*Notes:* 1. For main reinforcement up to 12 mm diameter bars for mild exposure the nominal cover may be reduced by 5 mm (i.e. 15 mm).
2. Minimum concrete cover should not deviate from the required by (+) 10 mm to (–) 0 mm.
3. Where concrete grade is M35 and above, for severe and very severe exposure conditions, a reduction of 5 mm may be allowed.

**Table 1.7(b):** Nominal cover for specified period of fire resistance (IS:456-2000)

| Fire resistance (hours) | Beams | | Slabs | | Ribs | | Columns (mm) |
|---|---|---|---|---|---|---|---|
| | Simply supported (mm) | Continuous (mm) | Simply supported (mm) | Continuous (mm) | Simply supported (mm) | Continuous (mm) | |
| 0.50 | 20 | 20 | 20 | 20 | 20 | 20 | 40 |
| 1.00 | 20 | 20 | 20 | 20 | 20 | 20 | 40 |
| 1.50 | 20 | 20 | 25 | 20 | **35** | 20 | 40 |
| 2.00 | **40** | 30 | **35** | 25 | 45 | **35** | 40 |
| 3.00 | 60 | **40** | 45 | **35** | 55 | 45 | 40 |
| 4.00 | 70 | 50 | 55 | 45 | 65 | 55 | 40 |

*Notes:* 1. The nominal covers given relate to specifically to the minimum member dimensions.
2. Cases below bold line require extra attention.

### 1.3.10 Mix Design (Mix Proportions), W/C Ratio and Concrete Grade

To achieve durability of cement concrete, we need careful selection of mix proportions and type of materials. Mix design for durability is based on various considerations as given in Tables 1.4–1.7 derived from IS:456-2000.

For 20 mm nominal maximum size of aggregate for different grades of cement concrete for various exposure conditions, minimum cement content and maximum W/C ratio limits are given in Table 1.8 for suitable durability.

Concrete ingredients shall be mixed in a mechanical mixer. The mixer should comply with Indian standards 1791 and 12119. The mixer shall be fitted with water measuring (metering) device. The mixing shall be continued until there is uniform distribution of ingredients and the mass is homogeneous and of uniform colour and consistency.

**Table 1.8:** Minimum cement content and maximum W/C ratio in RCC (IS:456-2000)

| Exposure conditions | Grade of concrete | Minimum cement content (kg/m$^3$) | Maximum W/C ratio by mass |
|---|---|---|---|
| Mild | M20 | 300 | 0.55 |
| Moderate | M25 | 300 | 0.50 |
| Severe | M30 | 320 | 0.45 |
| Very severe | M35 | 340 | 0.45 |
| Extreme | M40 | 360 | 0.40 |

structures adjacent to the joint should preferably be supported on separate columns or walls but not necessarily separate foundations.

### 1.5.3 Stresses and Design

Various design stresses and permissible stresses are specified in different Tables 1.12–1.19.

Shear reinforcement is provided as per design shear strength of concrete ($\tau_c$) in limit state design method (Table 1.12). In working stress method, the shear reinforcement is determined by considering permissible shear stress (Table 1.16).

**Table 1.12:** Limit state design shear strength of concrete ($\tau_c$)

| % Steel $\frac{100 A_s}{bd}$ | Grade of concrete | | | | | |
|---|---|---|---|---|---|---|
| | M15 | M20 | M25 | M30 | M35 | M40 and above |
| ≤ 0.15 | 0.28 | 0.28 | 0.29 | 0.29 | 0.29 | 0.30 |
| 0.25 | 0.35 | 0.36 | 0.36 | 0.37 | 0.37 | 0.38 |
| 0.50 | 0.46 | 0.48 | 0.49 | 0.50 | 0.50 | 0.51 |
| 0.75 | 0.54 | 0.56 | 0.57 | 0.59 | 0.59 | 0.60 |
| 1.00 | 0.60 | 0.62 | 0.64 | 0.66 | 0.67 | 0.68 |
| 1.25 | 0.64 | 0.67 | 0.70 | 0.71 | 0.73 | 0.74 |
| 1.50 | 0.68 | 0.72 | 0.74 | 0.76 | 0.78 | 0.79 |
| 1.75 | 0.71 | 0.75 | 0.78 | 0.80 | 0.82 | 0.84 |
| 2.00 | 0.71 | 0.79 | 0.82 | 0.84 | 0.86 | 0.88 |
| 2.25 | 0.71 | 0.81 | 0.85 | 0.88 | 0.90 | 0.92 |
| 2.50 | 0.71 | 0.82 | 0.88 | 0.91 | 0.93 | 0.95 |
| 2.75 | 0.71 | 0.82 | 0.92 | 0.94 | 0.96 | 0.98 |
| 3.00 and above | 0.71 | 0.82 | 0.92 | 0.96 | 0.99 | 1.01 |

**Table 1.13:** Maximum limit state design shear stress, $\tau_{c\,max}$ (N/mm$^2$)

| Concrete grade | M15 | M20 | M25 | M30 | M35 | M40 and above |
|---|---|---|---|---|---|---|
| $\tau_{c\,max}$ (N/mm$^2$) | 2.5 | 2.8 | 3.1 | 3.5 | 3.7 | 4.0 |

Shear reinforcement shall be provided to carry a shear force equal to $(V_u - \tau_c \cdot b \cdot d)$. $V_u$ is the shear force and $\tau_c$ is the design shear stress for the given grade of concrete and % age of steel reinforcement. The strength of shear reinforcement $V_{us}$ shall be calculated as below:

(a) For vertical stirrups: $V_{us} = \dfrac{0.87 A_{sv} \cdot f_y \cdot d}{S_v}$ ... Eq. (1.5)

(b) For inclined stirrups: $V_{us} = \dfrac{0.87 f_y \cdot A_{sv} \cdot d}{S_v} (\sin\alpha + \cos\alpha)$ ... Eq. (1.6)

(c) For single bar or single group of bars: $V_{us} = 0.87 f_y \cdot A_{sv} \cdot \sin\alpha$ ... Eq. (1.7) where,

$A_{sv}$ = Total cross-sectional area of stirrup legs or bent up bars within a distance ($S_v$)

$S_v$ = Spacing of the stirrups or bent up bars along the length (span) of the member

$\tau_c$ = Shear strength of the concrete (design shear strength in limit state and permissible shear stress in working stress)

$b$ = Breadth of the member which for flanged beams shall be taken as the breadth of the web ($b_w$)

$d$ = Effective depth of the section

$\sigma_{sv}$ = Permissible tensile stress in shear reinforcement which shall not be taken greater than 230 N/mm$^2$ while in limit state it shall be taken as 0.87 $f_y$ N/mm$^2$

$\alpha$ = Angle between the inclined stirrups or bent up bars and the axis of the member not less than 45°

**Table 1.18:** Permissible stresses in steel reinforcement (working stress method)

| S. No. | Type of stress in steel reinforcements | Permissible stresses (N/mm$^2$) | | |
|---|---|---|---|---|
| | | MS grade I (IS:432) | Medium tensile steel (IS:432) | HYSD Fe 415 (IS:1786) |
| 1 | Tensile stress ($\sigma_{st}$, $\sigma_{sv}$)<br>(a) Diameters up to 20 mm<br>(b) Diameters over 20 mm | <br>140<br>130 | Half yield stress subject to a maximum 190 | <br>230<br>230 |
| 2 | Compressive stress in columns (direct) $\sigma_{sc}$ | 130 | 130 | 190 |
| 3 | Compressive stress in bars in bending elements (beams, slabs) when the compressive resistance of the concrete is taken into account | The calculated compressive stress in the surrounding concrete multiplied by 1.5 times the modular ratio ($\sigma_{cbc}$ × 1.5 m) or $\sigma_{sc}$ whichever is lower | | |
| 4 | Compressive stress in bars in bending elements (beams, slabs) when the compressive resistance of the concrete is not taken into account<br>(a) Up to 20 mm diameter<br>(b) Over 20 mm diameter | <br>140<br>130 | Half the guaranteed yield stress subject to a maximum of 190 | <br>190<br>190 |

*Notes:* (i) For HYS deformed bars of grade Fe 500, the permissible stress in direct tension and flexural tension shall be 0.55 $f_y$. The permissible stress for shear and compression reinforcement shall be same as for grade Fe 415.

(ii) For the purpose of standard IS:456, the yield stress of steels for which there is no clearly defined yield point, should be taken to be 0.20% proof stress.

and height above ground level. The wind load on the structure also depends on the shape of the structure and plan dimensions. Relevant wind pressure coefficients are adopted according to the shape of the structure in plan. These coefficients are also specified in IS:875-1987 (Part III). Wind loads on sloping roofs may vary according to the slope of the roof slab.

India is divided in different zones according to intensity of earthquake. Earthquake induces acceleration in the structure due to vibration. This causes horizontal and vertical forces on the structure. According to the location zone, the acceleration coefficients are specified in IS codes. From these coefficients, horizontal and vertical forces caused by earthquake are calculated by multiplying the mass with the respective acceleration coefficients (Fig. 1.1).

Force = mass × acceleration coefficient

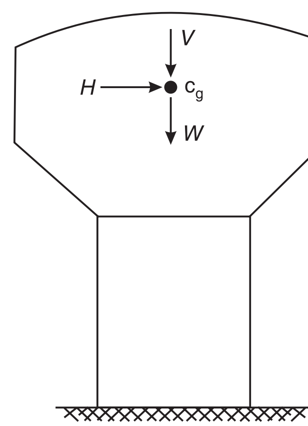


**Fig. 1.1** Earthquake forces on the structure

Horizontal force ($H$) acting at mass centre of structure = mass × horizontal acceleration coefficient = $(m \times \alpha_H)$

Vertical force ($V$) acting at the mass centre of structure = mass × vertical acceleration coefficient = $(m \times \alpha_V)$

These loads shall be considered in design of tall structures, OHSR, multistoreyed buildings, etc.

## 1.7 ARRANGEMENT OF REINFORCEMENT

### (a) Slabs

Minimum reinforcements, cover, and spacing of main and secondary (distribution) bars are shown in Fig. 1.2 as per IS:456-2000.

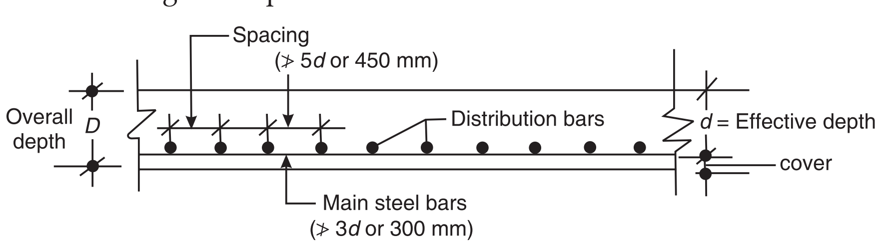


**Fig. 1.2** Reinforcement details in RCC slab

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# Unit II : Limit State Design of Beams

## 4. Limit State Design of Beam Section for Bending Moment



## 5. Limit State Design for Shear, Torsion, Bond and Development Length of Reinforcement in Beams



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# Unit III: Limit State Design of Slabs

## 7. Limit State Design of Slabs

# UNIT VII: Miscellaneous Structures

## 12. Introduction to Prestressed Structural Concrete



## 13. Design of RCC Staircases



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## 15. Yield Line Analysis of Slabs