DESIGN AND DETAILING OF FLAT SLAB

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CONTENT

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- Design Considerations
- Design Methodology
- Analysis of Flat Slab
- Detailing
INTRODUCTION

What is a flat slab?

• a reinforced concrete slab supported directly by concrete columns without the use of beams
INTRODUCTION

- Flat slab
- Flat slab with drop panels
- Flat slab with column head
- Flat slab with drop panel and column head
INTRODUCTION

Uses of column heads:

- increase shear strength of slab
- reduce the moment in the slab by reducing the clear or effective span

Flat slab with column head
INTRODUCTION

Uses of drop panels:

- increase shear strength of slab
- increase negative moment capacity of slab
- stiffen the slab and hence reduce deflection
BENEFITS
BENEFITS

• Flexibility in room layout
• Saving in building height
• Shorter construction time
• Ease of installation of M&E services
• Prefabricated welded mesh
• Buildable score
FLEXIBILITY IN ROOM LAYOUT

- allows Architect to introduce partition walls anywhere required
- allows owner to change the size of room layout
- allows choice of omitting false ceiling and finish soffit of slab with skim coating
SAVING IN BUILDING HEIGHT

- Lower storey height will reduce building weight due to lower partitions and cladding to façade
- approx. saves 10% in vertical members
- reduce foundation load
SHORTER CONSTRUCTION TIME

flat plate design will facilitate the use of big table formwork to increase productivity
• Simplified the table formwork needed
EASE OF INSTALLATION OF M&E SERVICES

• all M & E services can be mounted directly on the underside of the slab instead of bending them to avoid the beams

• avoids hacking through beams
PRE-FABRICATED WELDED MESH

- Prefabricated in standard sizes
- Minimised installation time
- Better quality control
Benefits . . .

**BUILDABLE SCORE**

- allows standardized structural members and prefabricated sections to be integrated into the design for ease of construction

- this process will make the structure more buildable, reduce the number of site workers and increase the productivity at site

- more tendency to achieve a higher Buildable score
DESIGN CONSIDERATIONS
Design Considerations...

WALL AND COLUMN POSITION

- Locate position of wall to maximise the structural stiffness for lateral loads
- Facilitates the rigidity to be located to the centre of building

Typical floor plan of Compass the Elizabeth
OPTIMISATION OF STRUCTURAL LAYOUT PLAN

• the sizes of vertical and structural structural members can be optimised to keep the volume of concrete for the entire superstructure inclusive of walls and lift cores to be in the region of 0.4 to 0.5 m³ per square metre

• this figure is considered to be economical and comparable to an optimum design in conventional of beam and slab systems
**DEFLECTION CHECK**

- necessary to include checking of the slab deflection for all load cases both for short and long term basis

- In general, under full service load, $\delta < L/250$ or 40 mm whichever is smaller

- Limit set to prevent unsightly occurrence of cracks on non-structural walls and floor finishes
CRACK CONTROL

• advisable to perform crack width calculations based on spacing of reinforcement as detailed and the moment envelope obtained from structural analysis

• good detailing of reinforcement will
  – restrict the crack width to within acceptable tolerances as specified in the codes and
  – reduce future maintenance cost of the building
FLOOR OPENINGS

- No opening should encroach upon a column head or drop
- Sufficient reinforcement must be provided to take care of stress concentration
PUNCHING SHEAR

- always a critical consideration in flat plate design around the columns
- instead of using thicker section, shear reinforcement in the form of shear heads, shear studs or stirrup cages may be embedded in the slab to enhance shear capacity at the edges of walls and columns
Design Considerations...

PUNCHING SHEAR

Shear
Studs
CONSTRUCTION LOADS

• critical for fast track project where removal of forms at early strength is required

• possible to achieve 70% of specified concrete cube strength within a day or two by using high strength concrete

• alternatively use 2 sets of forms
LATERAL STABILITY

• buildings with flat plate design is generally less rigid

• lateral stiffness depends largely on the configuration of lift core position, layout of walls and columns

• frame action is normally insufficient to resist lateral loads in high rise buildings, it needs to act in tandem with walls and lift cores to achieve the required stiffness
LATERAL STABILITY

MULTIPLE FUNCTION PERIMETER BEAMS
• adds lateral rigidity
• reduce slab deflection
DESIGN
METHODOLOGY
METHODS OF DESIGN

- the finite element analysis
- the simplified method
- the equivalent frame method
**FINITE ELEMENT METHOD**

- Based upon the division of complicated structures into smaller and simpler pieces (elements) whose behaviour can be formulated.

- E.g of software includes SAFE, ADAPT, etc

- results includes
  - moment and shear envelopes
  - contour of structural deformation
SAFE - 984apart2results - [Structural Layer Plan View]
SIMPLIFIED METHOD

Table 3.19 may be used provided

- Live load > 1.25 Dead load
- Live load (excluding partitions) > 5KN/m²
- there are at least 3 rows of panels of approximately equal span in direction considered
- lateral stability is independent of slab column connections
**SIMPLIFIED METHOD**

Table 3.19: BM and SF coefficients for flat slab or 3 or more equal spans

<table>
<thead>
<tr>
<th>Outer Support</th>
<th>Near centre of 1st span</th>
<th>First interior span</th>
<th>Centre of interior span</th>
<th>Interior span</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Column</td>
<td>Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moment</td>
<td>-0.04FI*</td>
<td>0.086FI</td>
<td>0.083FI*</td>
<td>-0.063FI</td>
</tr>
<tr>
<td>Shear</td>
<td>0.45F</td>
<td>0.4F</td>
<td>-</td>
<td>0.6F</td>
</tr>
<tr>
<td>Total column moments</td>
<td>0.04FI</td>
<td>-</td>
<td>-</td>
<td>0.022FI</td>
</tr>
</tbody>
</table>

* the design moments in the edge panel may have to be adjusted according to 3.7.4.3

F is the total design ultimate load on the strip of slab between adjacent columns considered (1.4gk + 1.6 qk)

l is the effective span
EQUIVALENT FRAME METHOD

- most commonly used method

- the flat slab structure is divided longitudinally and transversely into frames consisting of columns and strips of slabs with:
  - stiffness of members based on concrete alone
  - for vertical loading, full width of the slab is used to evaluate stiffness
  - effect of drop panel may be neglected if dimension $< \frac{l_x}{3}$
EQUIVALENT FRAME METHOD

Plan of floor slab

Step 1: define line of support in X & Y directions
Step 2: define design strips in X & Y directions
ANALYSIS OF FLAT SLAB
Effective dimension of a head, \( l_h (mm) = \text{lesser of } l_{ho} \text{ or } l_{h \text{ max}} \)

where \( l_{ho} = \) actual dimension, \( l_{h \text{ max}} = l_c + 2(d_h - 40) \)

(i) \( l_h = l_{h \text{ max}} \)  
(ii) \( l_h = l_{ho} \)
For circular column or column head,
effective diameter, \( h_c = 4 \times \frac{\text{area}}{\theta} < 0.25 \, l_x \)
DIVISION OF PANELS

The panels are divided into ‘column strips’ and middle strips’ in both directions.

(a) Slab Without Drops
(b) Slab With Drops

Note: Ignore drop if dimension is less than lx/3.
### MOMENT DIVISION

Apportionment between column and middle strip expressed as % of the total negative design moment

<table>
<thead>
<tr>
<th></th>
<th>Column strip</th>
<th>Middle strip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>Positive</td>
<td>55%</td>
<td>45%</td>
</tr>
</tbody>
</table>

• Note: For slab with drops where the width of the middle strip exceeds L/2, the distribution of moment in the middle strip should be increased in proportion to its increased width and the moment resisted by the column strip should be adjusted accordingly.
A floor slab in a building where stability is provided by shear walls in one direction (N-S). The slab is without drops and is supported internally and on the external long sides by square columns. The imposed loading on the floor is 5 KN/m² and an allowance of 2.5KN/m² for finishes, etc. $f_{cu} = 40$ KN/m², $f_y = 460$ KN/m²
Division of panels into strips in x and y direction
Analysis of flat slab.

MOMENT DIVISION - EXAMPLE

Column strip
- exterior support = 0.75*35 on 2.5m strip = 10.5Kn-m
- centre of 1st span = 0.55*200 on 2.5 strip = 44Kn-m
- 1st interior support = 0.75*200 on 3m strip = 50Kn-m
- centre of interior span = 0.55 *369 on 3m strip = 67.7Kn-m

Middle strip
- exterior support = 0.25*35 on 2.5m strip = 3.5Kn-m
- centre of 1st span = 0.45*200 on 2.5 strip = 36Kn-m
- 1st interior support = 0.25*200 on 3m strip = 16.7Kn-m
- centre of interior span = 0.45 *369 on 3m strip = 55.4Kn-m
DESIGN FOR BENDING

INTERNAL PANELS

- columns and middle strips should be designed to withstand design moments from analysis
DESIGN FOR BENDING

EDGE PANELS

• apportionment of moment exactly the same as internal columns
• max. design moment transferable between slab and edge column by a column strip of breadth $b_e$ is

$$M_{t,\text{max}} = 0.15 b_e d^2 f_{cu}$$

• ≦ 0.5 design moment (EFM)
• ≦ 0.7 design moment (FEM)

Otherwise structural arrangements shall be changed.
PUNCHING SHEAR

1. Calculate $V_{\text{eff}} = kV_t$ at column perimeter (approx. equal span)
   $V_t = $ SF transferred from slab
   $k = 1.15$ for internal column, 1.25 corner columns and edge columns
   where M acts parallel to free edge and 1.4 for edge columns where M acts at right angle to free edge

2. Determine $v_{\text{max}} = V_{\text{eff}} / u_o d$ where $u_o$ is the length of column perimeter
   Check $v_{ma} < 0.8 \ f_{cu}$ or 5 N/mm$^2$

3. Determine $v = (V_{\text{eff}} - V / u d)$ where $u$ is the length of perimeter A and V is the column load and check $v < v_c$

4. Repeat step 3 for perimeter B and C
**DEFORMATION**

<table>
<thead>
<tr>
<th></th>
<th>Span/depth ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantilever</td>
<td>7</td>
</tr>
<tr>
<td>Simply supported</td>
<td>20</td>
</tr>
<tr>
<td>Continuous</td>
<td>26</td>
</tr>
</tbody>
</table>

(i) use normal span/effective depth ratio if drop width >1/3 span each way; otherwise

(ii) to apply 0.9 modification factor for flat slab, or where drop panel width < L/3 1.0 otherwise
Holes in areas bounded by the column strips may be formed providing:

- greatest dimension < 0.4 span length and

- total positive and negative moments are redistributed between the remaining structure to meet the changed conditions
Holes in **areas common to two column strips** may be formed providing:

- that their aggregate length or width does not exceed one-tenth of the width of the column strip;
- that the reduced sections are capable of resisting with the moments; and
- that the perimeter for calculating the design shear stress is reduced if appropriate.
Holes in areas common to the column strip and the middle strip may be formed providing:

- that in aggregate their length or width does not exceed one-quarter of the width of the column strip and
- that the reduced sections are capable of resisting the design moments
For all other cases of openings, it should be framed on all sides with beams to carry the loads to the columns.
DETAILING OF FLAT SLAB
TYPE OF REINFORCEMENT

**F-mesh** - A mesh formed by main wire with cross wire at a fixed spacing of 800 mm

**Main wire** - hard drawn ribbed wire with diameter and spacing as per design

**Cross wire** - hard drawn smooth wire as holding wire

H8-800mm c/c for main wire diameter > 10mm

H7-800mm c/c for main wire diameter of 10mm and below
TYPE OF REINFORCEMENT

Main Wire

F-Mesh 2

Holding Wire

Holding Wire (800mm c/c)

F-Mesh 1
<table>
<thead>
<tr>
<th>Mesh Type</th>
<th>Main Wire</th>
<th>Cross Wire</th>
<th>Mass Per Unit Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td>Spacing</td>
<td>Kg/m²</td>
</tr>
<tr>
<td>D10150780</td>
<td>D</td>
<td>10 @ 150</td>
<td>524</td>
</tr>
<tr>
<td>D1010780</td>
<td>D</td>
<td>10 @ 140</td>
<td>561</td>
</tr>
<tr>
<td>D1030780</td>
<td>D</td>
<td>10 @ 130</td>
<td>609</td>
</tr>
<tr>
<td>D1020780</td>
<td>D</td>
<td>10 @ 120</td>
<td>655</td>
</tr>
<tr>
<td>D10110780</td>
<td>D</td>
<td>10 @ 110</td>
<td>714</td>
</tr>
<tr>
<td>D10100780</td>
<td>D</td>
<td>10 @ 100</td>
<td>788</td>
</tr>
<tr>
<td>F13150880</td>
<td>D</td>
<td>13 @ 150</td>
<td>685</td>
</tr>
<tr>
<td>F13140880</td>
<td>D</td>
<td>13 @ 140</td>
<td>949</td>
</tr>
<tr>
<td>F13130880</td>
<td>D</td>
<td>13 @ 130</td>
<td>1022</td>
</tr>
<tr>
<td>F13120880</td>
<td>D</td>
<td>13 @ 120</td>
<td>1107</td>
</tr>
<tr>
<td>F13110880</td>
<td>D</td>
<td>13 @ 110</td>
<td>1207</td>
</tr>
<tr>
<td>F13100880</td>
<td>D</td>
<td>13 @ 100</td>
<td>1335</td>
</tr>
<tr>
<td>F13090880</td>
<td>D</td>
<td>13 @ 90</td>
<td>1475</td>
</tr>
<tr>
<td>F13080880</td>
<td>D</td>
<td>13 @ 80</td>
<td>1660</td>
</tr>
</tbody>
</table>

| 2F13140880 | 2D         | 13 @ 140   | 1897  | 15.38 | 15.15 |
| 2F13130880 | 2D         | 13 @ 130   | 2143  | 16.53 | 16.28 |
| 2F13120880 | 2D         | 13 @ 120   | 2413  | 17.65 | 17.69 |
| 2F13110880 | 2D         | 13 @ 110   | 2413  | 19.44 | 19.15 |
| 2F13100880 | 2D         | 13 @ 100   | 2835  | 21.33 | 21.01 |
| 2F13090880 | 2D         | 13 @ 90    | 2950  | 23.06 | 23.30 |
| 2F13080880 | 2D         | 13 @ 80    | 3318  | 26.55 | 25.15 |

D10  denote 10mm deformed wire
D12  denote 13mm deformed wire
D13w denote twin 13mm deformed wire

Main Wire

Main Wire - Staggered

Table of T-Mesh available in BRC

Holding Wire
Typical Main Lap Details

Holding Wire

Tension Lap = 45 dia.

Main Wire
F - Mesh

Main Wire

Cross Wire
REINFORCEMENT FOR INTERNAL PANELS

- Reinforcement are arranged in 2 directions parallel to each span; and

- 2/3 of the reinforcement required to resist negative moment in the column strip must be placed in the centre half of the strip

- for slab with drops, the top reinforcement should be placed evenly across the column strip
STANDARD LAPPING OF MESH
(FOR FLAT SLAB)
TYPICAL DETAIL SHOWING RECESS AT SLAB SOFFIT FOR SERVICES
TYPICAL SECTION AT STAIRCASE

PRECAST FLIGHT

REINF. REFER TO PLAN

1ST STOREY FL. LEV.

250

ACTUAL POSITION AND SIZE OF GROUT HOLE TO REFER TO PRECAST STAIRCASE DWGS.
DETAILS OF INSPECTION CHAMBER AT APRON
DETAILS OF INSPECTION CHAMBER AT APRON
DETAILS OF INSPECTION CHAMBER AT APRON
DETAILS OF INSPECTION CHAMBER AT APRON
DETAILS OF INSPECTION CHAMBER AT PLAY AREA

2T16-100 EXTRA

REINF. (c) FROM INSPECTION CHAMBER

250 OR VARIES

REINF. NOT SHOWN
REFER TO SEPARATE DWG.

C - C
1ST STOREY (DWELLING UNIT) SLAB DETAILS OF HOUSEHOLD SHELTER
TYPICAL DETAILS OF 125X250 RC CHANNEL FOR GAS PIPE ENTRY

DETAIL TYPE 1

THROUTH APRON DRAIN
TYPICAL SECTION
THRU’ COVERED HOUSEDRAIN (PRECAST)