The study is arranged by

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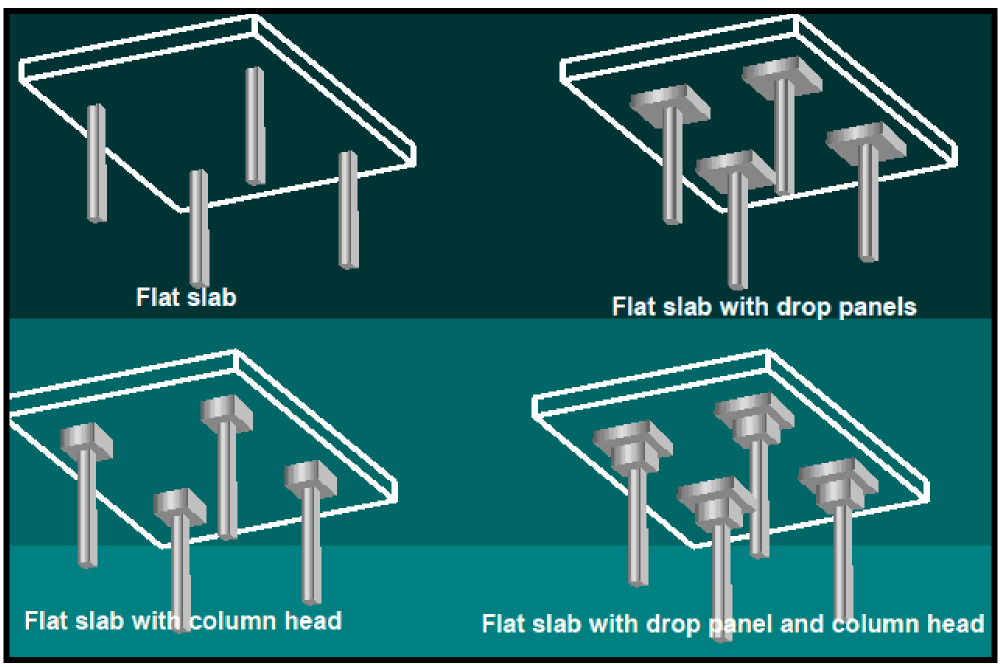
DESIGN AND DETAILING OF FLAT SLAB

- **Introduction**
- **Benefits**
- **Design Cnsiderations**
- **Analysis of Flat Slab**
- **Detailing**

Introduction:

A flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams.



Uses of column heads:

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

Uses of drop panels :

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

BENEFITS:

Faster construction

The benefits of using flat slab construction are becoming increasingly recognised. Flat slabs without drops (thickened areas of slab around the columns to resist punching shear) can be built faster because formwork is simplified and minimised, and rapid turn-around can be achieved using a combination of early striking2 and flying systems. The overall speed of construction will then be limited by the rate at which vertical elements can be cast.

Reduced services and cladding costs

Flat slab construction places no restrictions on the positioning of horizontal services and partitions and can minimize floor-to-floor heights when there is no requirement for a deep false ceiling. This can have knock-on benefits in terms of lower building height, reduced cladding costs and prefabricated services.

Flexibility for the occupier

Flat slab construction offers considerable flexibility to the occupier who can easily alter internal layouts to accommodate changes in the use of the structure. This flexibility results from the use of a square or near-square grid and the absence of beams, down stands or drops that complicate the routing of services and location of partitions.

Slab thickness

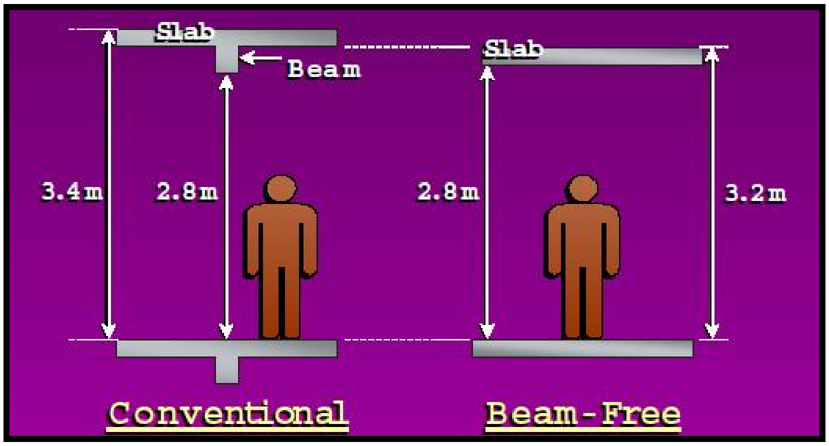
Having chosen a flat slab solution, the next key issue is to determine an appropriate slab thickness. In general, thinner slabs not only save on direct material costs for the frame and the supporting foundations but also provide knock-on benefits in terms of reduced height of the structure and lower cladding costs. Further guidance is given in Reference 1. There is, of course, a lower limit to the slab thickness. As this is approached, the savings identified above become outweighed by the extra reinforcement required to deal with serviceability issues and the increased difficulty in designing and fixing it. There is also a case for providing some margin, particularly at outline scheme stage, to accommodate late changes in architectural requirements.

Flexibility in room layout:

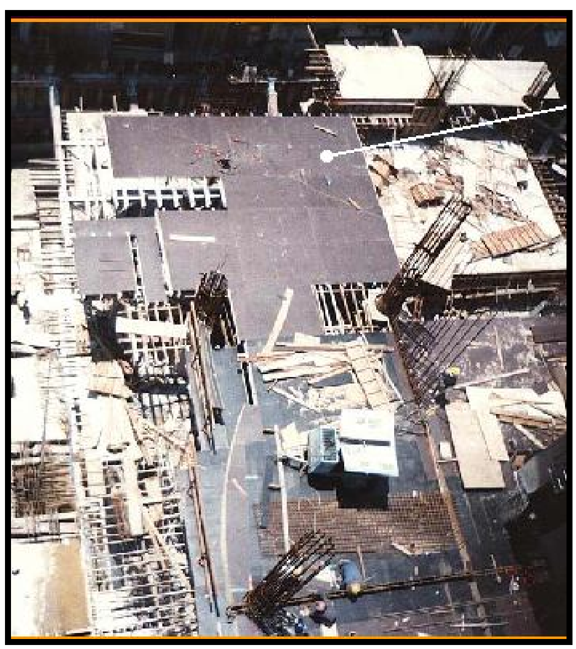
Allows Architect to introduce partition walls any anywhere required, allows owner to change the size of room layout, allows choice of omitting false ceiling and finish soffit of slab with skim coating.

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.

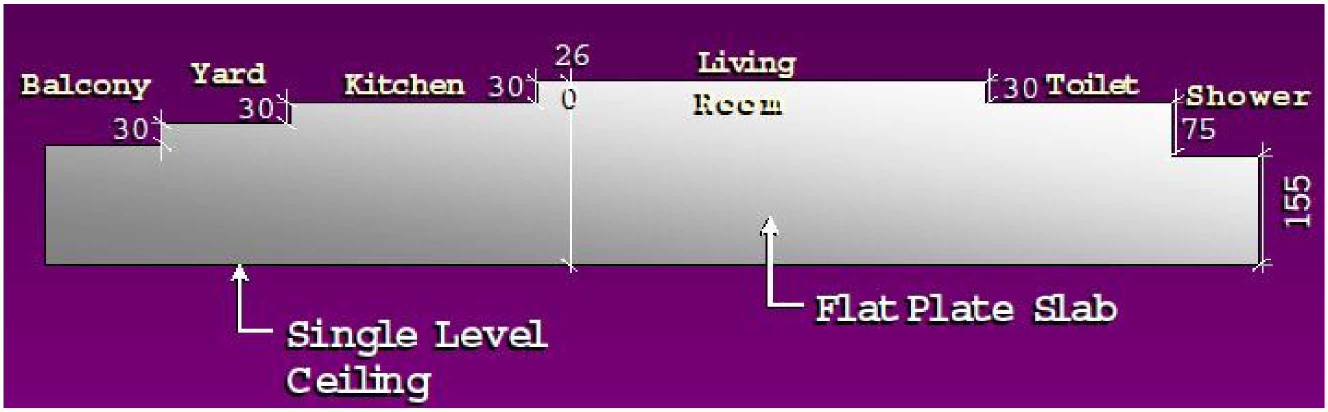


Shorter construction time:



Flat plate design will facilitate the use of big table formwork to increase productivity

Single soffit level



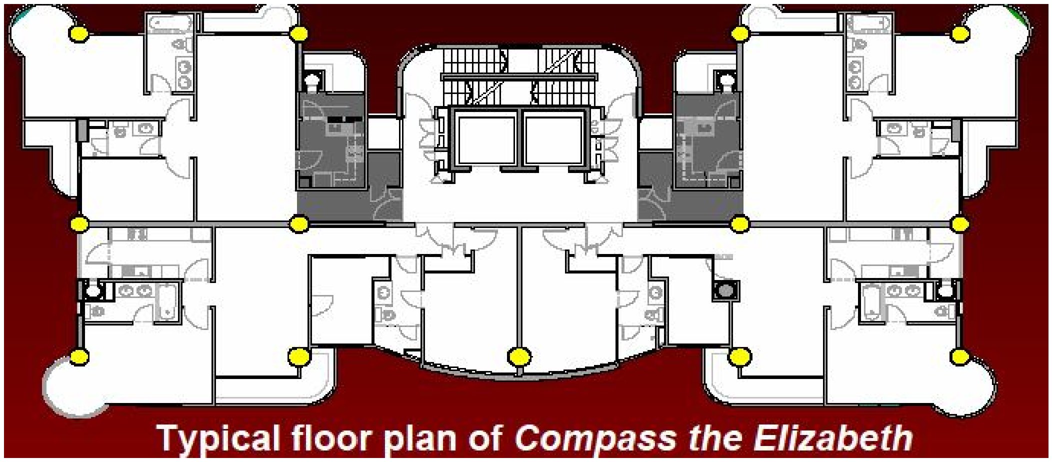
- Simplified the table formwork needed

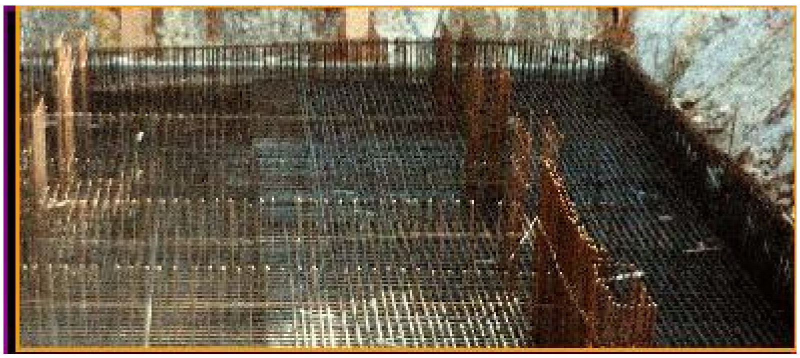
Ease of installation of m&e services:

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
•Minimized installation time
•Better quality control





•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

WALL AND COLUMN POSITION:

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

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 m3per square metre
•this figure is considered to be economical and comparable to an optimum design in conventional of beam and slab systems

DEFLECTION CHECK

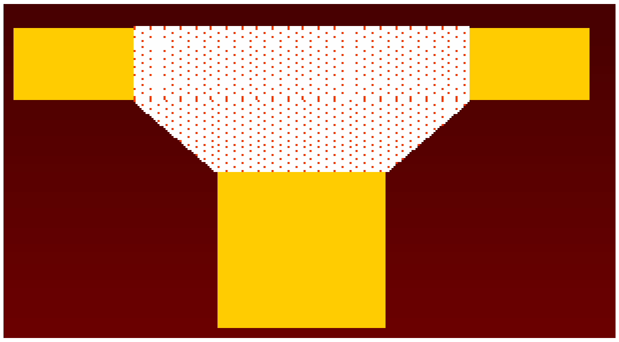
•necessary to include checking of the slab deflection for all load cases both for short and long term basis
•In general, under full service load, $\delta < L/250$ or 40 mm whichever is smaller
•Limit set to prevent unsightly occurrence of cracks on non-structural walls and floor finishes

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

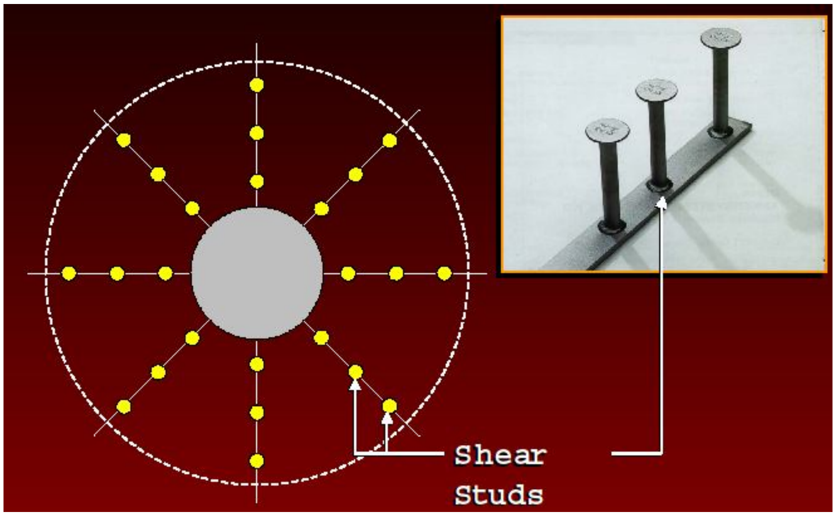
FLOOR OPENINGS

•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



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 tendam with walls and lift cores to achieve the required stiffness

MULTIPLE FUNCTION PERIMETER BEAMS

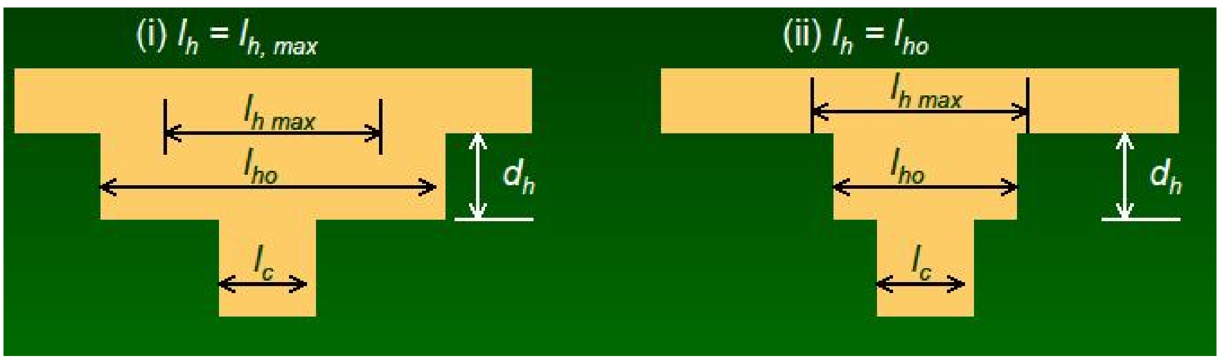
•adds lateral rigidity
•reduce slab deflection

ANALYSIS OF FLAT SLAB

- **COLUMN HEAD**

Effective dimension of a head , $l_h\ (mm) = \text{lesser of } l_{ho} \text{ or } l_{h\ max}$

where l_{ho} = actual dimension, lh max= lc+ 2(dh-40)

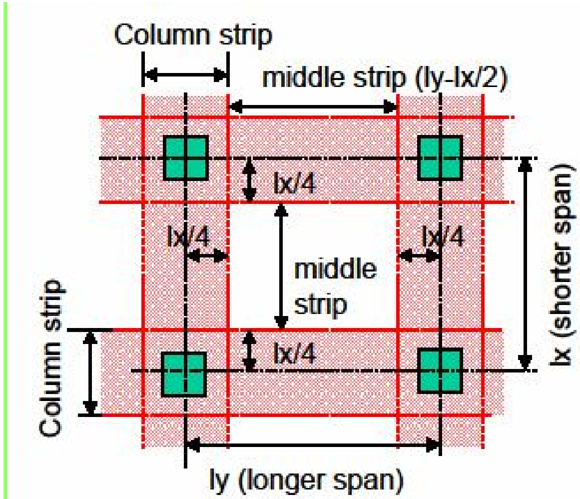


For circular column or column head, effective diameter

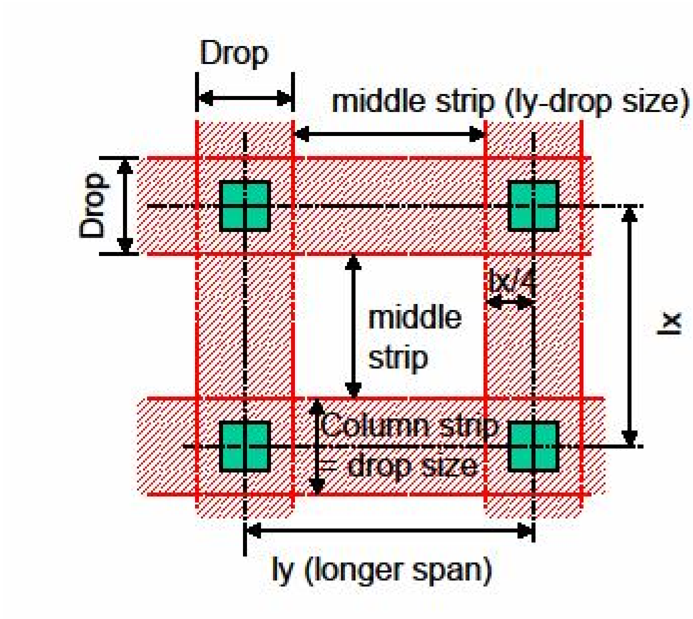
$h_c = 4 \text{ x area/o} < 0.25\ l_x$,

DIVISION OF PANELS

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



Slab without drops



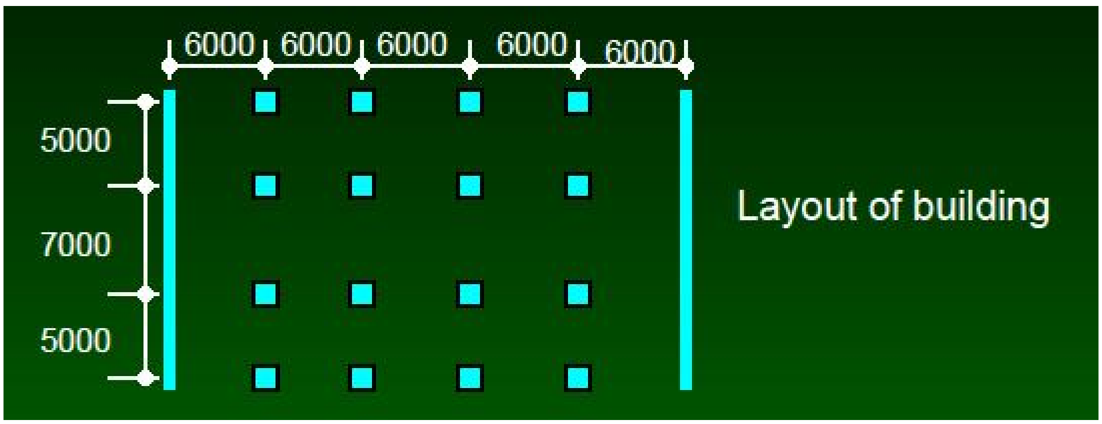
Slab with drops

MOMENT DIVISION

	Apportionment between column and middle strip expressed as % of the total negative design moment	
	Column strip	Middle strip
Negative	75%	25%
Positive	55%	45%

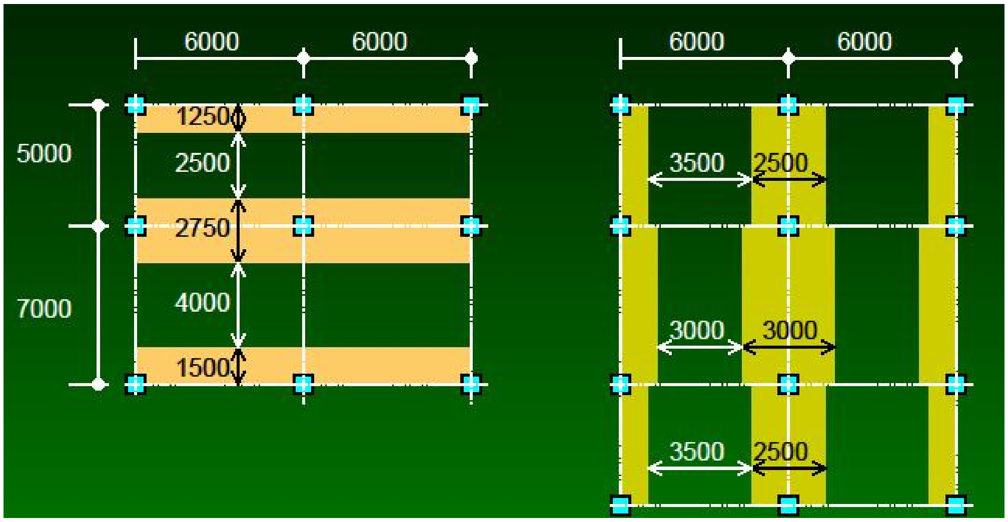
•Note : For slab with drops where the width of the middle strip exceeds L/2, the distribution of moment in the middle strip should be increased in proportion to its increased width and the momentresisted by the column strip should be adjusted accordingly.

MOMENT DIVISION –EXAMPLE

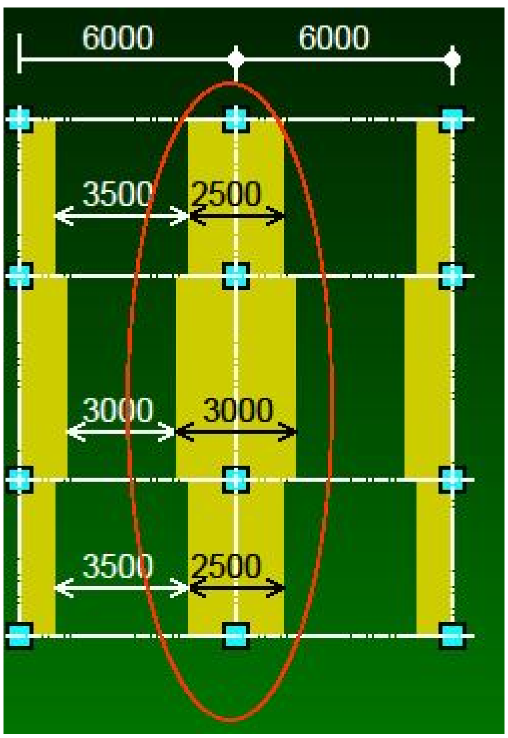


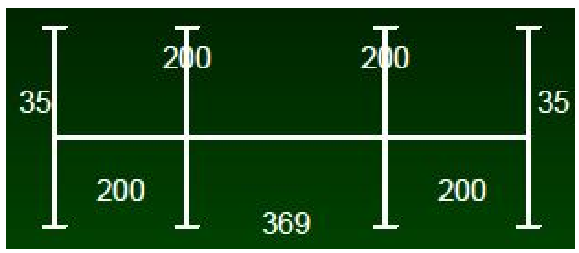
A floor slab in a building where stability is provided by shear walls in one direction (N-S). The slab is without drops and is supported internally and on the external long sides by square columns . The imposed loading on the floor is 5 KN/m2and an allowance of 2.5KN/m2for finishes, etc. fcu = 40 KN/m2, fy = 460KN/m2

MOMENT DIVISION –EXAMPLE



Division of panels into strips in x and y direction





Column strip

exterior support = 0.75*35 on 2.5m strip = 10.5Knm

centre of 1st span = 0.55*200 on 2.5 strip = 44KNm

1st interior support = 0.75*200 on 3m strip = 50KNm

centre of interior span = 0.55 *369 on 3m strip = 67.7KNm

Middle strip

exterior support = 0.25*35 on 2.5m strip = 3.5KNm

centre of 1st span = 0.45*200 on 2.5 strip = 36KNm

1st interior support = 0.25*200 on 3m strip = 16.7KNm

centre of interior span = 0.45 *369 on 3m strip = 55.4KNm

DESIGN FOR BENDING

INTERNAL PANELS

•columns and middle strips should be designed to withstand design moments from analysis

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 beis

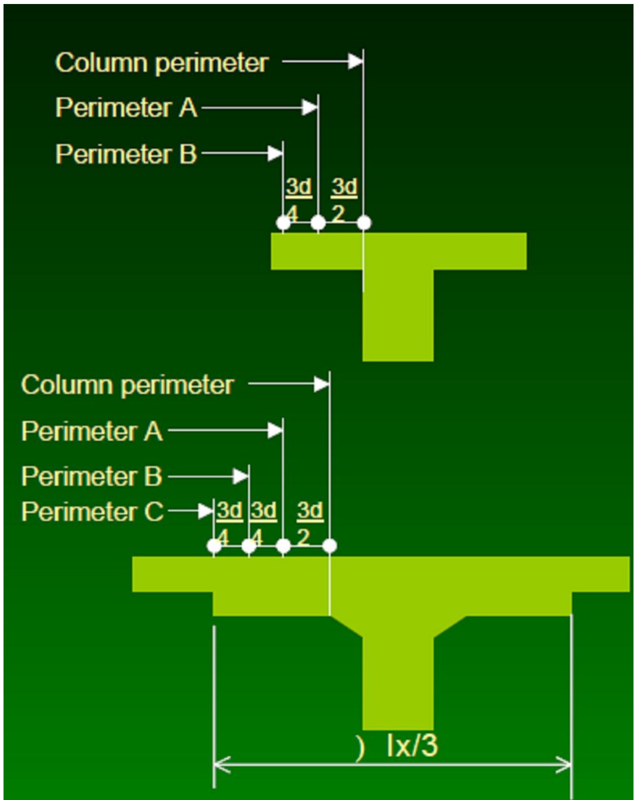
$$M_{t,\,max} = 0.15\, b_e\, d^2\, fcu$$

$\not<$ 0.5 design moment (EFM)

$\not<$ 0.7 design moment (FEM)

Otherwise structural arrangements shall be changed.

PUNCHING SHEAR



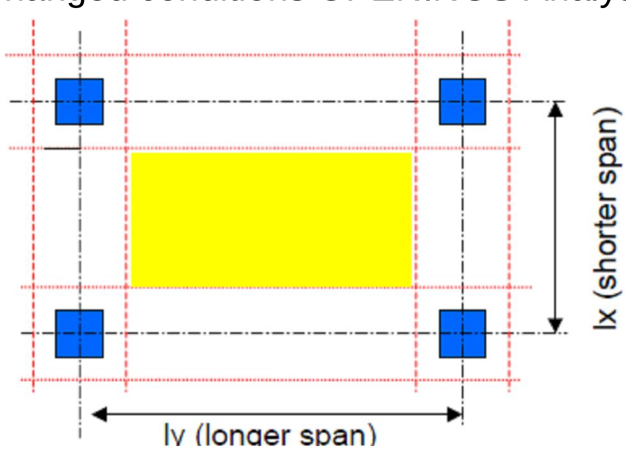
1. **Calculate $V_{eff} = kV_t$ at column perimeter (approx. equal span)**
   V_t = SF transferred from slab
   k = 1.15 for internal column, 1.25 corner columns and edge columns where M acts parallel to free edge and 1.4 for edge columns where M acts at right angle to free edge
2. **Determine $v_{max} = V_{eff}/u_o d$** where u_o is the length of column perimeter
   Check v_{ma} < 0.8 f cu or 5 N/mm^2
3. **Determine $v = (V_{eff} - V/ud)$** 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**

DEFLECTION

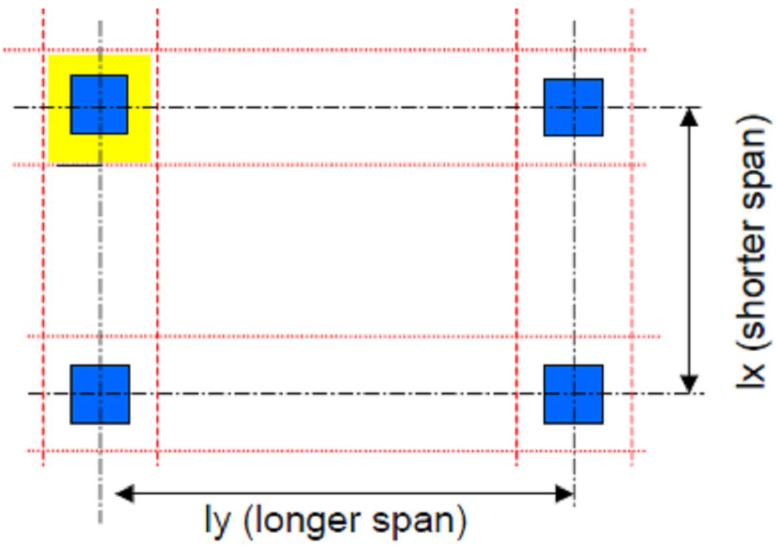
(i) use normal span/effective depth ratio if drop width >1/3 span each way; otherwise(ii) to apply 0.9modification factor for flat slab, or where drop panel width < L/31.0otherwiseSpan

OPENINGS

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 OPENINGS Analysis



Holes in areas common to two column strips may be formed providing :
•that their aggregate their 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;
•that the perimeter for calculating the design shear stress is reduced if appropriate



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

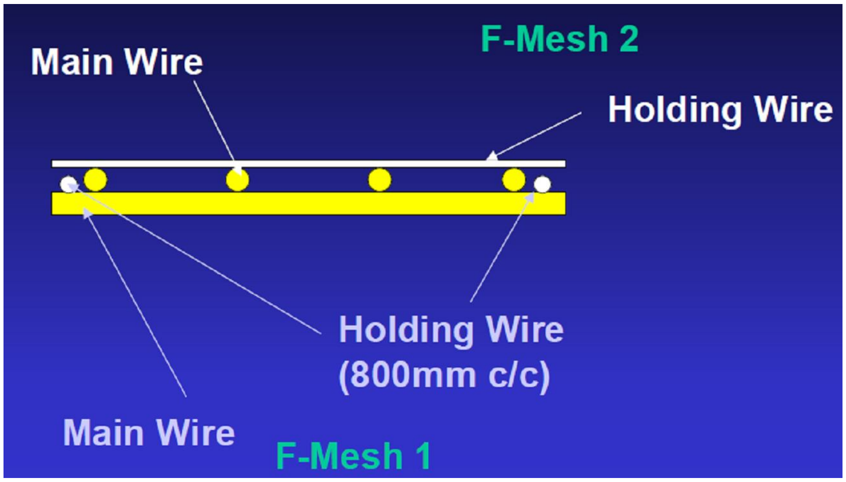
F-mesh-A mesh formed by main wire with cross wire at a fixed spacing of 800 mm

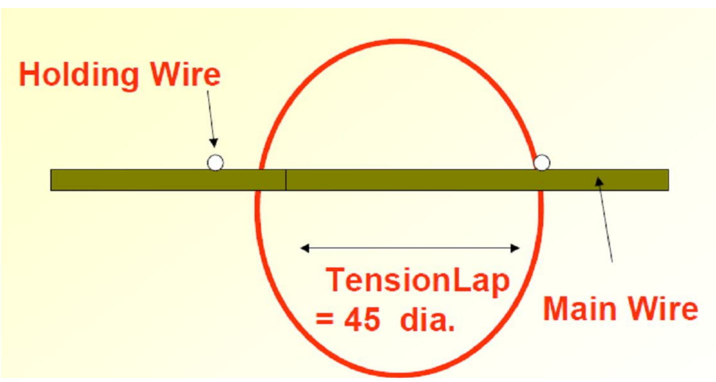
#Main wire-hard drawn ribbed wire with diameter and spacing as per design

#Cross wire-hard drawn smooth wire as holding wire

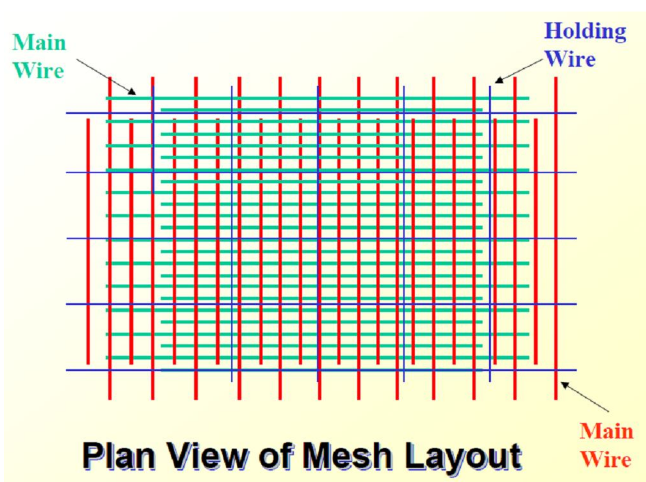
H8-800mm c/c for main wire diameter > 10mm

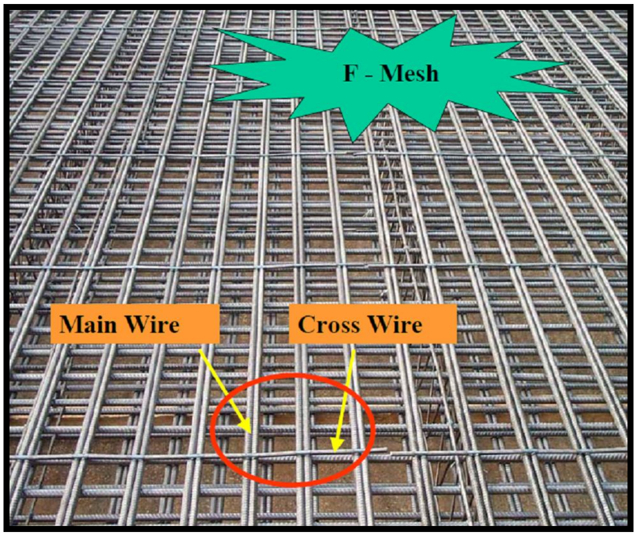
H7-800mm c/c for main wire diameter of 10mm and below

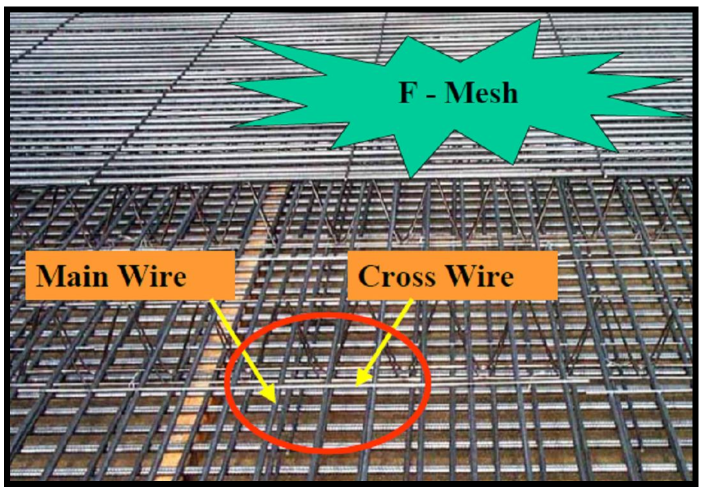




Typical main lap details



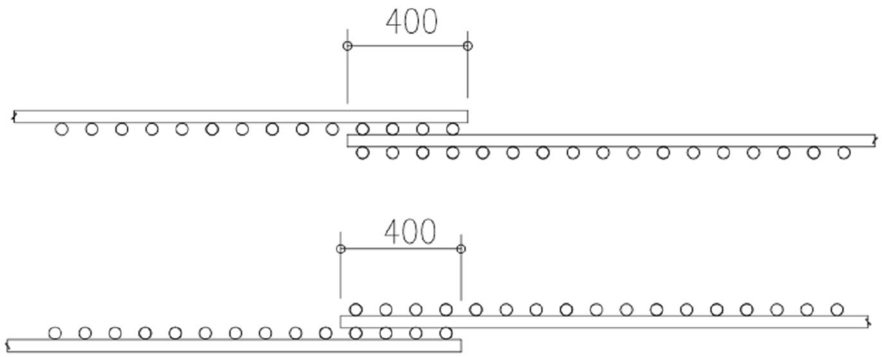




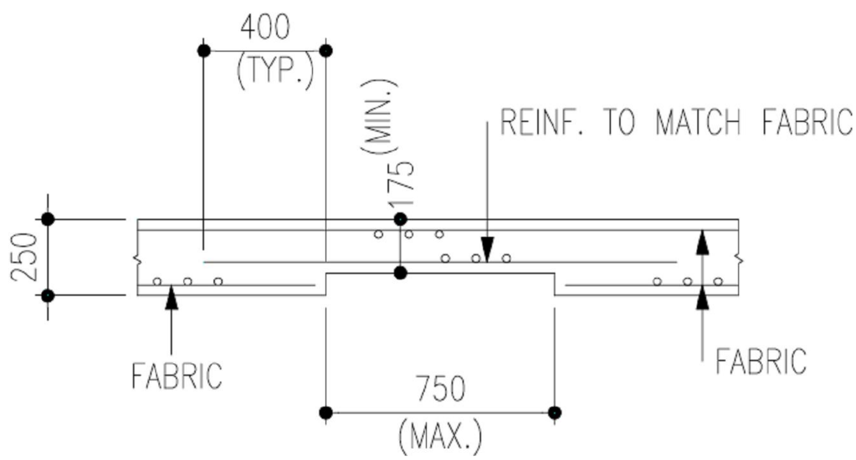
REINFORCEMENT FOR INTERNAL PANELS

- 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

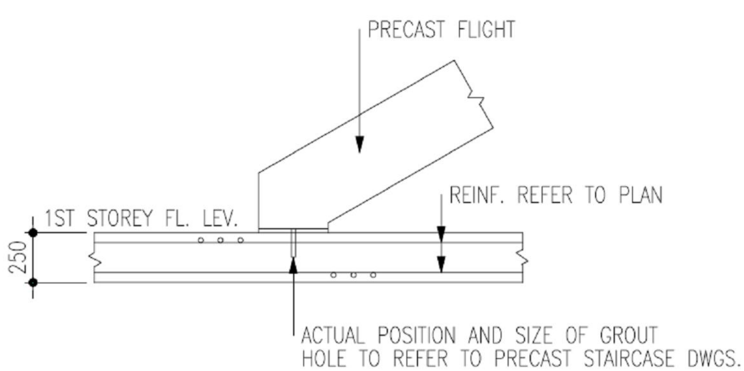
STANDARD LAPPING OF MESH (FOR FLAT SLAB)



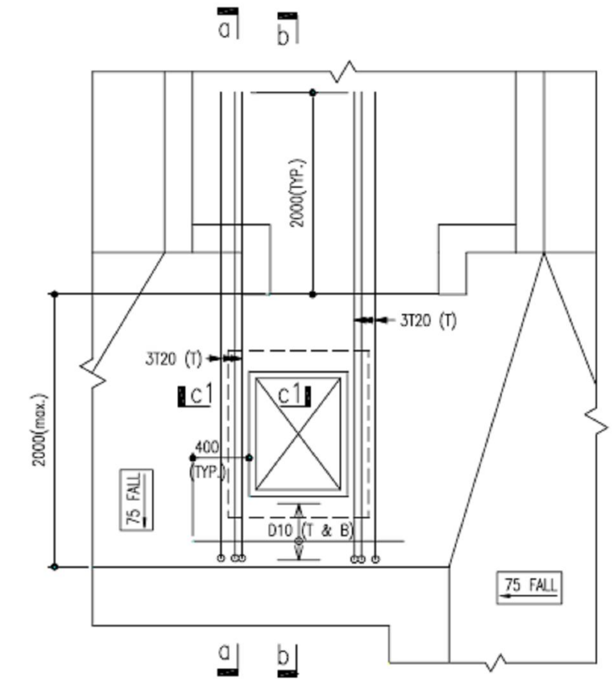
TYPICAL DETAIL SHOWING RECESS AT SLAB SOFFIT FOR SERVICES



TYPICAL SECTION AT STAIRCASE



DETAILS OF INSPECTION CHAMBER AT APRON



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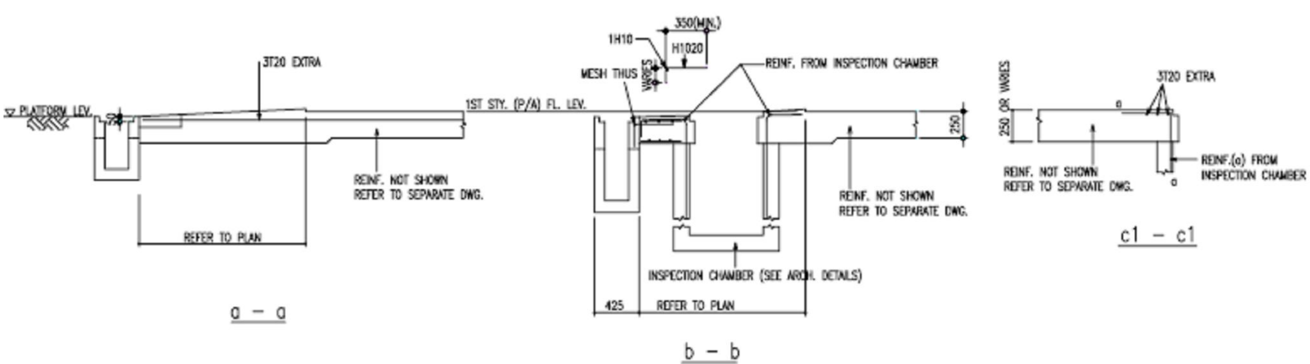

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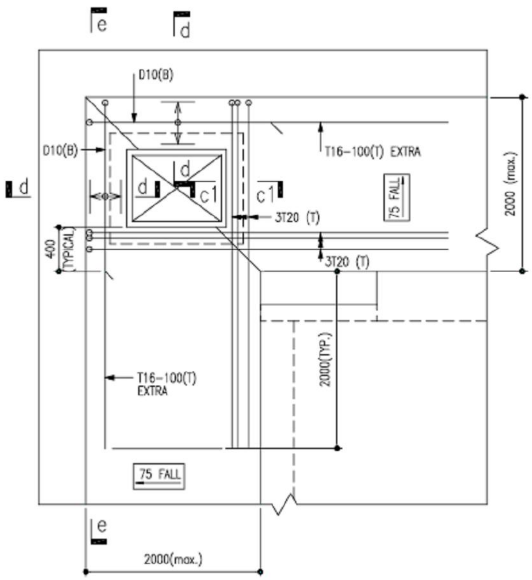

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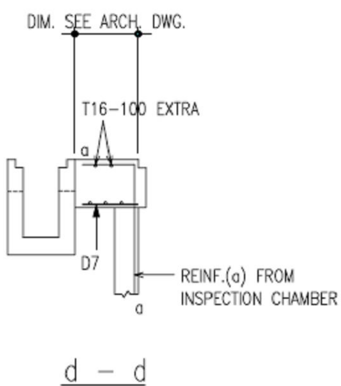
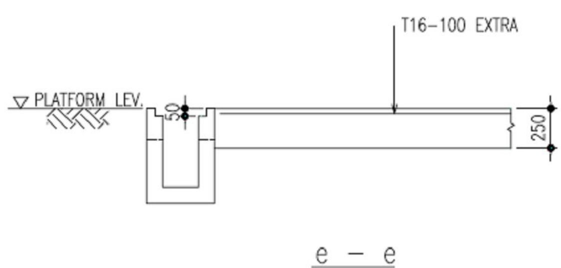
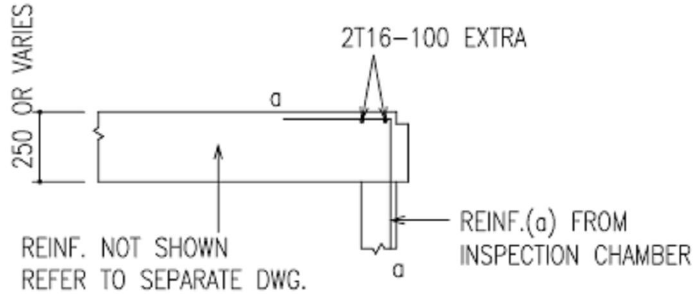


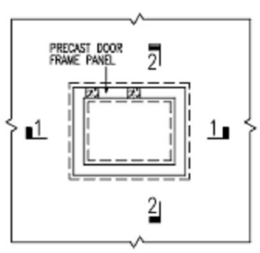


DETAILS OF INSPECTION CHAMBER AT PLAY AREA

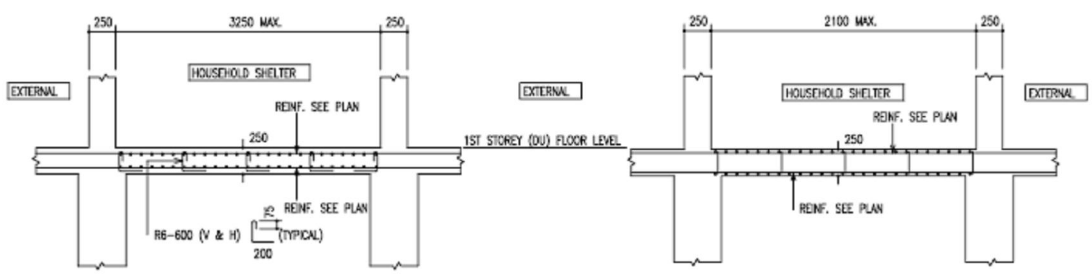


C — C

1ST STOREY (DWELLING UNIT) SLAB DETAILS OF HOUSEHOLD SHELTER



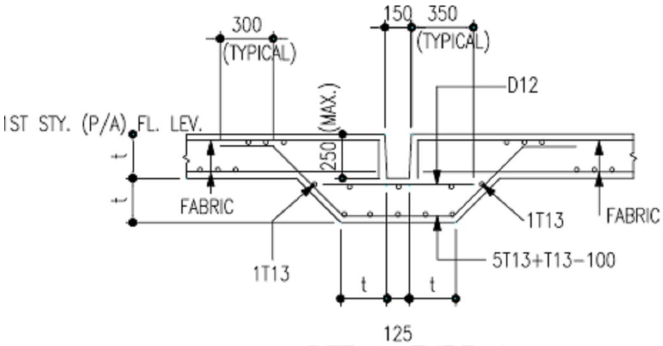
REFERENCE HOUSEHOLD SHELTER 1ST STOREY (DWELLING UNIT) SLAB PLANS



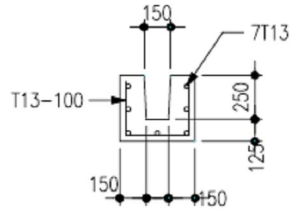
2 – 2

1 – 1

TYPICAL DETAILS OF 125X250 RC CHANNEL FOR GAS PIPE ENTRY



DETAIL TYPE 1



DETAIL TYPE 2
THROUTH APRON DRAIN