g. between groups of bars), the expected crack widths should be checked by calculation (see Section 3 of BS 8110-2:1985).

# Curtailment R/F on solid slab

The general recommendations given in clause 3.12.9.1 for curtailment of bars apply. These were discussed in connection with beams in section 7.1.2. The code sets out simplified rules for slabs in clause 3.12.10.3 and Fig. 3.25 in the code. These rules may be used subject to the following provisions:

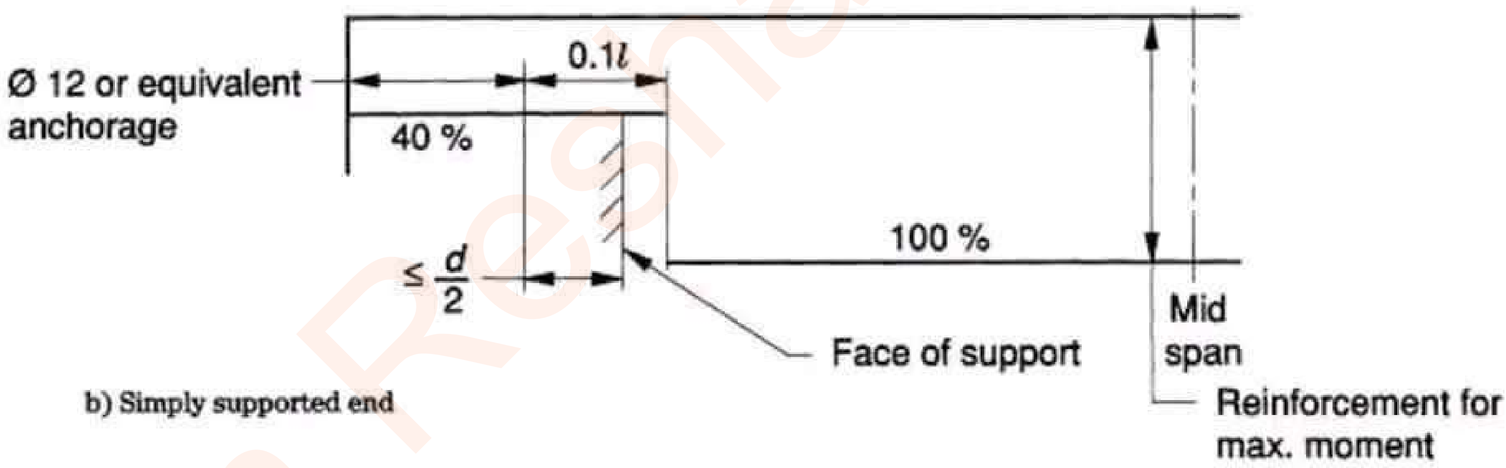
1. The slabs are designed for predominantly uniformly distributed loads;
2. In continuous slabs the design has been made for the single load case of maximum design load on all spans.



# Curtailment detailing in Slab

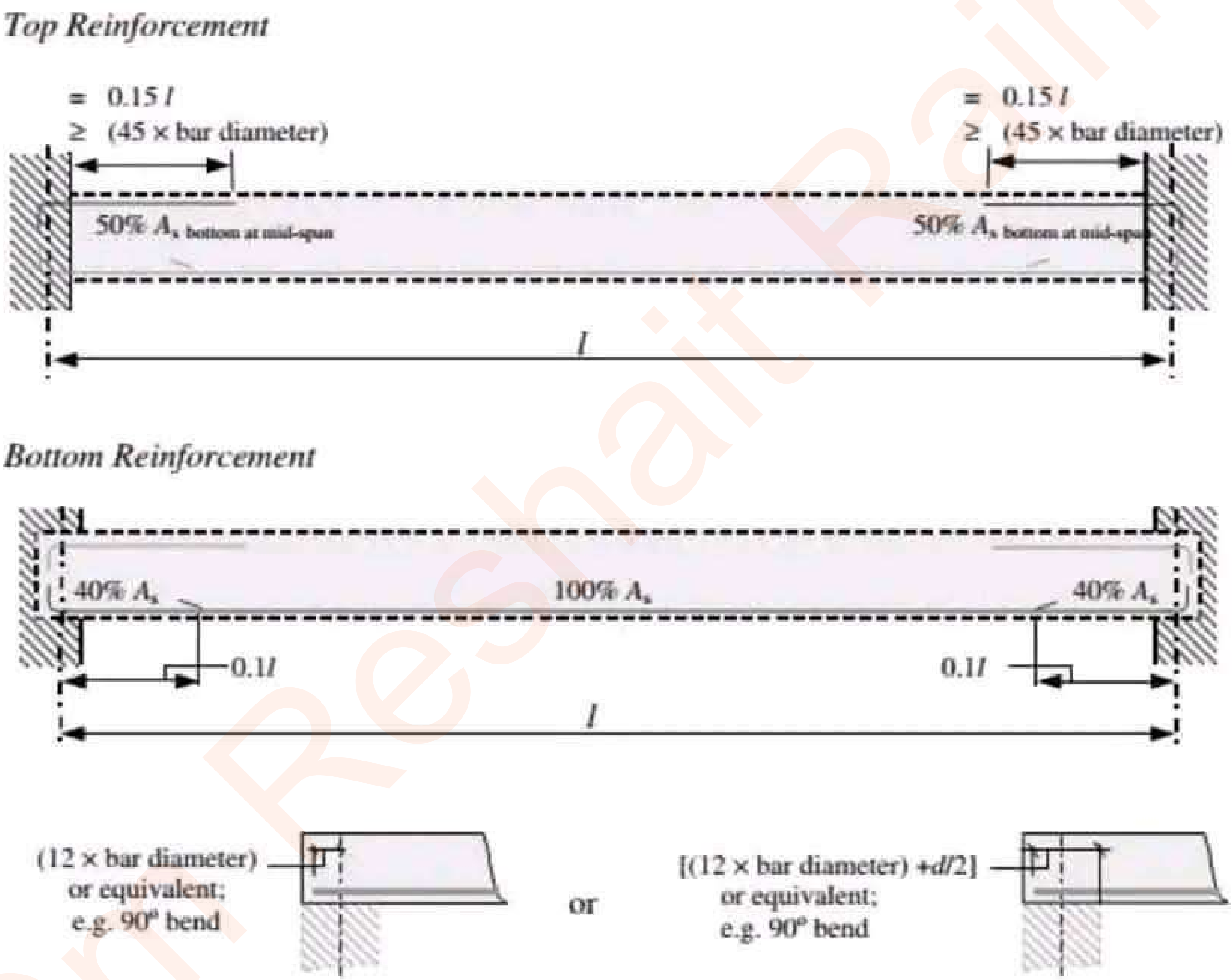
Similar curtailment and anchorage rules are given in Clause 3.12.10.3 and Figure 3.25 of the code for slabs in BS8110 – 1997 – Part – 01

**a) Simply supported slab**

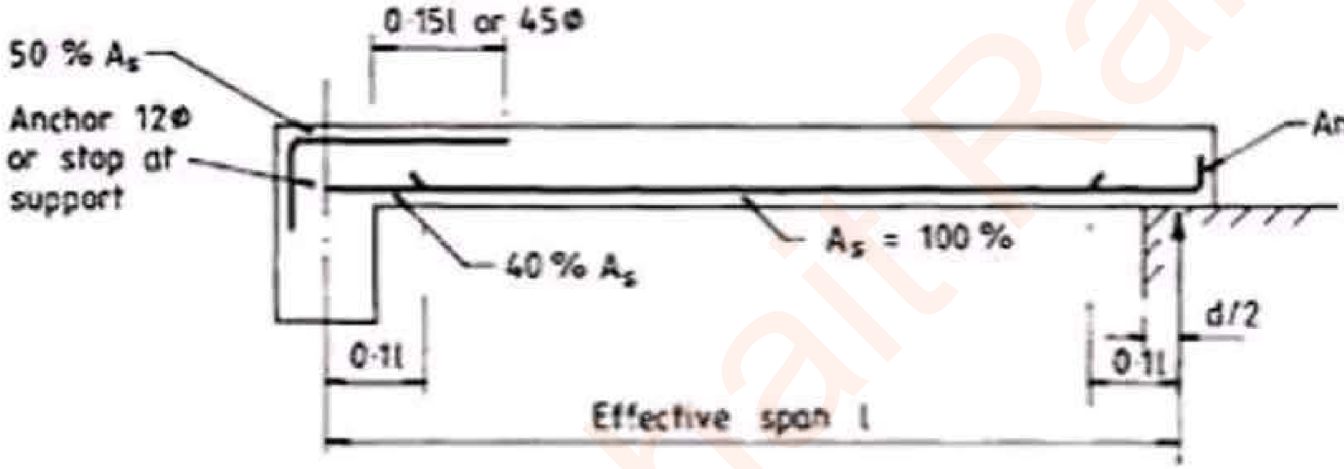



b) Simply supported end

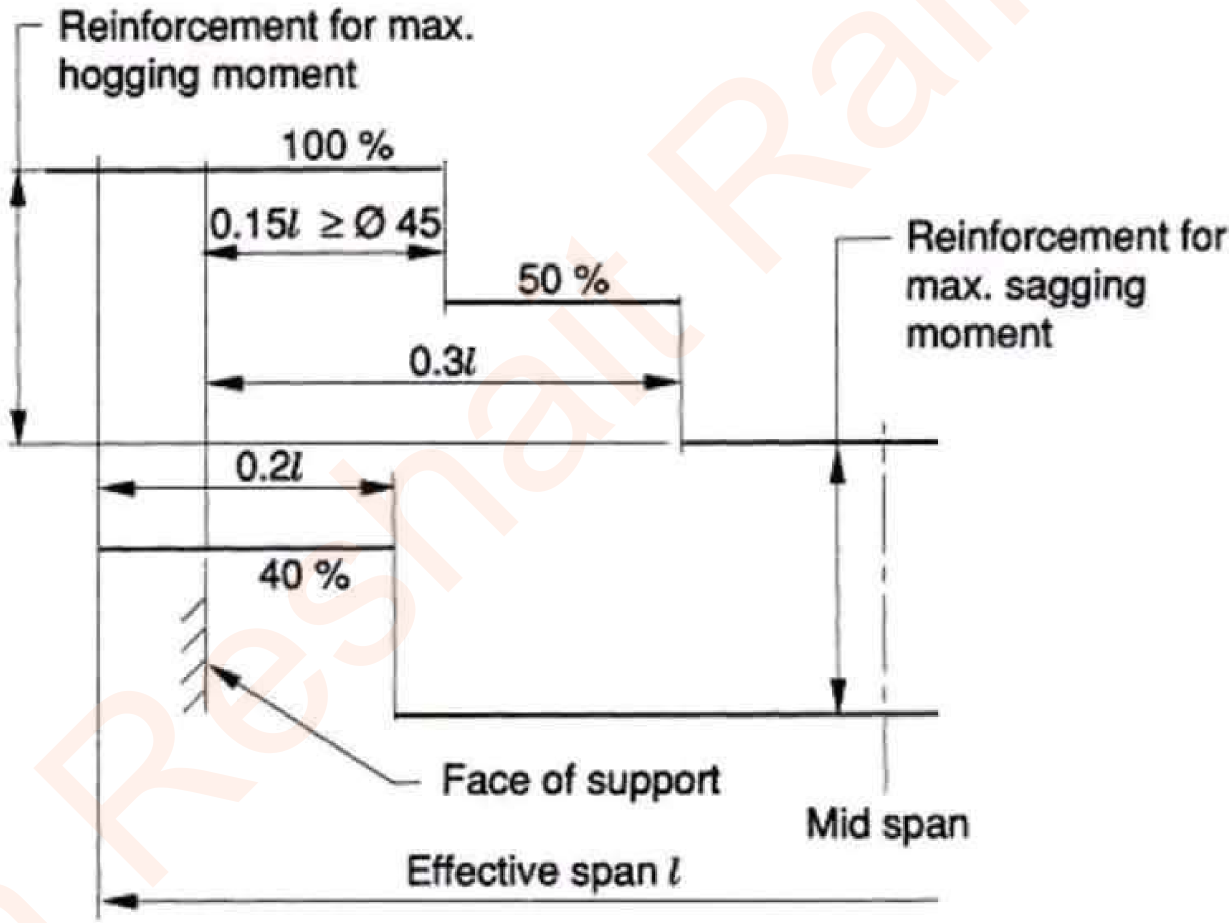
## a) Simply supported slab



## a) Simply supported slab

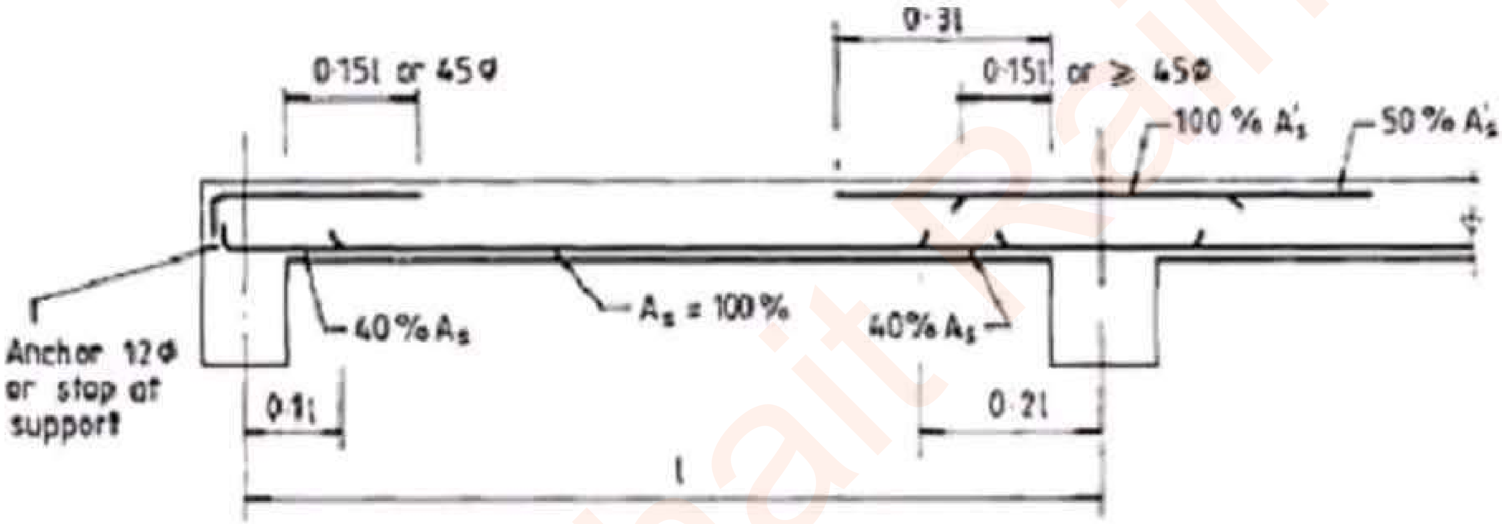


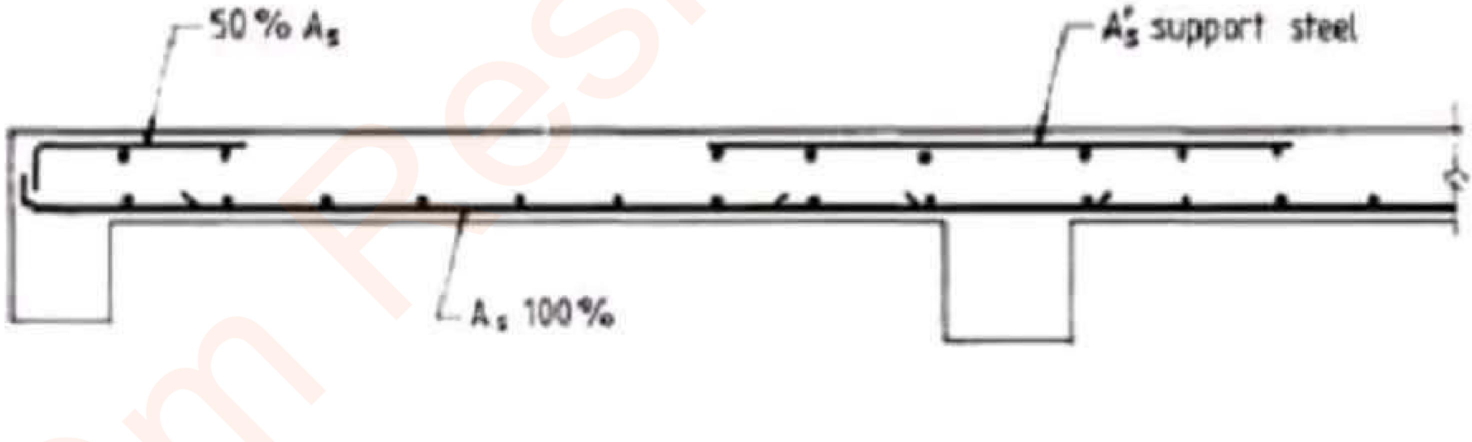
## b) Continuous slab



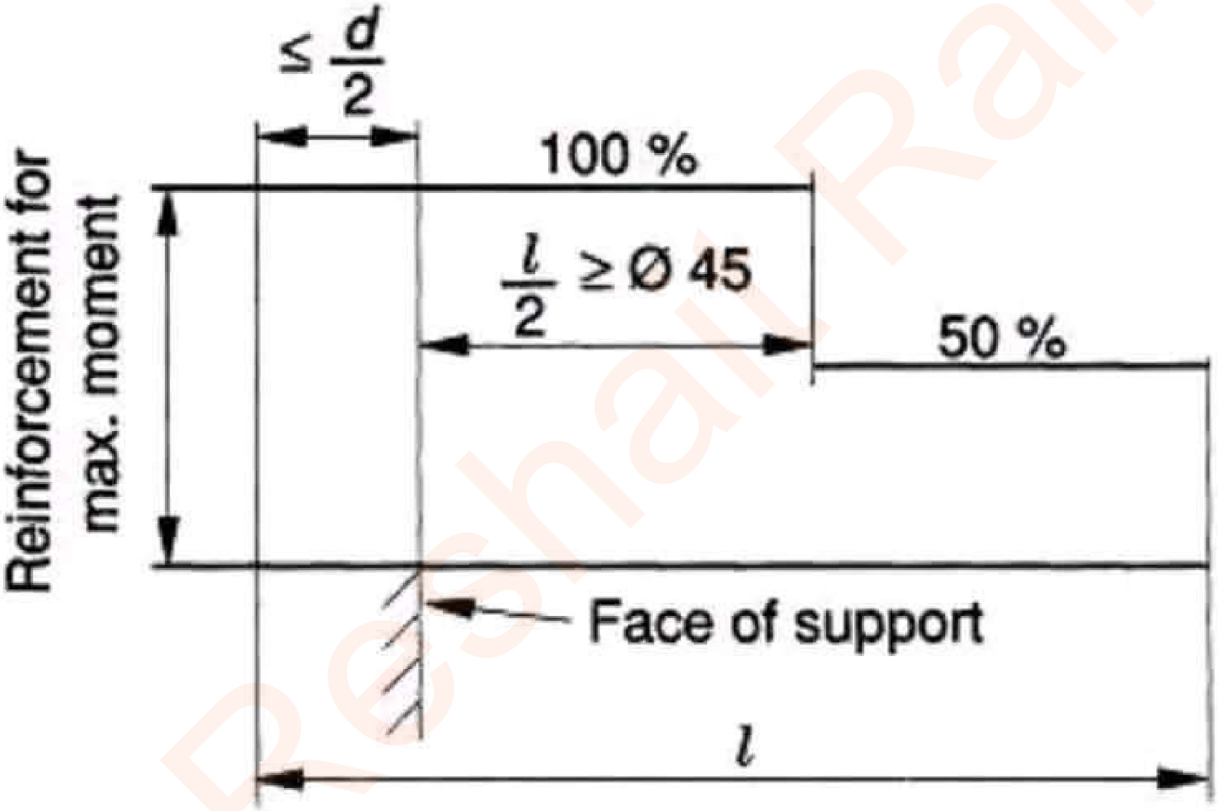

a) Continuous member (approximately equal spans using simplified load arrangement)

## b) Continuous slab



**b) Cantilever slab**



b) Cantilever slab