Flat Slab Design (for flexure)- full design includes the punching shear design

Introduction

Analysis methods

A range of methods is available for designing flat slabs and analysing them in flexure at ultimate limit state.

- Elastic Plane Frame – Equivalent Frame Method, Annex I
- **Tabular method - Equivalent Frame Method, Annex I** < selected
- Yield line – Plastic method of design
- Finite element analysis
  - – Elastic method
  - – Elasto plastic

This calculator analyse and design flat slab using tabular method. For a small regular frame, the empirical method using tabular moment and shear coefficients. (Eurocode 2, Concise table 15.3 is used)

According to *Concise Tables 15.3*- The web calculator use the tabular method analysis to determine the respective moments and shear forces.

– Suitable for regular grids and spans of similar length

– Design for full load in both directions

– (Suitable for 2-span)

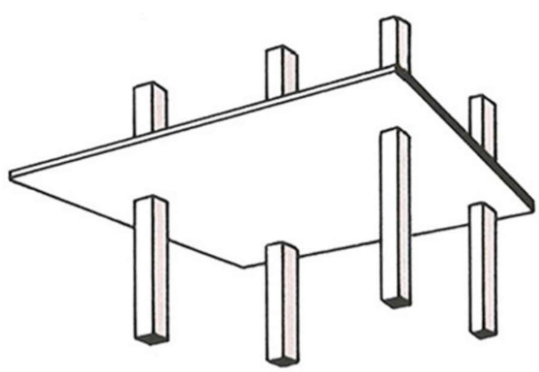

Figure 1 Flat slab

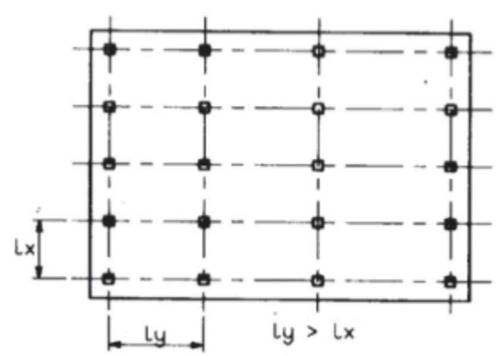

Figure 2 Series of flat slab span in a floor grid

Column strip and middle strip

The width of column strips is the minimum of ($0.5l_x$, $0.5l_y$). The middle strip will become the span length in X and Y direction minus the column strip.

The strips between column strips are middle strips.

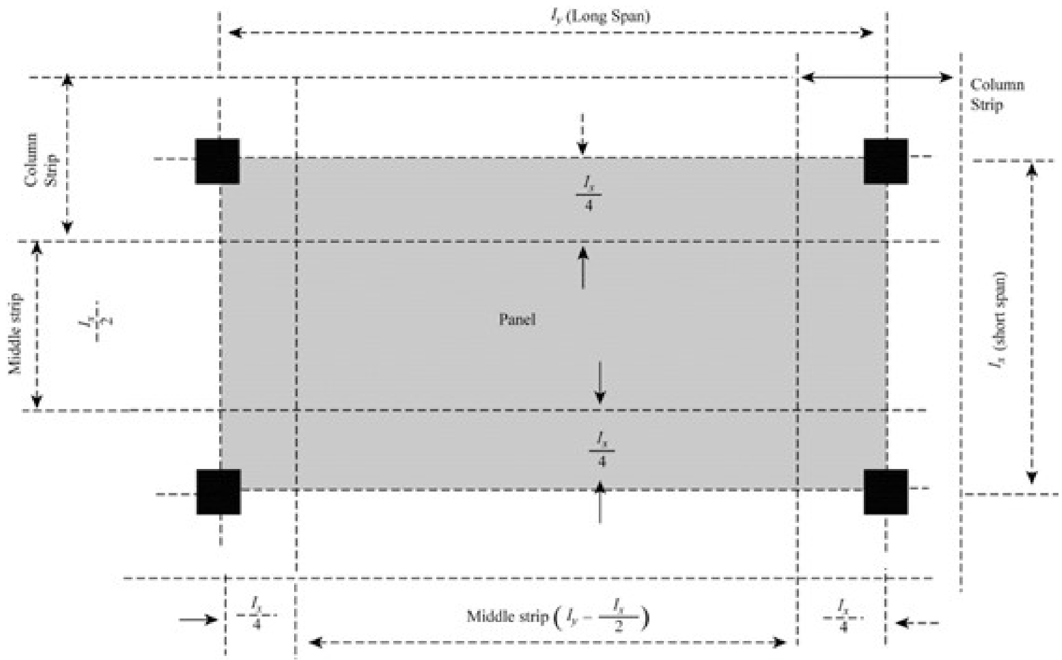

Figure 3 Column and middle strip

Design procedure

Design for bending

- ❑ Loading

Safety Factor	
SF for live load; qk	1.25,1.3, 1.4 ,1.5, 1.6
SF for dead load; gk	1.25, 1.35, 1.4, 1.5 , 1.6

Design load = Live load * $SF_{,qk}$ + Dead load * $SF_{,gk}$

where : $SF_{,qk}$ and $SF_{,gk}$ are safety factors for live load and dead load respectively.

- Effective span

  $Span,_{eff} = l_y – 2* \text{column size} + 2 * \text{Slab thickness}/2$

  where : l_y is a span length in the Y direction.

  (It is assumed $l_y > l_x$)

- Moment
  - Sagging moment (In panel)

    $M_{ED,S} = [SF,_{gk} * gk * 0.09 + SF,_{qk} * qk * 0.100] * l_x*(Span,eff)^2$

    where : gk and qk are dead load and live load respectively.

    The coefficient 0.09 is 'Moment gk' from the EC concise table.

  - Hogging moment (Along support)

    $M_{ED,H} = \text{Design load} * 0.106 * l_x *(Span,eff)^2$

    Where :

    The coefficient 0.106 is 'Moment qk' from the EC concise table.

  - Division of moments

    Sagging moment (Positive moments) (50% taken in both column and middle strips)

    Column strip

    $M_{ED,+ve} = 0.5 * M_{ED,S}$ / column strip

    Middle strip

    $M_{ED,+ve} = 0.5 * M_{ED,S}$ / column strip

    Hogging moments (Negative moments) (70% taken in column strip and 30% in middle strip)

    Column strip

    $M_{ED,-ve} = 0.70 * M_{ED,H}$ / column strip

    Middle strip

    $M_{ED,-ve} = 0.30 * M_{ED,H}$ / column strip

From analysis, determine design values for Sagging (column strip and middle strip) and Hogging (column strip and middle strip) moments.

- Effective depth, d:

  d = Slab thickness - concrete cover - bar dia/2

- Determine K for $M_{ED,+ve}$, $M_{ED,+ve}$, $M_{ED,-ve}$, and $M_{ED,-ve}$

  $K = M/ (bd^2 f_{ck})$

  where : d = effective depth = D - cover – Ø/2

  b = width = Since the moment is per metre, 1 m is taken

  f_{ck} = characteristic compressive strength (MPa)

- Determine lever arm, z for every K

  $$z = \frac{d}{2}[\, 1 + \sqrt{1 - 3.53\, K}] \leq 0.95d$$

- Steel area A_s for $M_{ED,+ve}$, $M_{ED,+ve}$, $M_{ED,-ve}$, and $M_{ED,-ve}$ with their respective *z*

  $$A_s = \frac{M}{f_{yd} * z}$$

  where : $f_{yd} = f_{yk}/\gamma_s$ = 500/1.15 = 434.8 MPa

  γ_s = Material safety factor

  f_{yk} = design yield stress

- Spacing , c/c: for every section area.

  $$s = b * \frac{as_1}{A_s} \leq 2 * D \text{ (mm)}$$

  where : as_1 = area of bar

  A_s = required amount of steel area

  D = slab thickness

  b = section width= 1000 mm is taken

Annex

Coefficient method, Concise table 15.3

Coefficients for use with beams (and one-way spanning slabs) to Eurocode 2

Coefficient	Location				
	Outer support	Near middle of end span	At 1st interior support	At middle of interior spans	At interior supports
Moment g_k and q_k	25% span[a]	—	0.094	—	0.075
Moment g_k	—	0.090	—	0.066	—
Moment q_k	—	0.100	—	0.086	—
Shear	0.45	—	0.63:0.55	—	0.50:0.50[b]

Conditions

- For slabs, 3 or more spans. (They may also be used for 2 span beams but support moment coefficient = 0.106 and internal shear coefficient = 0.63 both sides).
- Generally Qk ≤ Gk , and the loading should be substantially uniformly distributed. Otherwise special curtailment of reinforcement is required.
- Minimum span ≥ 0.85 x maximum (and design) span.

Basis: All- and alternate-spans-loaded cases as UK National Annex and 15% redistribution at supports.

- At outer support '15% span' relates to the UK Nationally Determined Parameter for BS EN 1992-1-1 Cl 9.3.1.2 for minimum percentage of span bending moment to be assumed at supports in slabs in monolithic construction.

Minimum thickness regulation

BS EN 1992-1-2: Table 5.8

Standard fire resistance, R, integrity, E, insulation, I	Minimum dimensions (mm)				
	Slab thickness h_s	Axis distance, a (simply supported)			Axis distance, a (continuous)
		One-way	Two-way		
			$l_y/l_x \le 1.5$	$1.5 < l_y/l_x \le 2$	
REI 60	80	20	10	15	10
REI 90	100	30	15	20	15
REI 120	120	40	20	25	20
REI 240	175	65	40	50	40

Reference

https://civiltoday.com/structural-engineering/54-flat-slab-design-and-detailing-pdf

Narayanan, R. and Goodchild, C. (2006). *Concise Eurocode*. 2nd ed. Crowthorne: British Cement Association.