ANALYSIS AND DESIGN OF CANTILEVER SLABS

INTRODUCTION

A slab is like a flat plate loaded transversely and supported on its edges. Under the loads, it bends and the directions of its bending depend on its shape and support conditions. A beam bends only in one direction, i.e. in its own plane; where as a slab may have multidirectional bending. Therefore, slabs may have different names depending upon its bending, support conditions and shapes. For example, a slab may be called

(a) One-way simply supported rectangular slab,

(b) Two-way simply supported or restrained rectangular slab,

(c) Cantilever rectangular slab,

(d) Fixed or simply supported circular slab, etc

One-way slab means it bends only in one direction and, therefore, reinforcement for bending (i.e. main reinforcement) is provided only in that direction. A slab supported on all sides bends in all the directions so the main reinforcements provided shall be such that they may be effective in all directions. For ease of analysis and convenience of reinforcement detailing, the bending moments in a slab are calculated in two principal directions only and, therefore, such a slab is called a two-way slab.

A slab is designed as a beam of unit width in the direction of bending. In this unit, only the most commonly used rectangular slabs, with uniformly distributed load is described.

Objectives

After studying this unit, you should be able to

• describe the design and detailing of cantilever slabs,

• design and explain detailing of one-way and two-way simply supported slabs, and

• explain the design and detailing of two-way restrained slabs

GENERAL PRINCIPLES OF DESIGN AND DETAILING OF SLABS

Following are the general principles for design and detailing applicable to all types of slabs

(a) The maximum diameter of reinforcing bars shall not exceed1/8 th of total thickness (D) of the slab.

(b) Normally, shear reinforcement is not provided in slabs. The shear resistance requirements may, then, be complied either by increasing the percentage of tensile reinforcement or by increasing the depth of slab, but the latter is preferred as it is economical. For solid slabs, the design shear strength for concrete slab shall be τ ,c, K, , where K has the values given IS 800.

(c) To take care of temperature and shrinkage stresses, minimum reinforcement in either direction shall not be less than 0.15 percent and 0.12 percent of total cross section area of concrete section for mild steel and high strength deformed bars, respectively.

(d) To meet the requirement for limit state of cracking the following two rules are observed:

   (i) The horizontal distance between parallel main reinforcement shall not be more than 3 times the effective depth of slab or 300 mm whichever is smaller.

   (ii) The horizontal distance between parallel bars provided against temperature and shrinkage shall not be more than 5 d or 450 mm, whichever is smaller

DESIGN OF SLAB

Definition :

Slab is a thin flexural member used as a floor of structure to support the imposed load

Loads on slab :

Generally in design of horizontal slab two types of loads are considered.

- Dead load
- Imposed load

Dead load :

The dead load in slab comprises of the immovable partitions. Floor finishes weathering courses and primarily its weight .The dead loads are to be determined based on the weight of the materials .

Imposed loads:

Imposed load is the load induced by the intent use or occupancy of the building including the weight of movable partitions load due to impact vibrations.

Basic rules for the design of the slab :

The two main factors to be considered while designing the slab are:

- Strength of the slab against flexure, shear, twisted.
- Stiffness against deflection

One way slab – codal requirements :

When the ratio of the longer span to shorter span is greater than 2, it is called one way slab and bending takes place along one direction. The loads on the slab is transferred to the supports only on the main reinforcement. Hence main reinforcement is provided in the shorter span.

Minimum requirement in slab :

As per clause 26.5.2.1 of IS 456:2000, the reinforcement in either direction ,in slabs shall not be less than 0.12% of the total cross sectional area , when HYSD bars Fe415 are used.

Maximum size of bars in slabs

As per clause 26.5.2.2 of IS 456 :2000 , the reinforcing bars shall not exceed 1/8 of the total thickness of the slab.

DESIGN OF CANTILEVER SLAB

Design a cantilever chajja slab projecting 1m from the support using M20 grade concreteand Fe415 HYSD bars. Adopt a live load of 3kN/m^2.

i. Given

$L = 1$ m

$q = 3$ kN/m^2

$f_{ck} = 20$ N/mm^2

$f_y = 415$ N/mm^2

$\tau_{bd} = 1.2$N/mm^2 for plain bars for

M20grade concrete

ii. Depth of slab

Effective depth d = (span/7)

= 1000/7 = 142.8 mm

Adopt d = 150 mm

D = 175 mm

Adopt maximum depth of 150 mm at support gradually reducing to 100 mm at the free end.

iii. Loads

Self-weight of slab = 0.5 (0.15 + 0.10) 2.5

= 3.125 kN/m

Live load = 3.000

Finishes = 0.875 kN/m

Total working load = 7.000 kN/m

Design ultimate load w_u = (1.5 x 7.00)

= 10.5 kN/m

iv. Ultimate design moments and shear forces

$M_u = 0.5\, w_u L^2$

$= 0.5 \times 10.5 \times 1^2$

$= 5.25$ kNm

$V_u = w_u\, l$

$= 10.5 \times 1$

$= 10.50$ kN

v. Check for depth

$M_{u\,lim} = 0.138\, f_{ck}\, bd^2$

$= (0.138 \times 20 \times 10^3 \times 150^2)\, 10^{-6}$

$= 62.10$ kNm

Since $M_u < M_{u\,lim}$,

Section is under – reinforced.

vi. Reinforcements

$$M_u = 0.87\, f_y\, Ast\, d\, (1 - \frac{f_y Ast}{f_{ck} bd})$$

$$5.25 \times 10^6 = 0.87 \times 415 \times Ast \times 150\, (1 - \frac{140\, Ast}{20 \times 1000 \times 150})$$

Solving Ast = $105\ mm^2 < Ast_{min}$

Hence provide 10 mm diameter bars at 300 mm centres ($Ast = 262\ mm^2$) in the span direction and the same as distribution reinforcement.

vii. Anchorage length

$$L_d = \frac{0.87 f_y\, \phi}{4 \tau_{bd}}$$

$$= \frac{0.87 \times 415 \times 10}{4 \times 1.2 \times 1.6}$$

$$= 470\ mm$$

viii. Check for deflection control

$$\left(\frac{L}{d}\right)_{max} = \left(\frac{L}{d}\right)_{Basic} \times k_t$$

And $k_c = k_f = 1.00$

$$p_t = \frac{100\, Ast}{bd}$$

$$= \frac{100 \times 262}{10^3 \times 150}$$

$$= 0.174\ mm$$

$$k_t = 1.8$$

Hence $\left(\frac{L}{d}\right)_{max} = 2.7 \times 1.8 = 12.6$

$$\left(\frac{L}{d}\right)_{Actual} = \frac{1000}{150} = 6.66 < 12.6$$

Hence the slab satisfies the deflection criteria.

ix. Reinforcement details

The reinforcement details in the cantilever slab is shown in fig.