DESIGN AND DETAILING OF FLAT SLAB

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27 FEBRUARY 2002

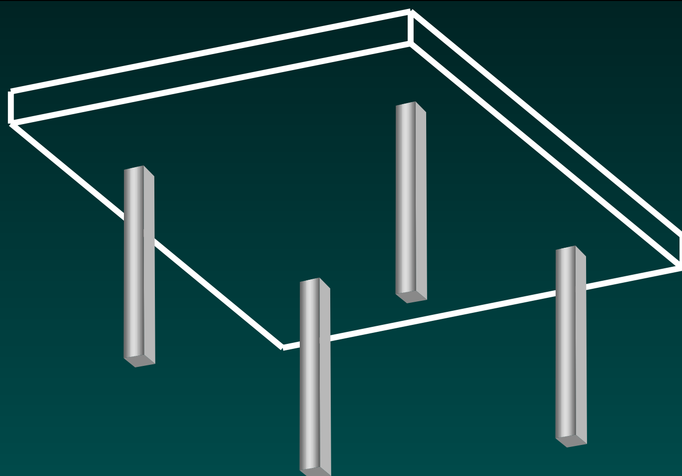
CONTENT

INTRODUCTION

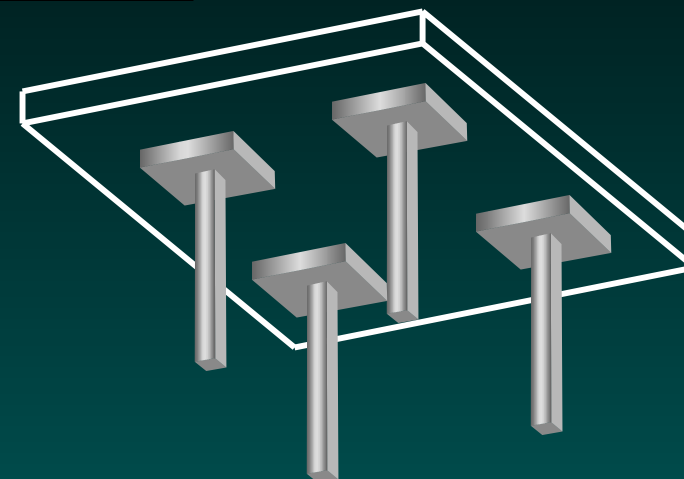
What is a flat slab?

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

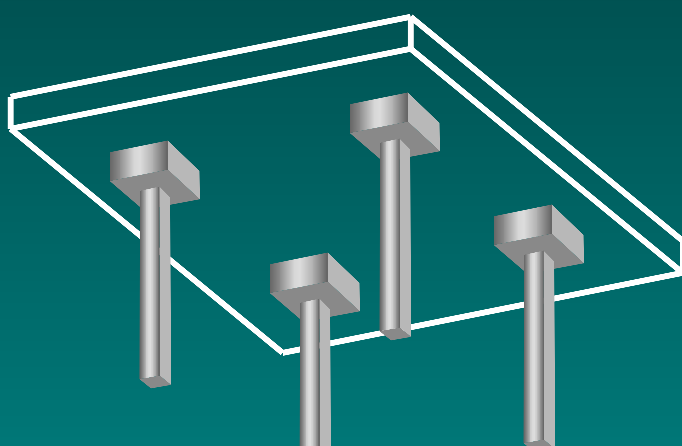
INTRODUCTION



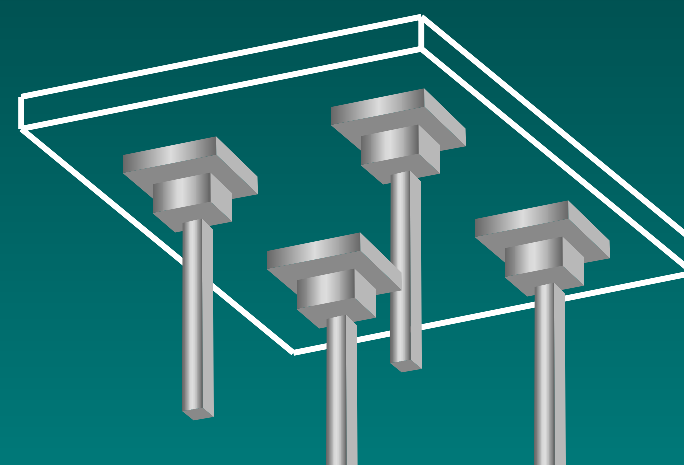
Flat slab



Flat slab with drop panels



Flat slab with column head

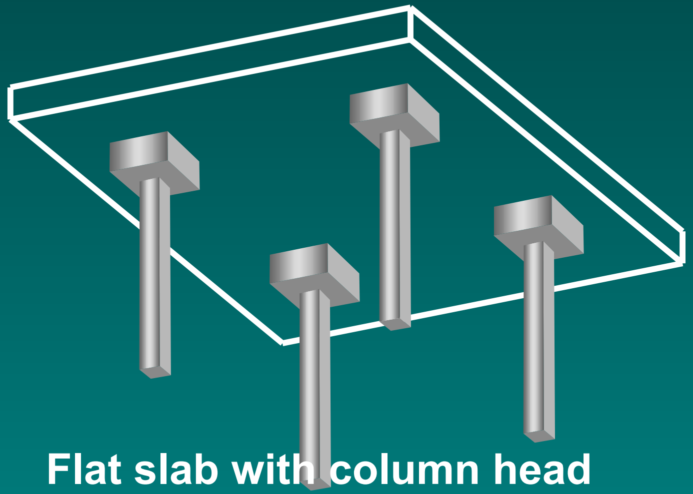


Flat slab with drop panel and column head

INTRODUCTION

Uses of column heads :

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

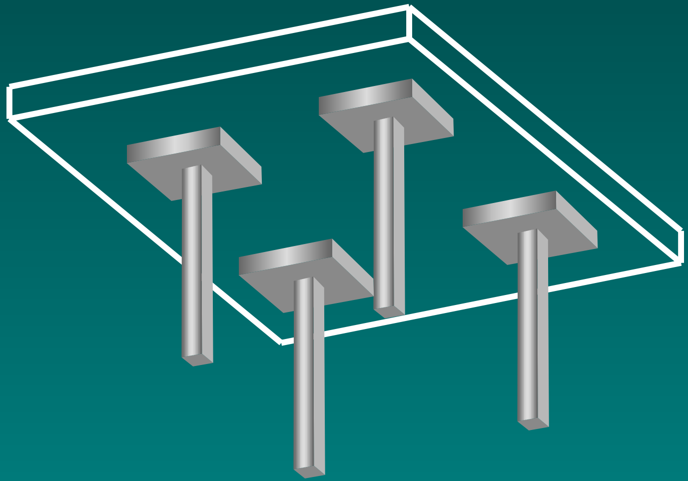


Flat slab with column head

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

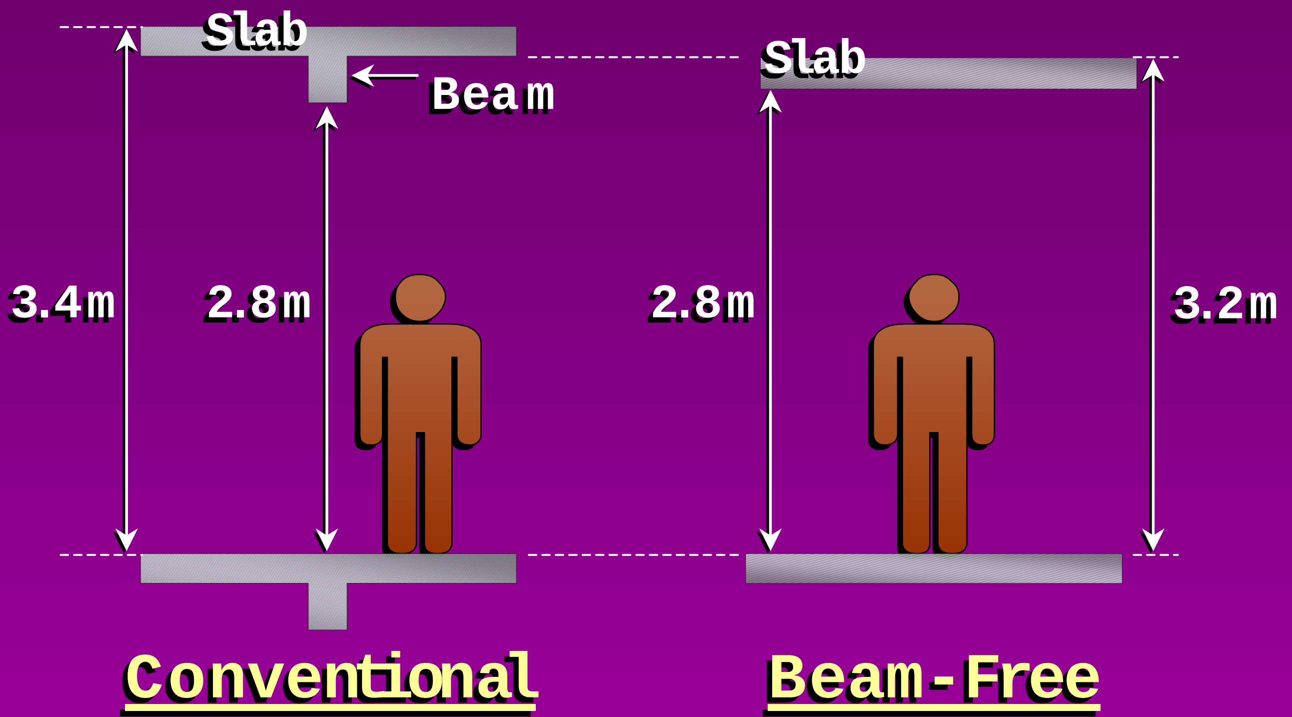
- Flexibility in room layout
- Saving in building height
- Shorter construction time
- Ease of installation of M&E services
- Prefabricated welded mesh
- Buildable score

FLEXIBILITY IN ROOM LAYOUT

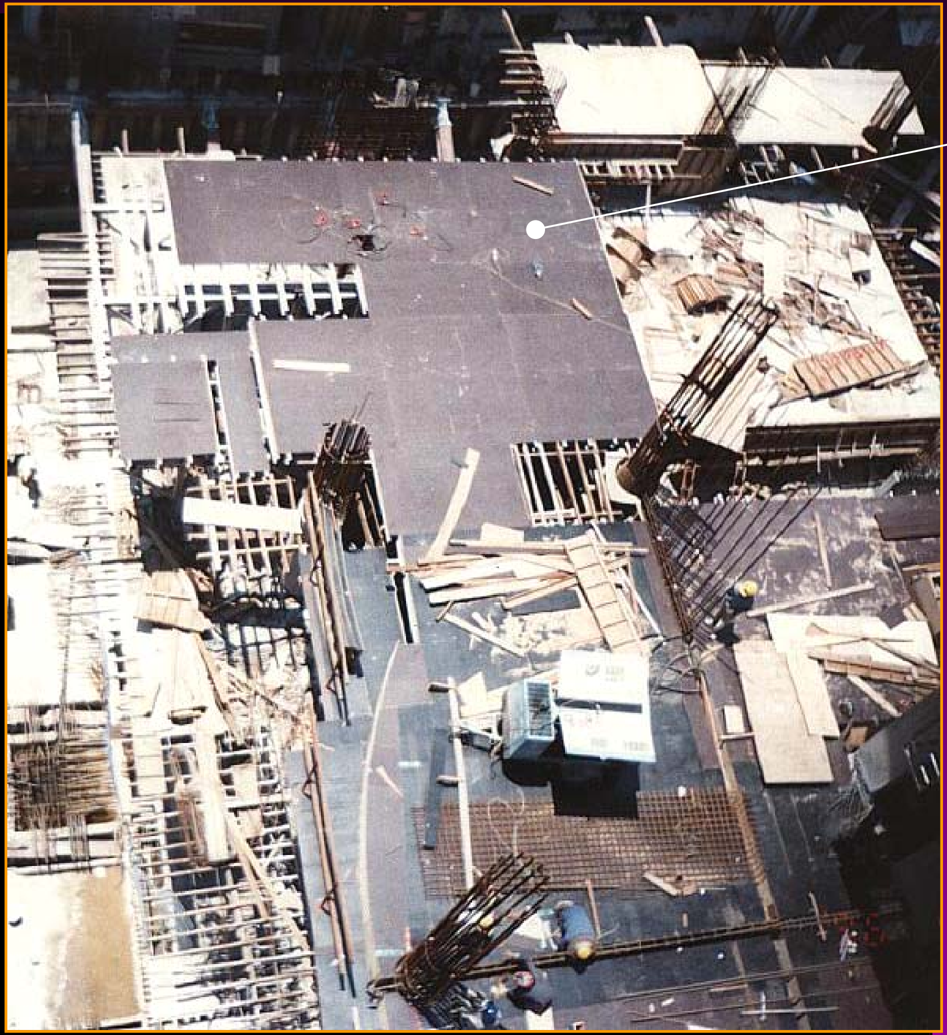
- allows Architect to introduce partition walls anywhere required
- allows owner to change the size of room layout
- allows choice of omitting false ceiling and finish soffit of slab with skim coating

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

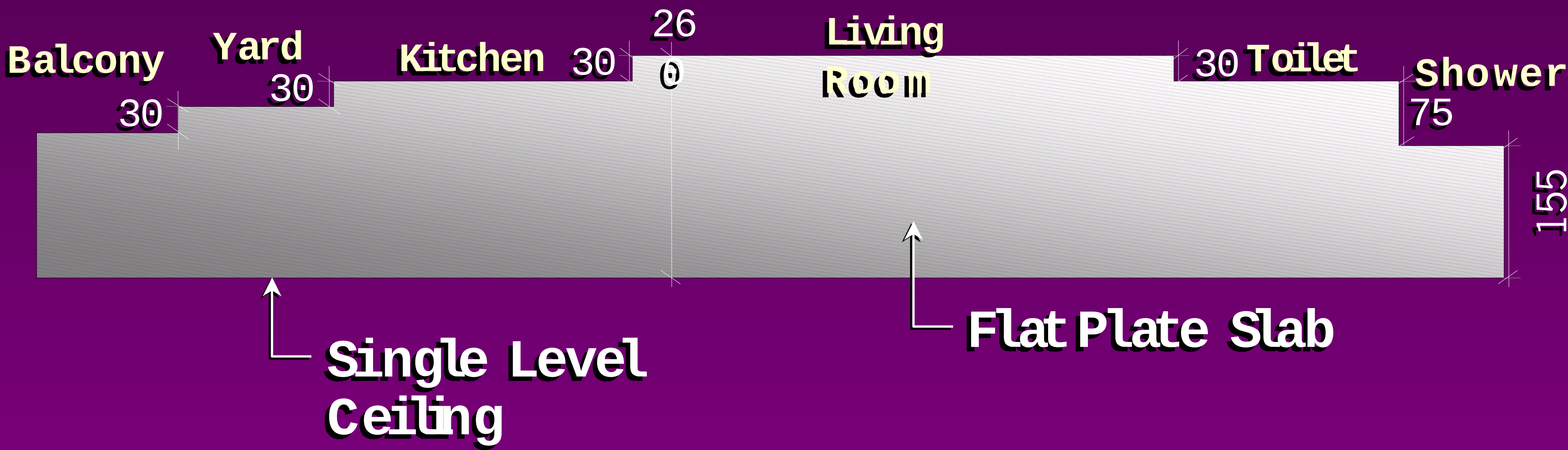


SHORTER CONSTRUCTION TIME



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

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
- Minimised installation time
- Better quality control

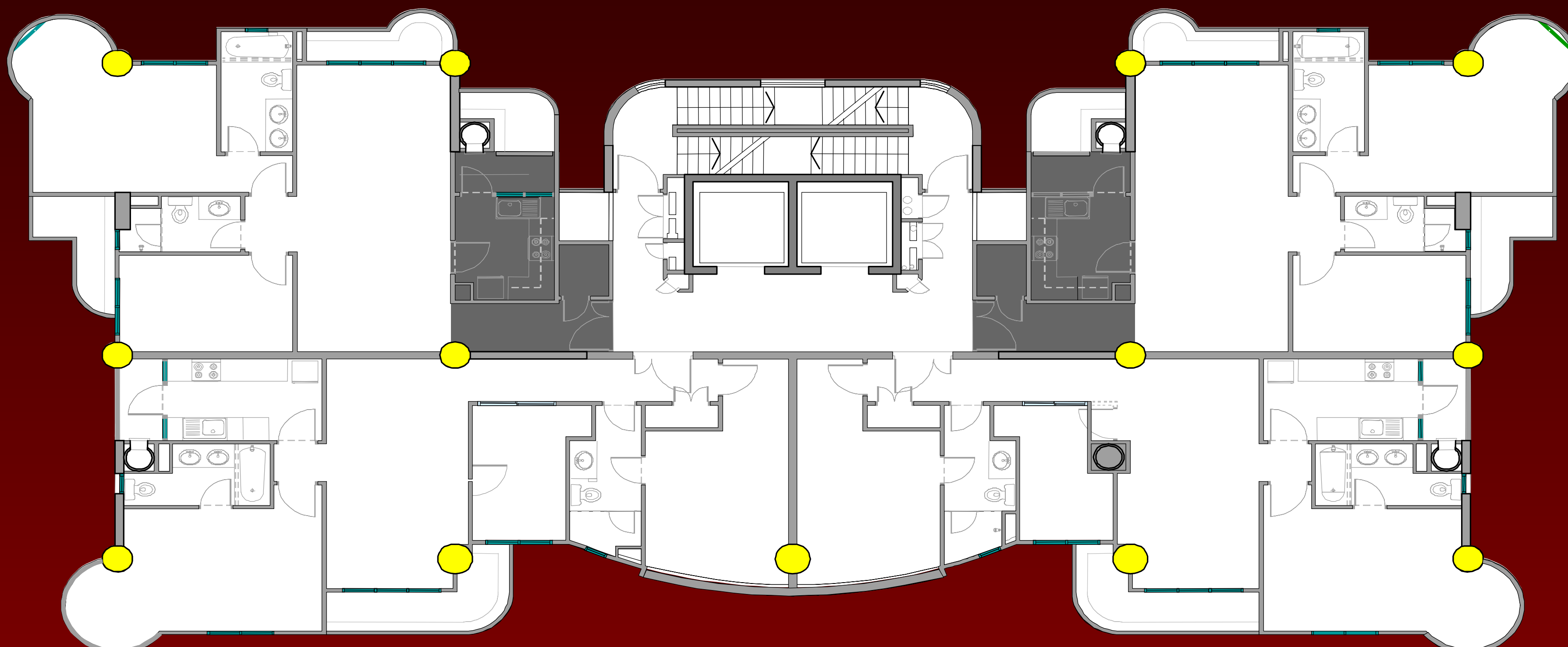
BUILDABLE SCORE

- 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 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 m^3 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, δ < L/250 or 40 mm whichever is smaller
- Limit set to prevent unsightly occurrence of cracks on non-structural walls and floor finishes

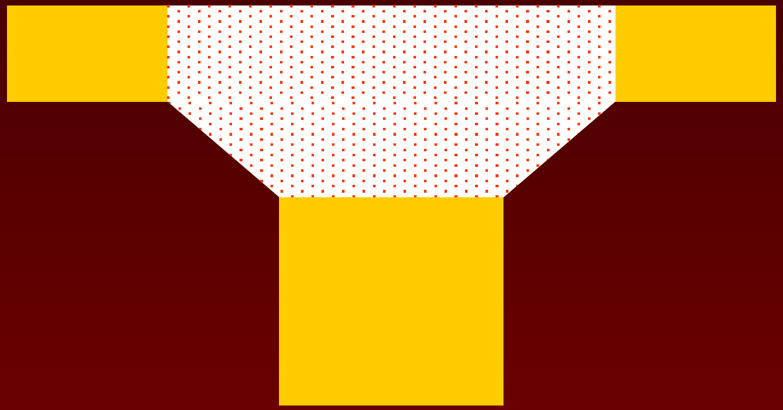
CRACK CONTROL

- 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

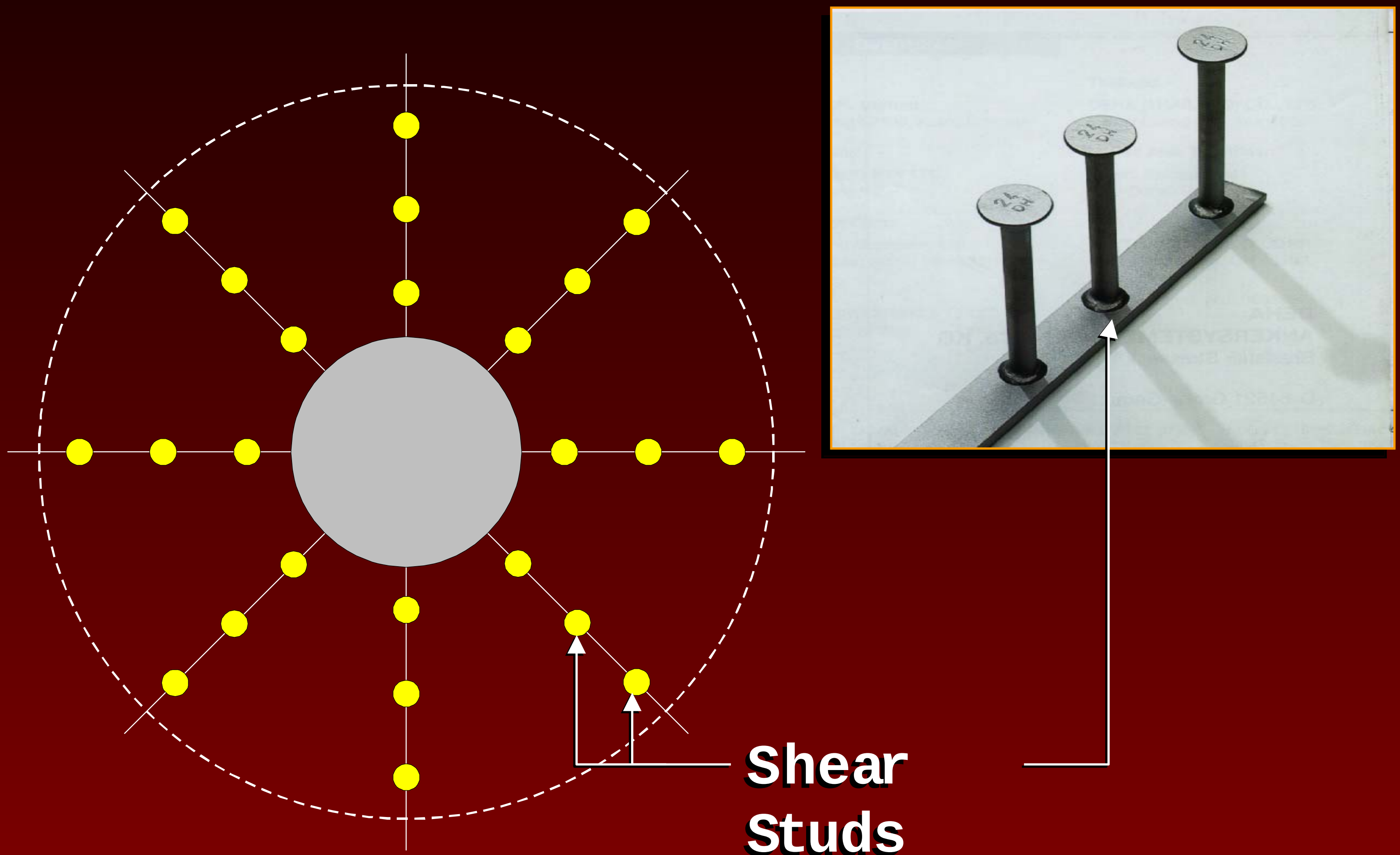
- No opening should encroach upon a column head or drop
- Sufficient reinforcement must be provided to take care of stress concentration



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

PUNCHING SHEAR



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

LATERAL STABILITY

MULTIPLE FUNCTION PERIMETER BEAMS

- **adds lateral rigidity**
- **reduce slab deflection**

DESIGN METHODOLOGY

METHODS OF DESIGN

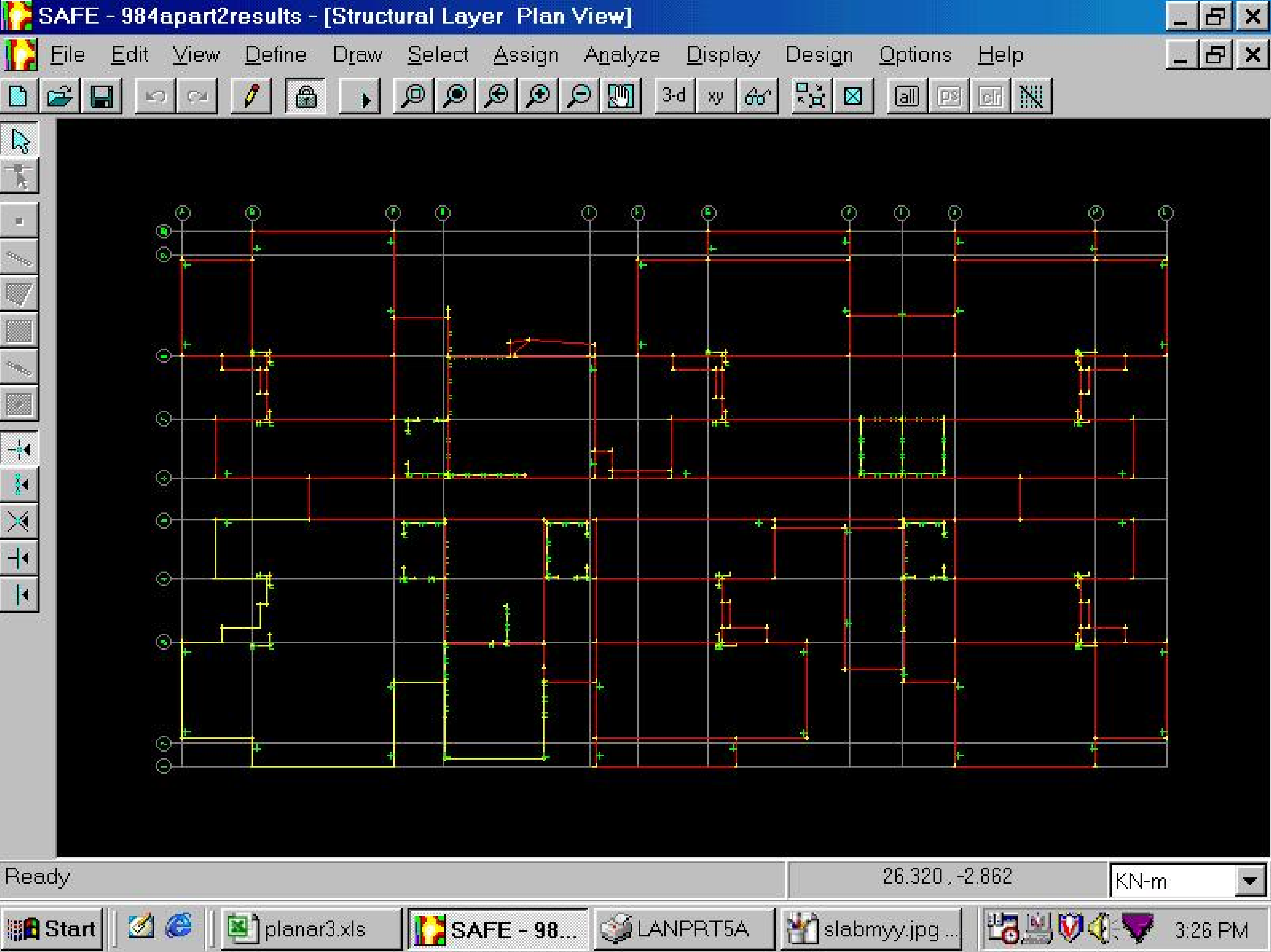
- the finite element analysis
- the simplified method
- the equivalent frame method

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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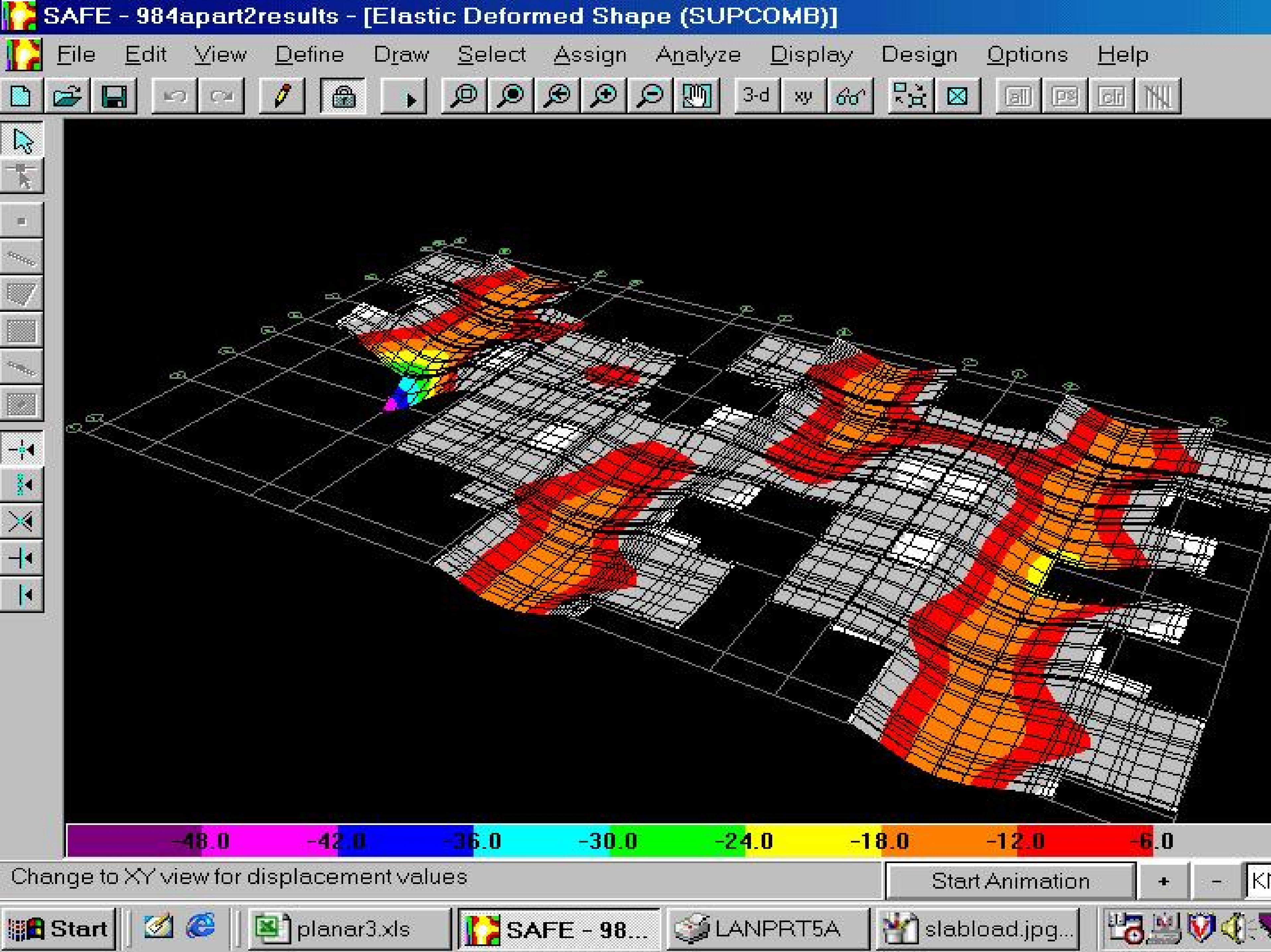
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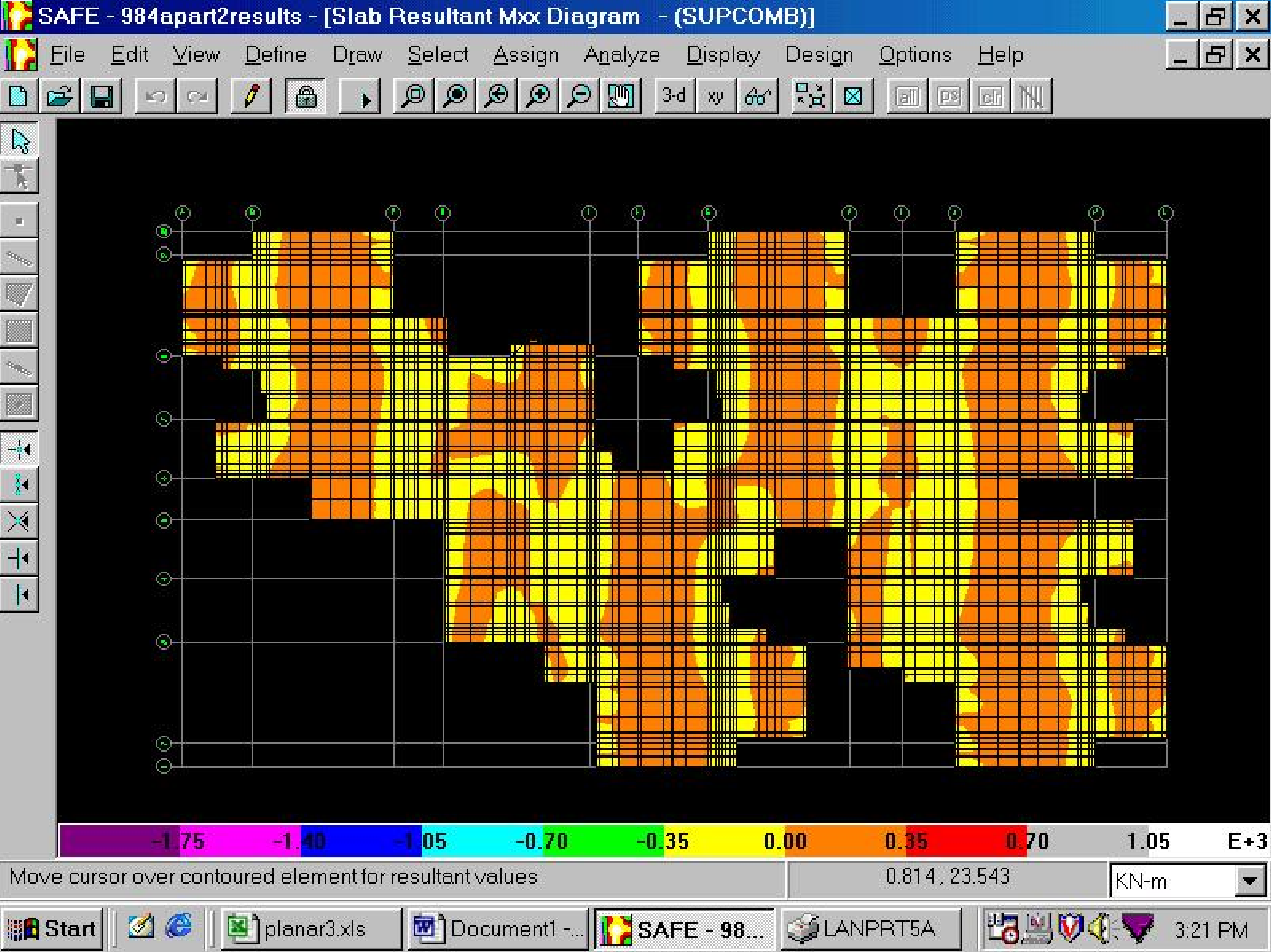
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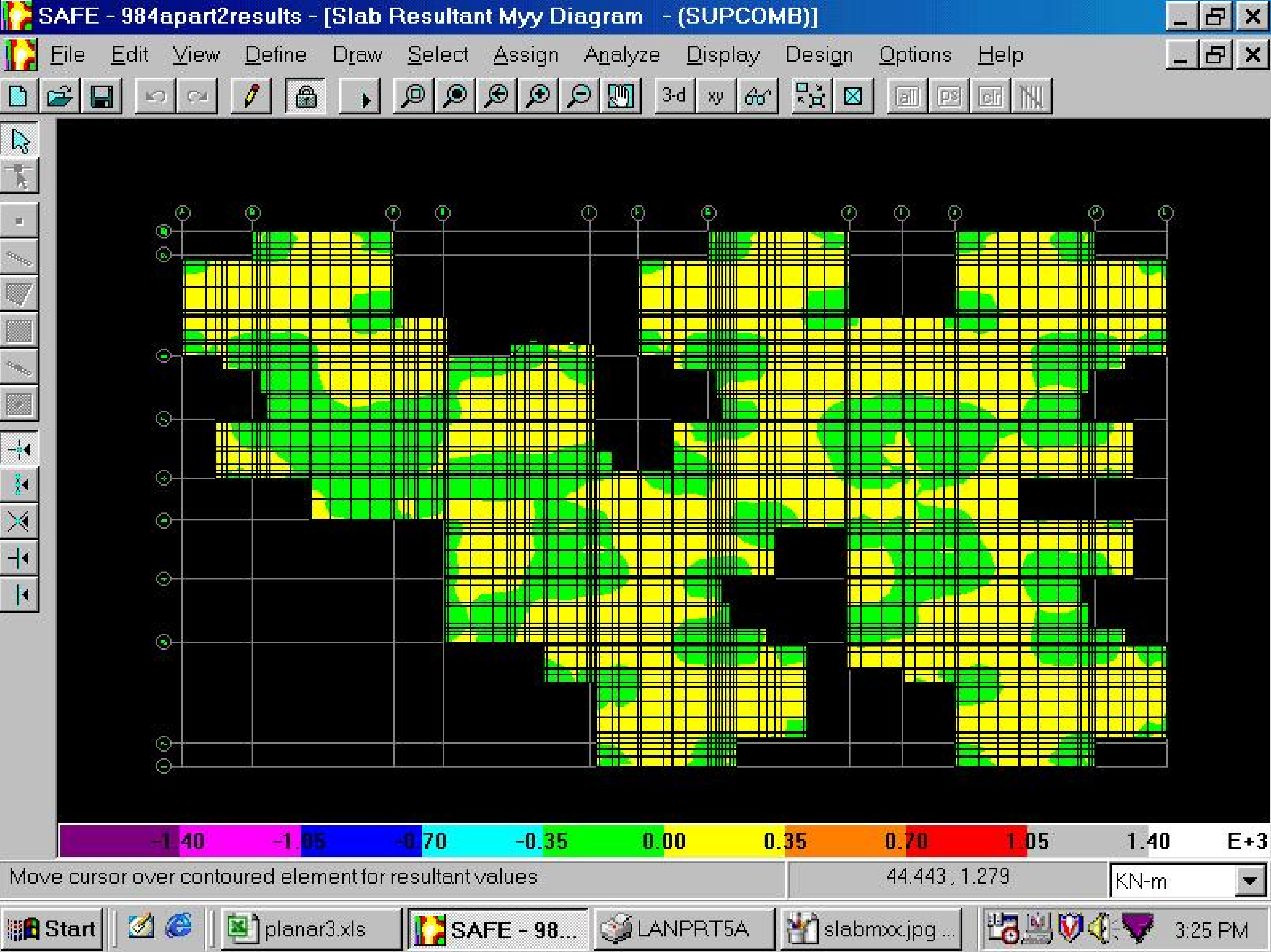
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KN-m
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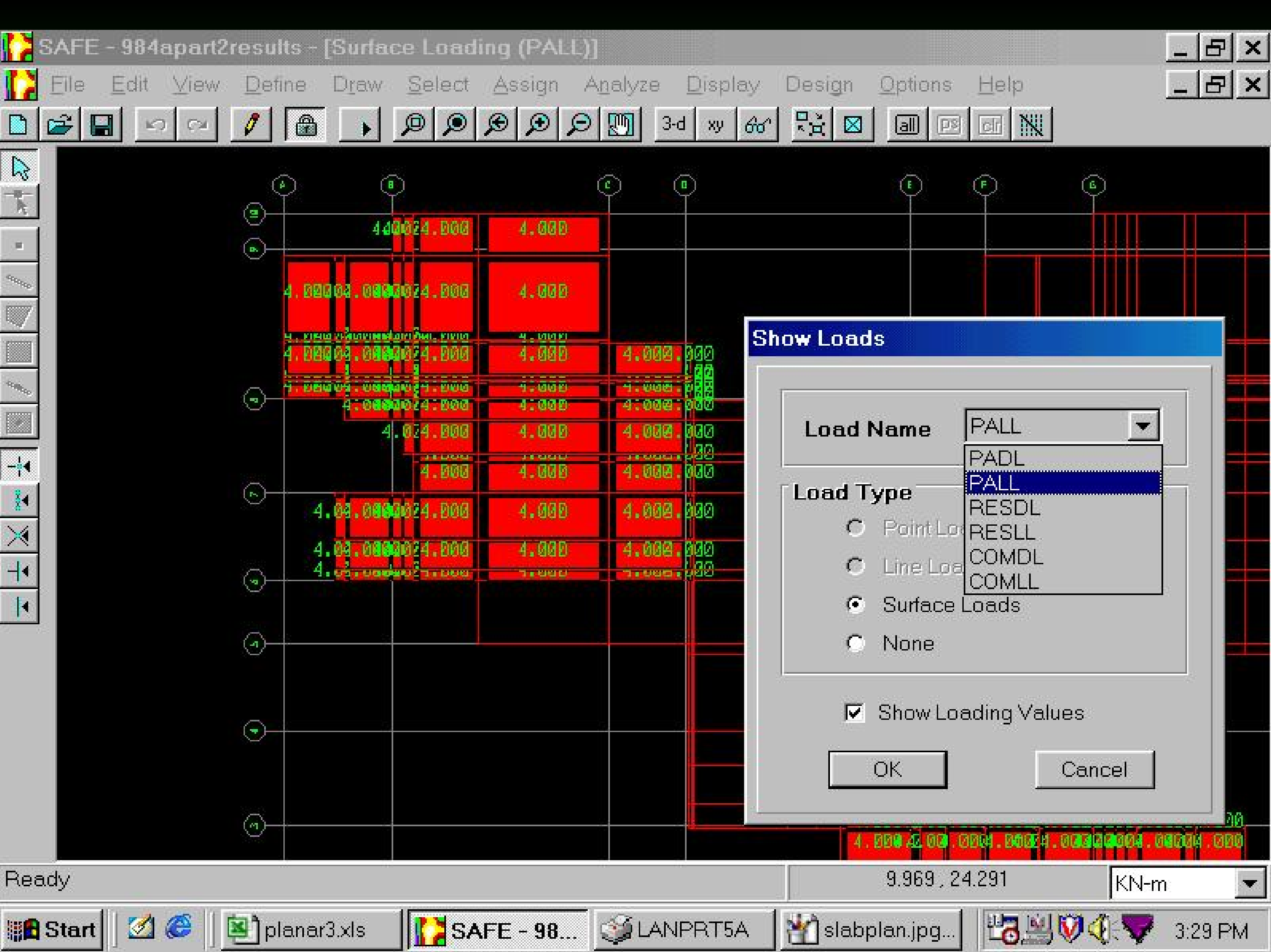
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9.969 , 24.291
KN-m
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SIMPLIFIED METHOD

Table 3.19 may be used provided

- Live load Þ 1.25 Dead load
- Live load (excluding partitions) Þ 5KN/m^2
- 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

	Outer Support		Near centre of 1st span	First interior span	Centre of interior span	Interior span
	Column	Wall				
Moment	-0.04*Fl**	0.086*Fl*	0.083*Fl**	-0.063*Fl*	0.071*Fl*	-0.055*Fl*
Shear	0.45*F*	0.4*F*	-	0.6*F*	-	0.5*F*
Total column moments	0.04*Fl*	-	-	0.022*Fl*	-	0.022*Fl*

* 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

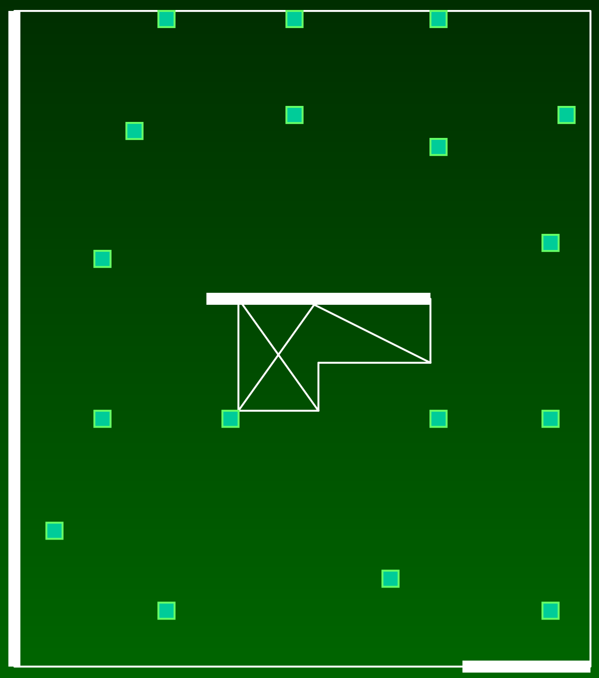
(1.4gk + 1.6 qk)

l is the effective span

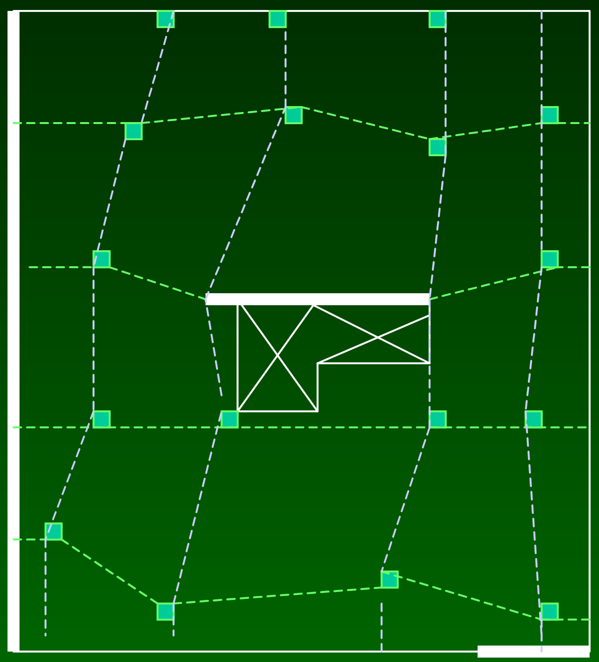
EQUIVALENT FRAME METHOD

- 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 < $l_x/3$

EQUIVALENT FRAME METHOD

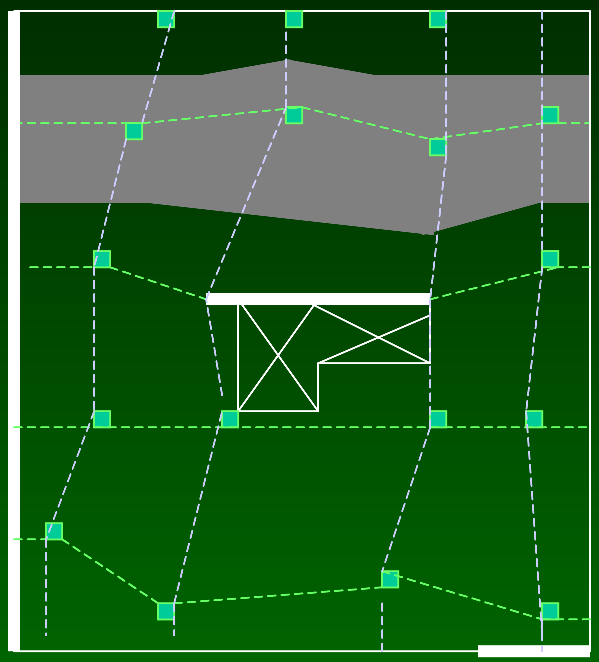


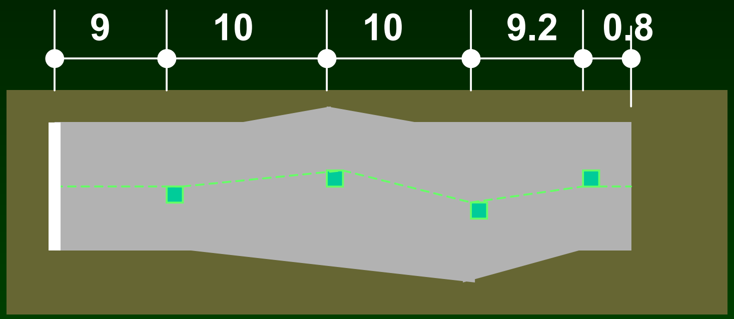
Plan of floor slab



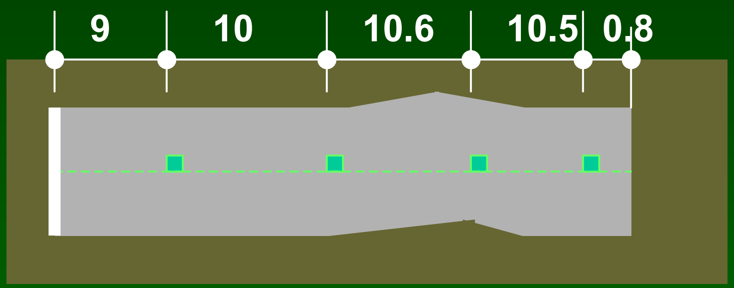
Step 1 : define line of support in X & Y directions

EQUIVALENT FRAME METHOD

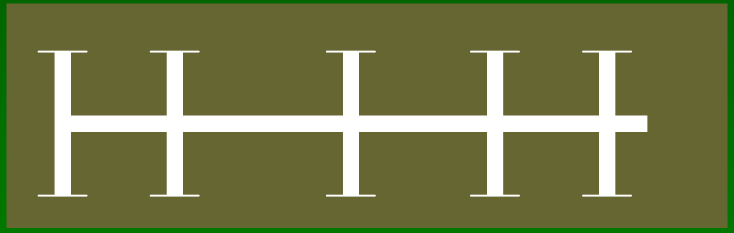




DESIGN STRIP IN PROTOTYPE



STRAIGHTENED DESIGN STRIP



DESIGN STRIP IN ELEVATION

Step 2 : define design strips in X & Y directions

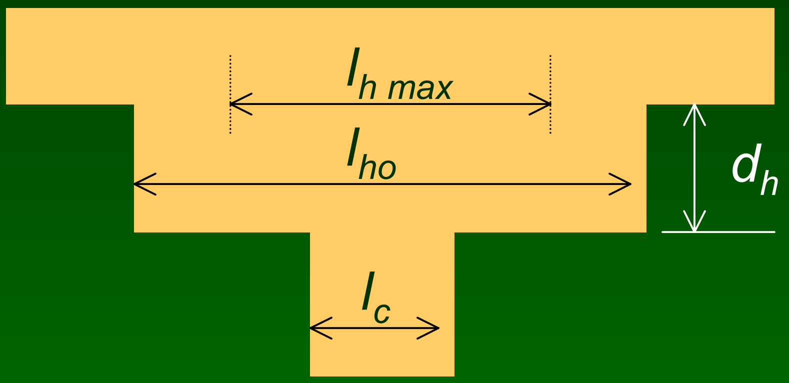
ANALYSIS OF FLAT SLAB

COLUMN HEAD

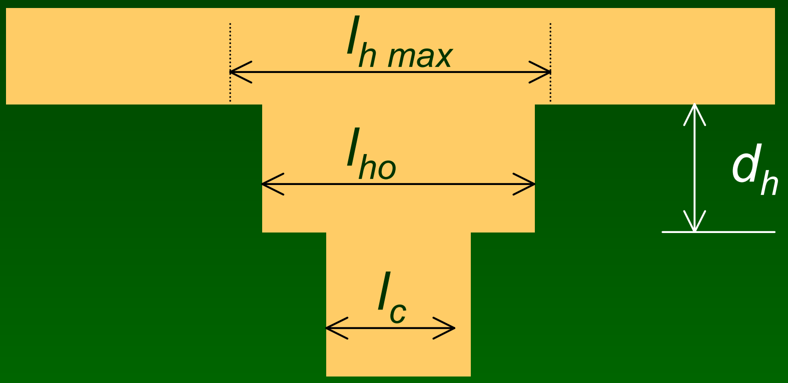
Effective dimension of a head , **l_h (mm) = lesser of l_{ho} or $l_{h\,max}$**

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

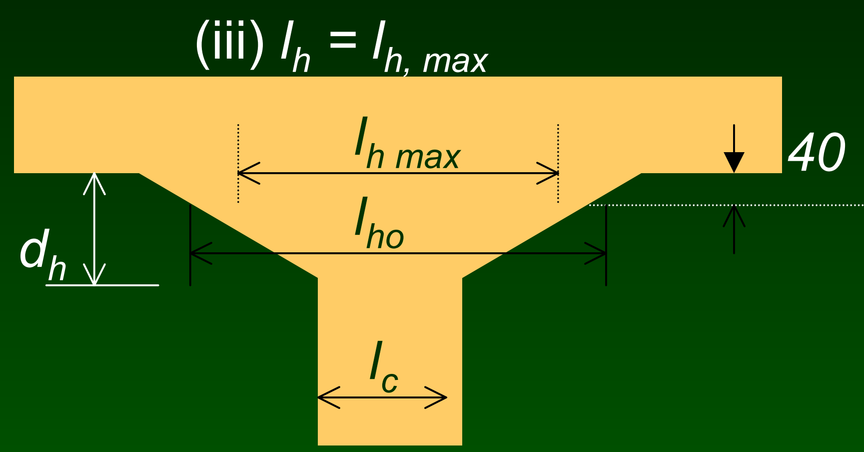
(i) $l_h = l_{h,\,max}$

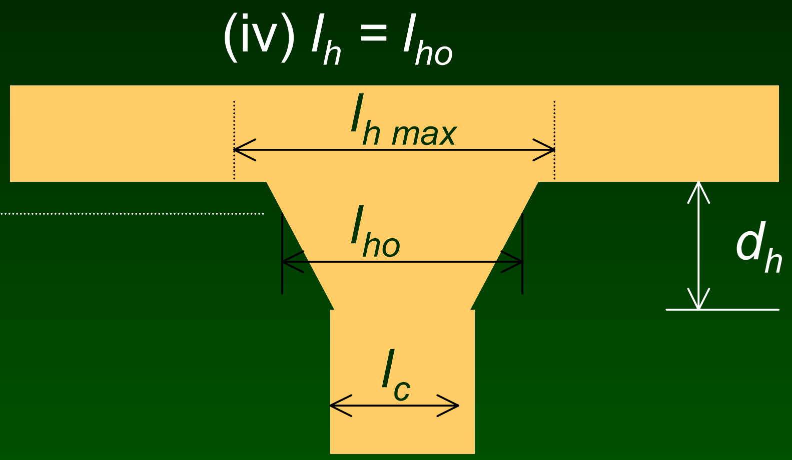


(ii) $l_h = l_{ho}$



COLUMN HEAD





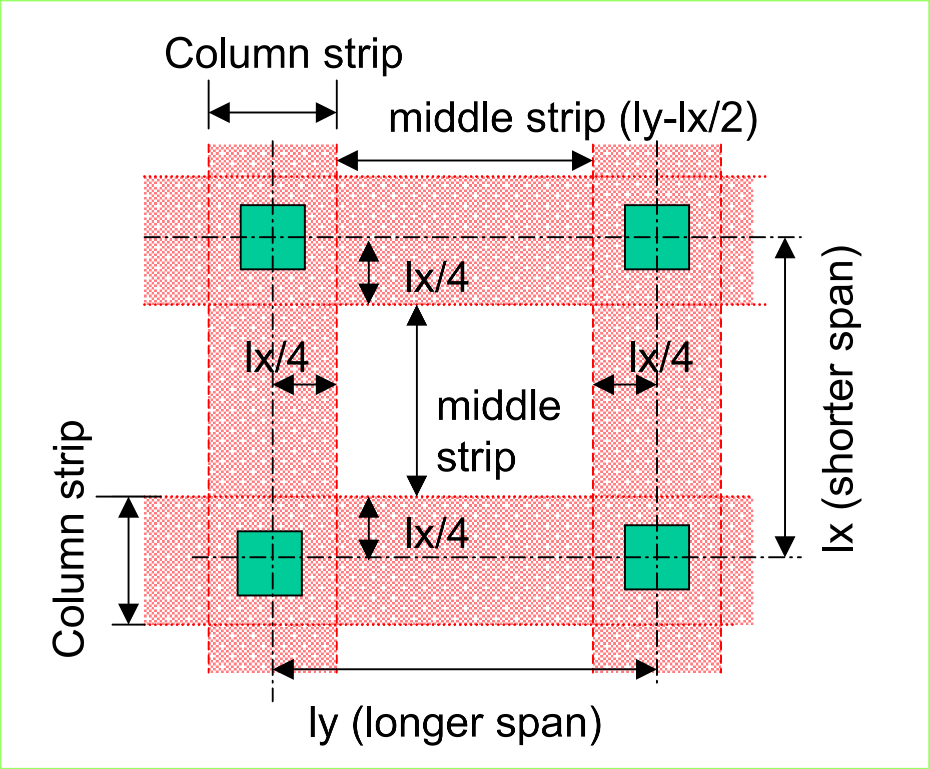
For circular column or column head,

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

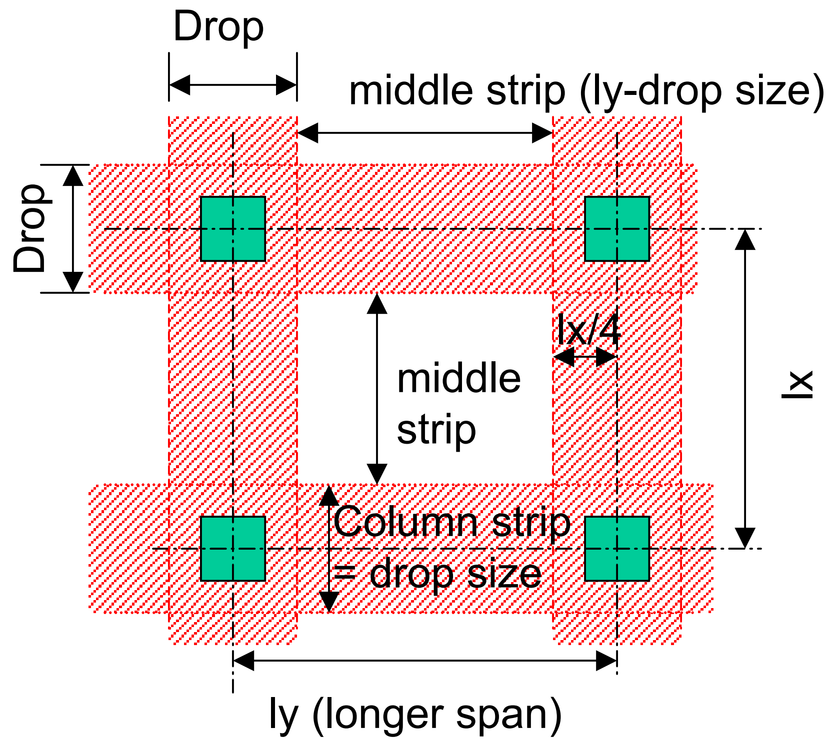
DIVISION OF PANELS

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

(a) Slab Without Drops



(b) Slab With Drops



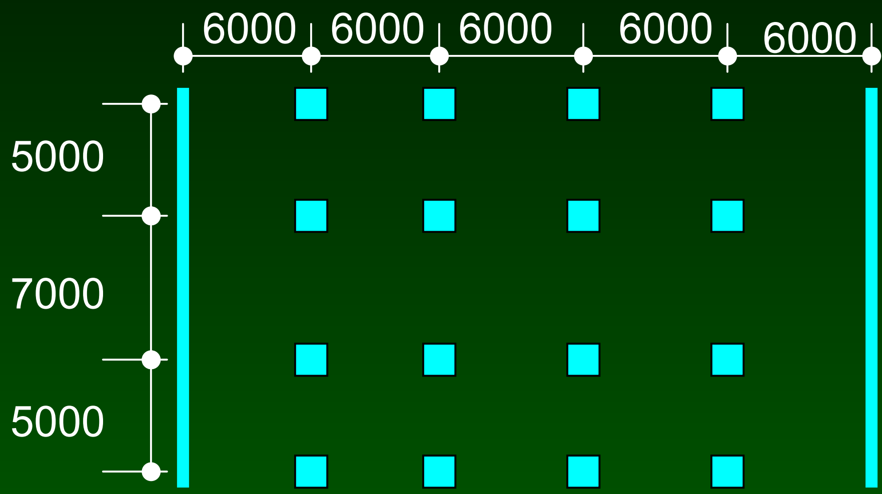
note : ignore drop if dimension is less than lx/3

MOMENT DIVISION

	Apportionment between column and middle strip expressed as % of the total negative design moment	
	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 moment resisted by the column strip should be adjusted accordingly.

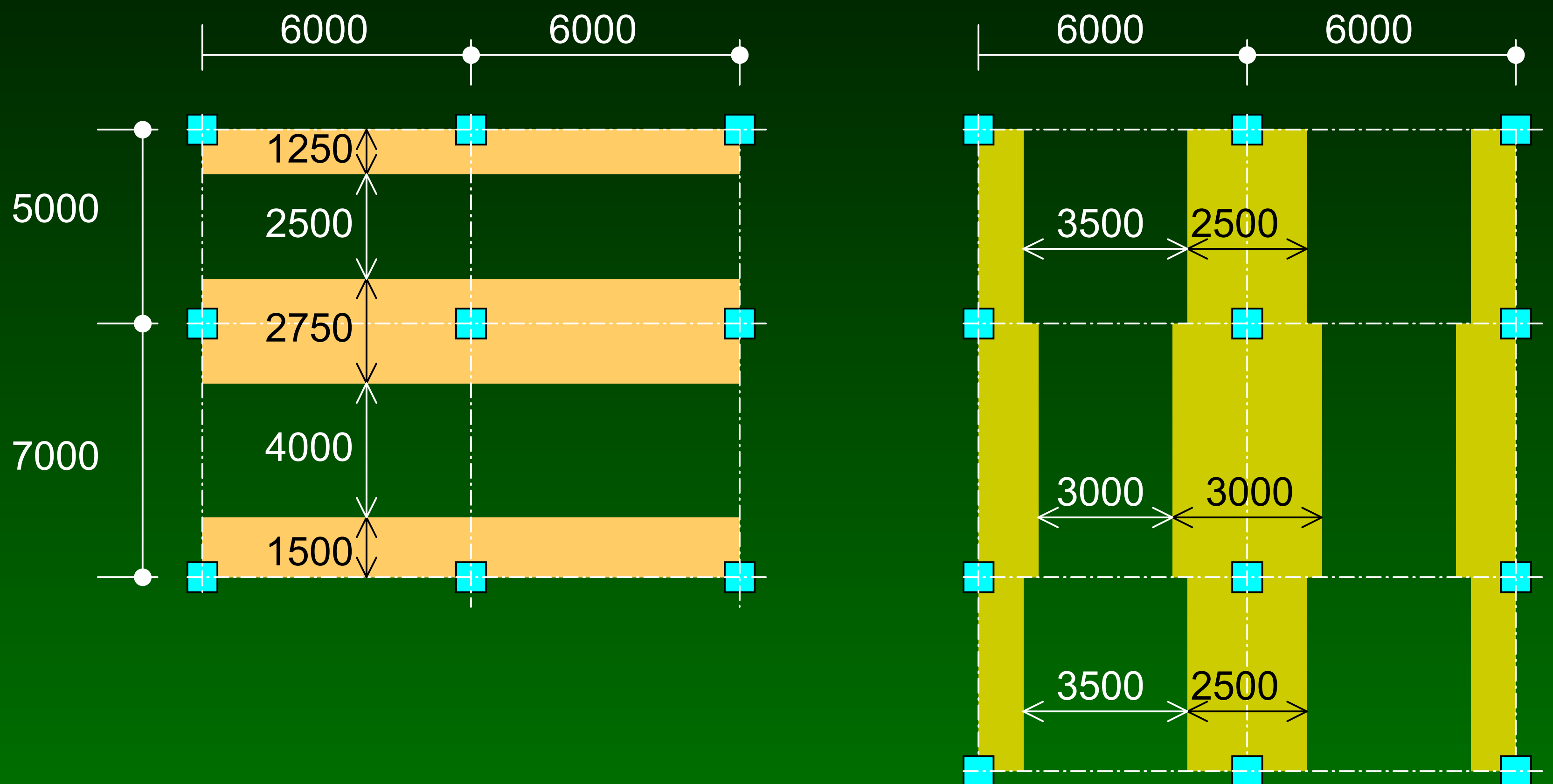
MOMENT DIVISION - EXAMPLE



Layout of building

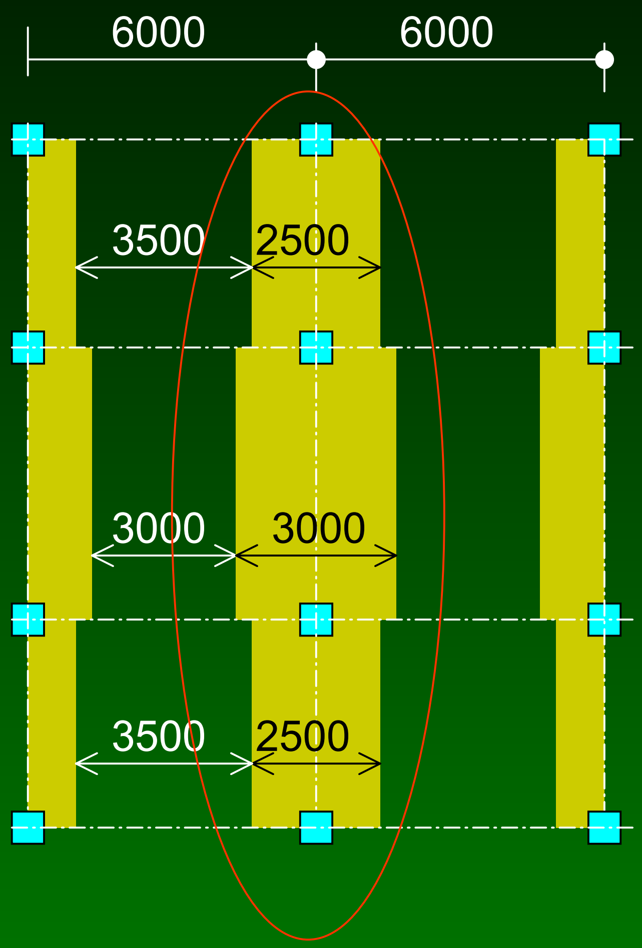
A floor slab in a building where stability is provided by shear walls in one direction (N-S). The slab is without drops and is supported internally and on the external long sides by square columns . The imposed loading on the floor is 5 KN/m^2 and an allowance of 2.5KN/m^2 for finishes, etc. fcu = 40 KN/m^2, fy = 460KN/m^2

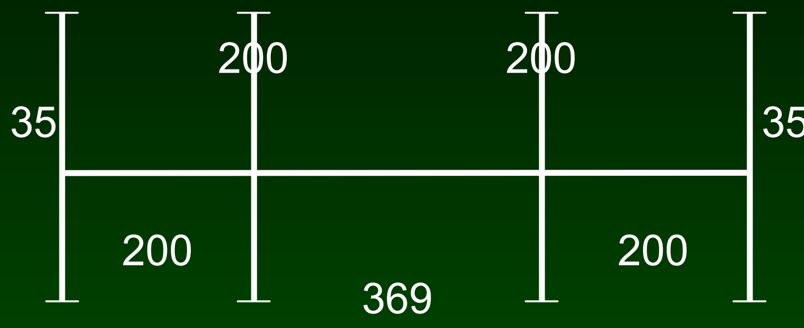
MOMENT DIVISION - EXAMPLE



Division of panels into strips in x and y direction

MOMENT DIVISION - EXAMPLE





<u>Column strip</u>

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

<u>Middle strip</u>

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

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

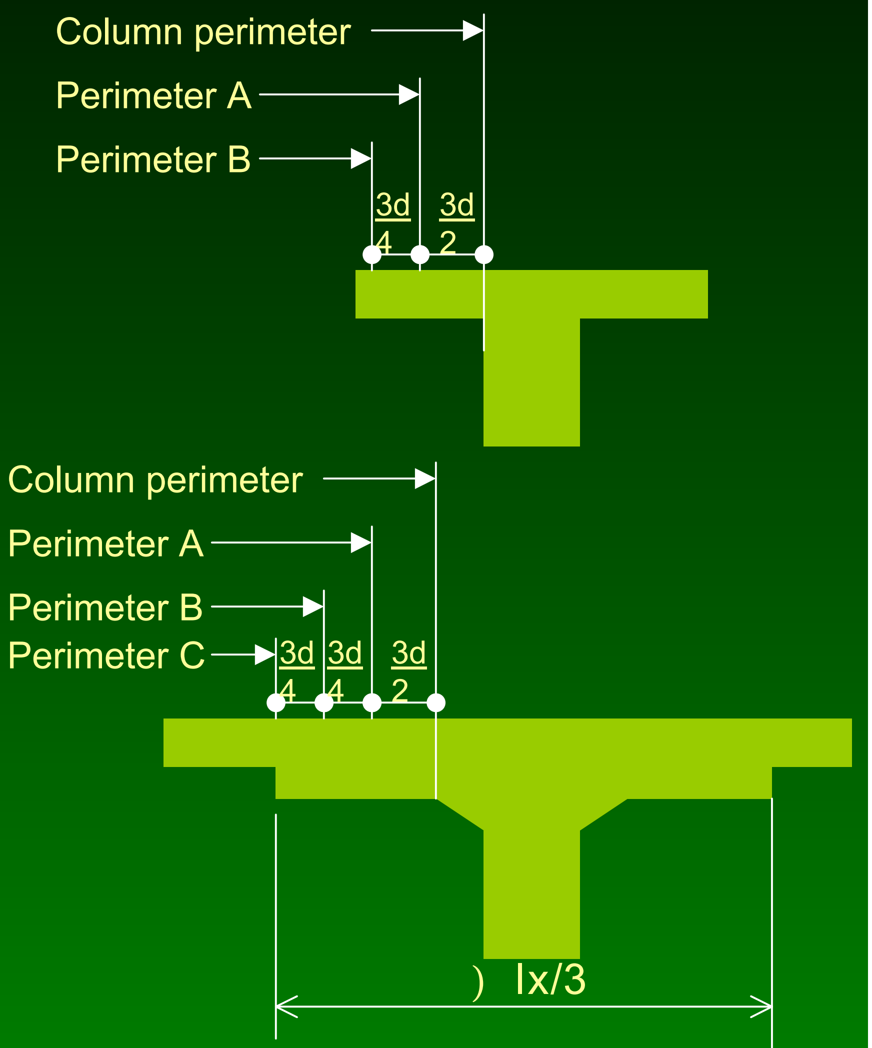
$$\boxed{M_{t,\,max} = 0.15\, b_e\, d^2\, fcu}$$

$\nless$ 0.5 design moment (EFM)

$\nless$ 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

	Span/depth ratio
Cantilever	7
Simply supported	20
Continuous	26

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

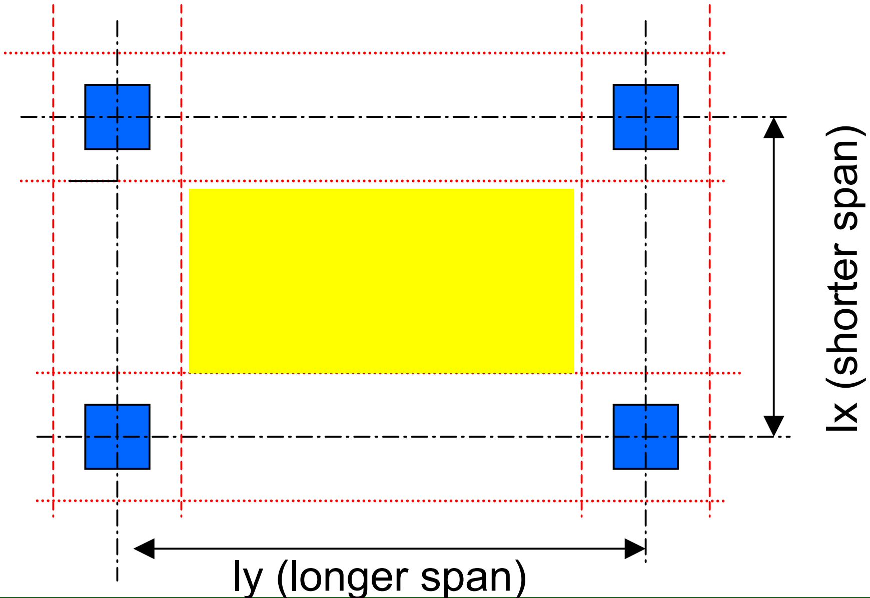
(ii) to apply 0.9 modification factor for flat slab, or where drop panel width < L/3

1.0 otherwise

OPENINGS

Holes in **areas bounded by the column strips** may be formed providing :

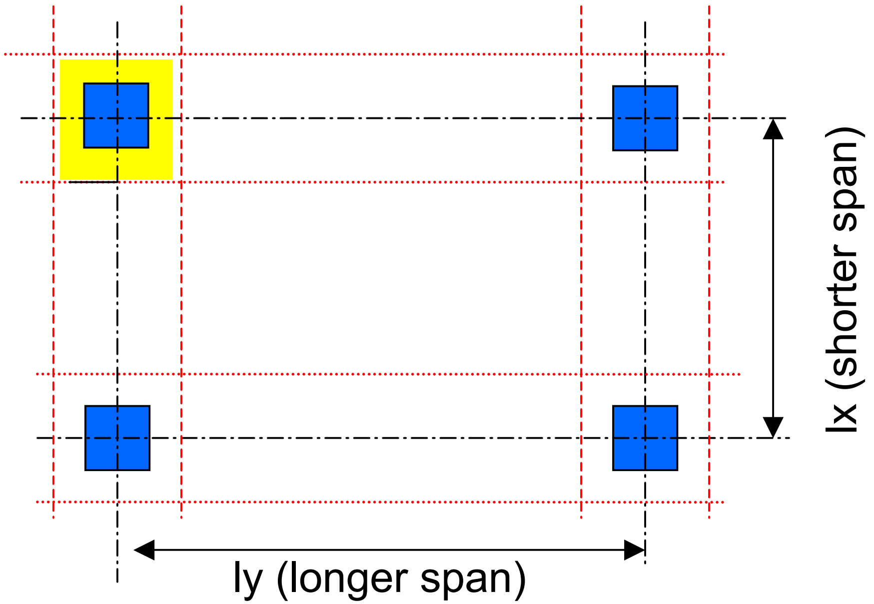
- greatest dimension < 0.4 span length and
- total positive and negative moments are redistributed between the remaining structure to meet the changed conditions



OPENINGS

Holes in **areas common to two column strips** may be formed providing :

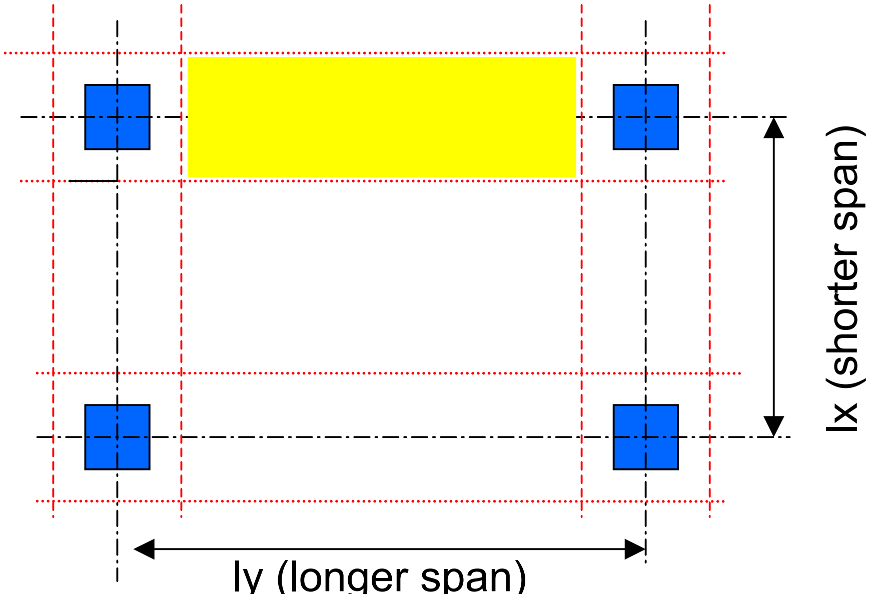
- that their aggregate their length or width does not exceed one-tenth of the width of the column strip;
- that the reduced sections are capable of resisting with the moments; and
- that the perimeter for calculating the design shear stress is reduced if appropriate



OPENINGS

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



OPENINGS

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

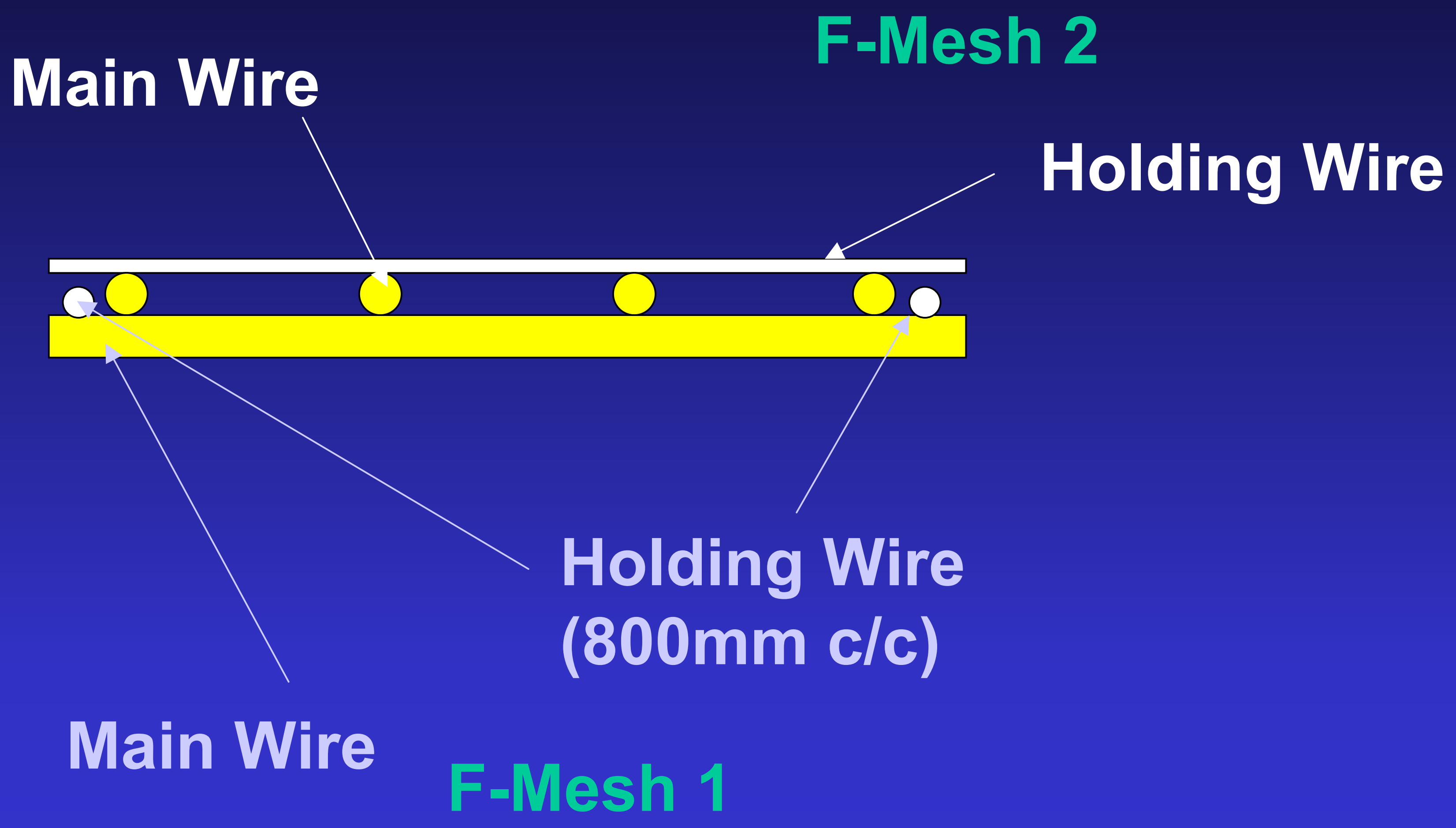
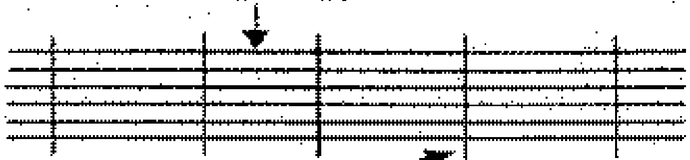


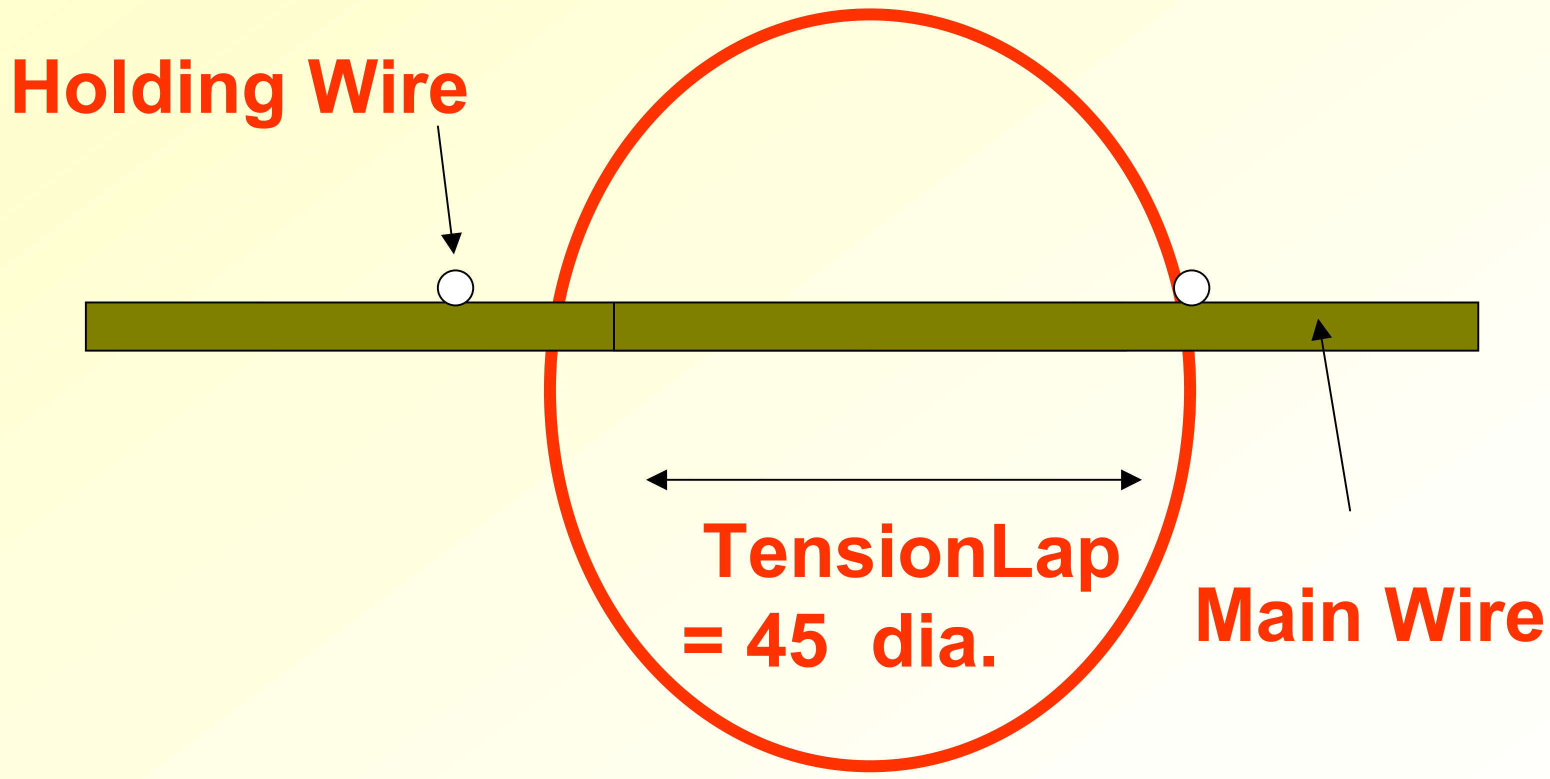
Table of F Mesh available in BRC

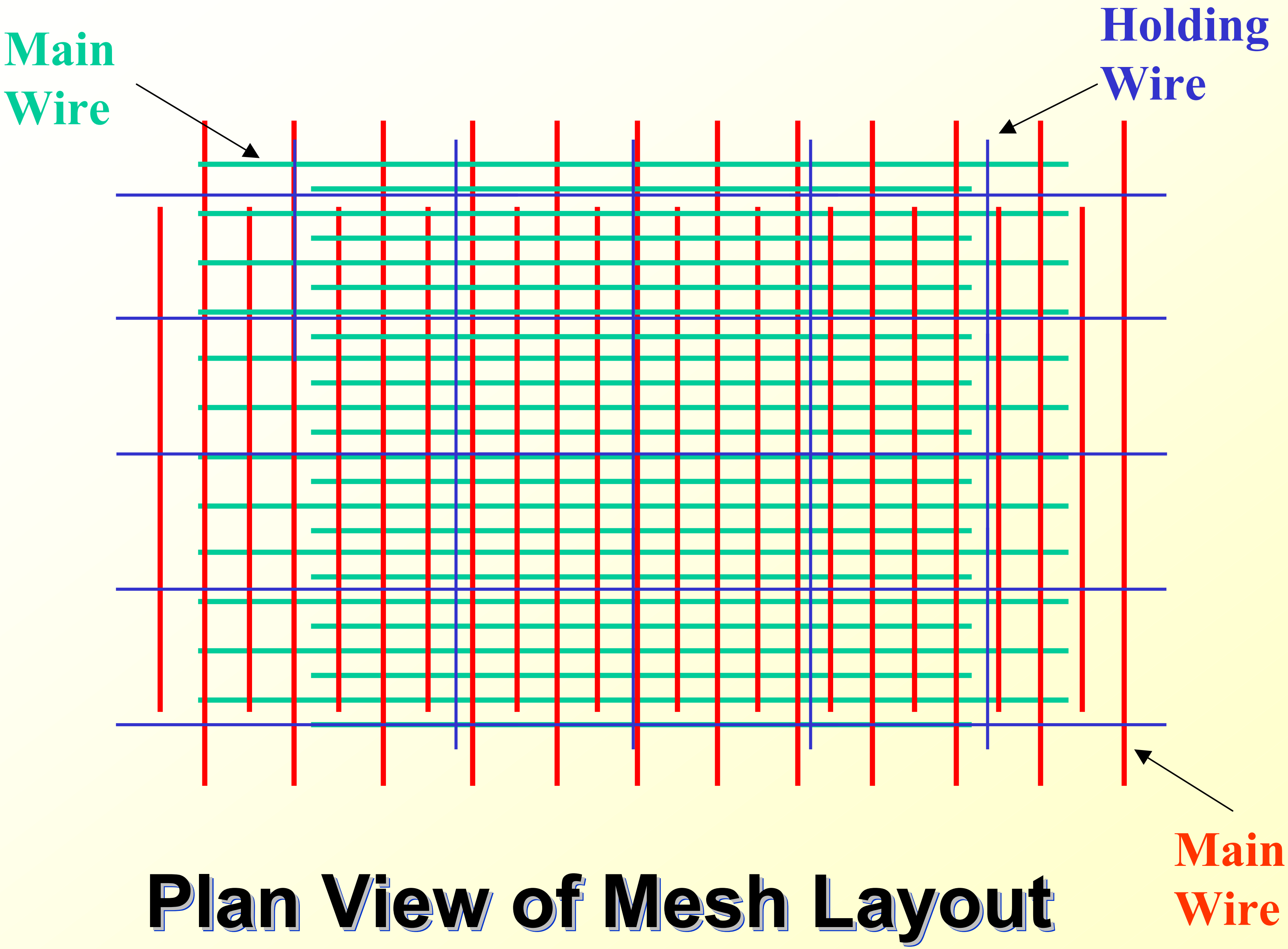
MESH TYPE	MAIN WIRE				AREA /M	CROSS WIRE				MASS PER UNIT AREA	
		Size mm		Spacing mm	mm^2/m		Size mm		Spacing mm	KG/M^2	$\#/M^2$
F1015 0780	D	10	@	150	524	H	7	@	800	4.49	4.42
F1014 0780	D	10	@	140	561	H	7	@	800	4.78	4.71
F1013 0780	D	10	@	130	605	H	7	@	800	5.12	5.04
F1012 0780	D	10	@	120	655	H	7	@	800	5.52	5.43
F1011 0780	D	10	@	110	714	H	7	@	800	5.98	5.89
F1010 0780	D	10	@	100	786	H	7	@	800	6.54	6.45
F1315 0880	D	13	@	150	885	H	8	@	800	7.44	7.33
F1314 0880	D	13	@	140	949	H	8	@	800	7.94	7.82
F1313 0880	D	13	@	130	1022	H	8	@	800	8.51	8.38
F1312 0880	D	13	@	120	1107	H	8	@	800	9.18	9.04
F1311 0880	D	13	@	110	1207	H	8	@	800	9.97	9.82
F1310 0880	D	13	@	100	1328	H	8	@	800	10.91	10.75
F1309 0880	D	13	@	90	1475	H	8	@	800	12.07	11.89
F1308 0880	D	13	@	80	1660	H	8	@	800	13.52	13.32
2F1315 0880	2D	13	@	150	1770	H	8	@	800	14.39	14.17
2F1314 0880	2D	13	@	140	1897	H	8	@	800	15.38	16.15
2F1313 0880	2D	13	@	130	2043	H	8	@	800	16.53	16.28
2F1312 0880	2D	13	@	120	2213	H	8	@	800	17.86	17.59
2F1311 0880	2D	13	@	110	2414	H	8	@	800	19.44	19.15
2F1310 0880	2D	13	@	100	2655	H	8	@	800	21.33	21.01
2F1309 0880	2D	13	@	90	2950	H	8	@	800	23.65	23.30
2F1308 0880	2D	13	@	80	3319	H	8	@	800	26.55	26.15

D10 denote 10mm deformed wire
D13 denote 13mm deformed wire
D13w denote twin 13mm deformed wire

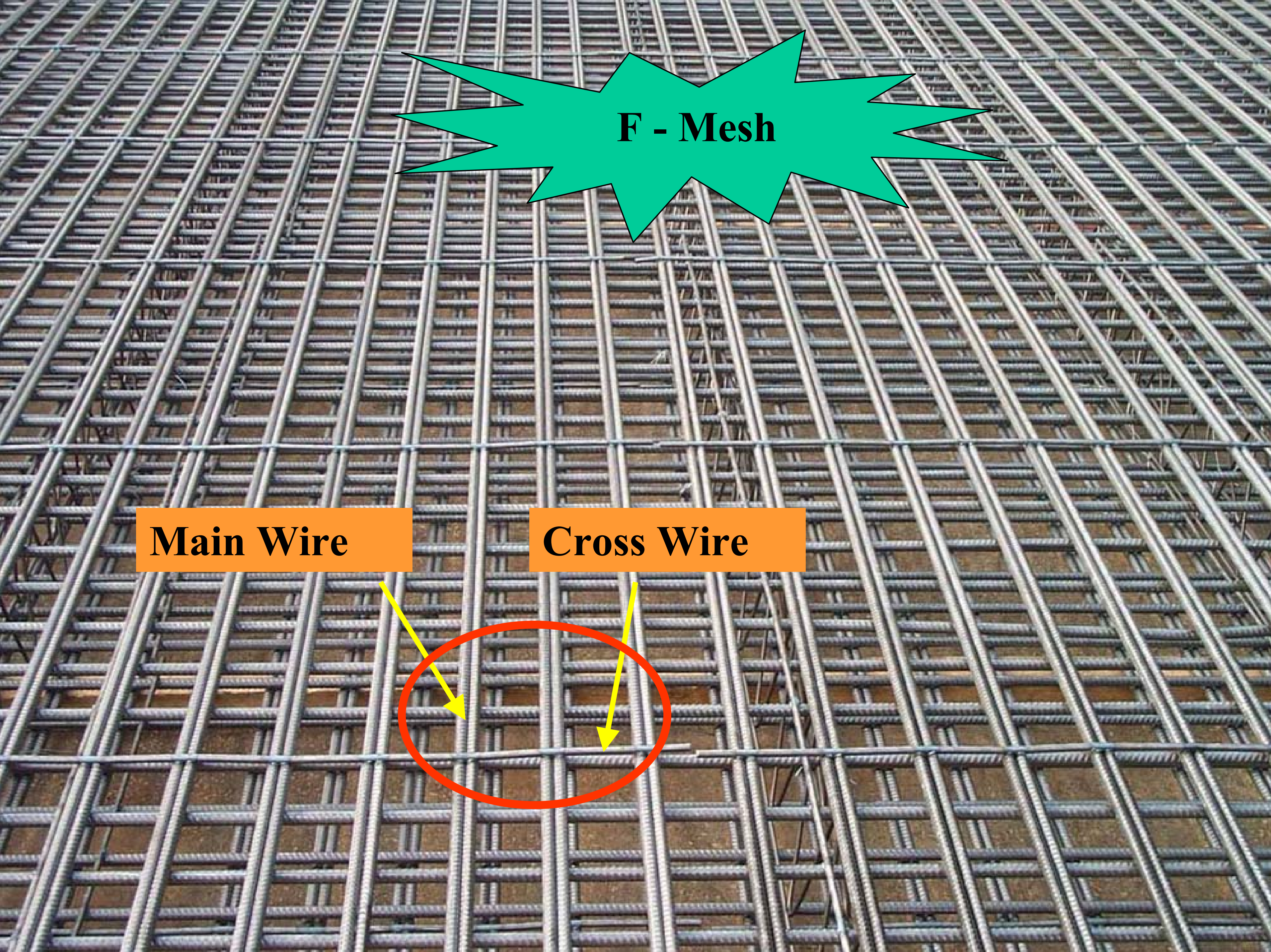


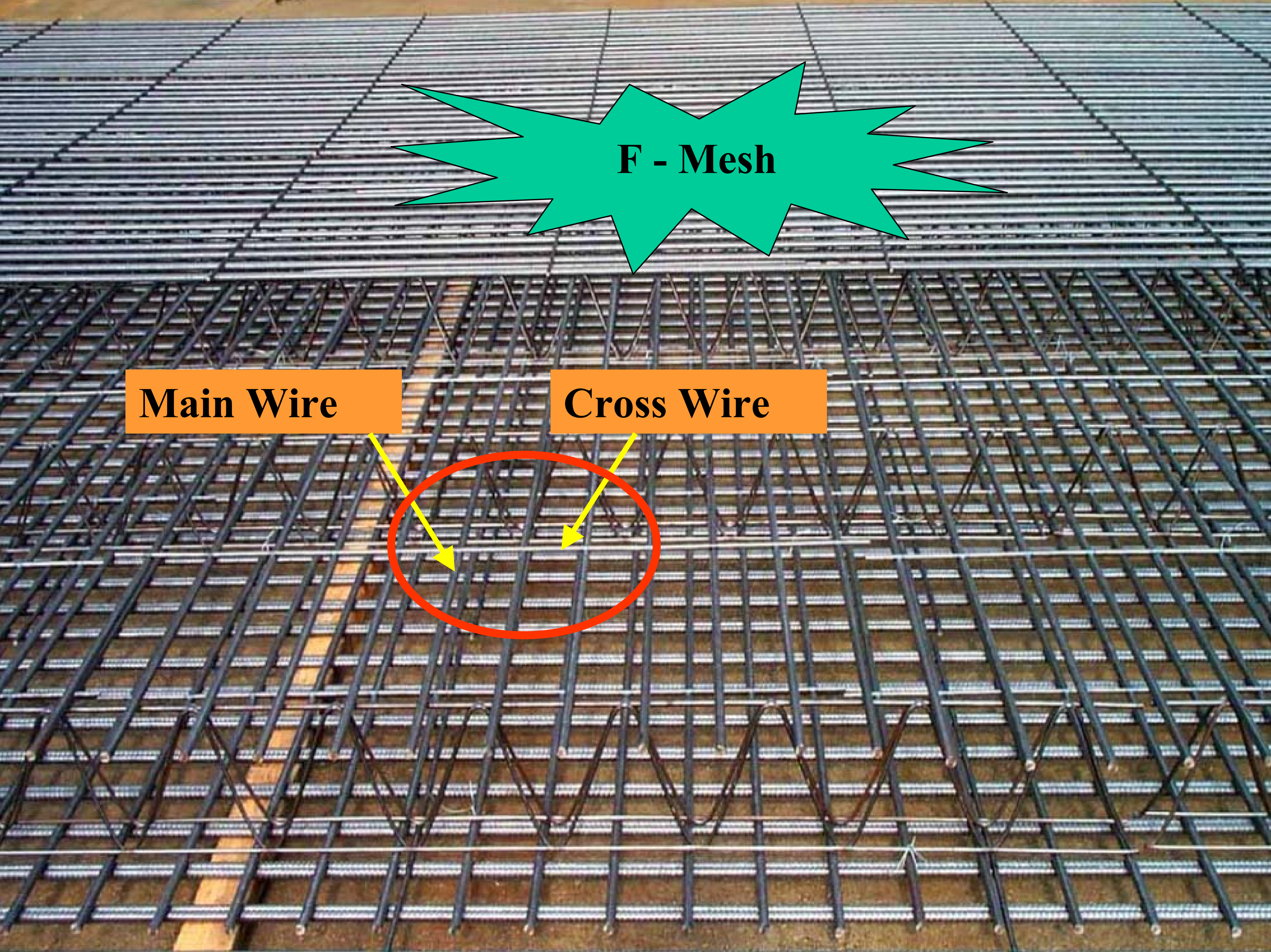
Typical Main Lap Details





Plan View of Mesh Layout

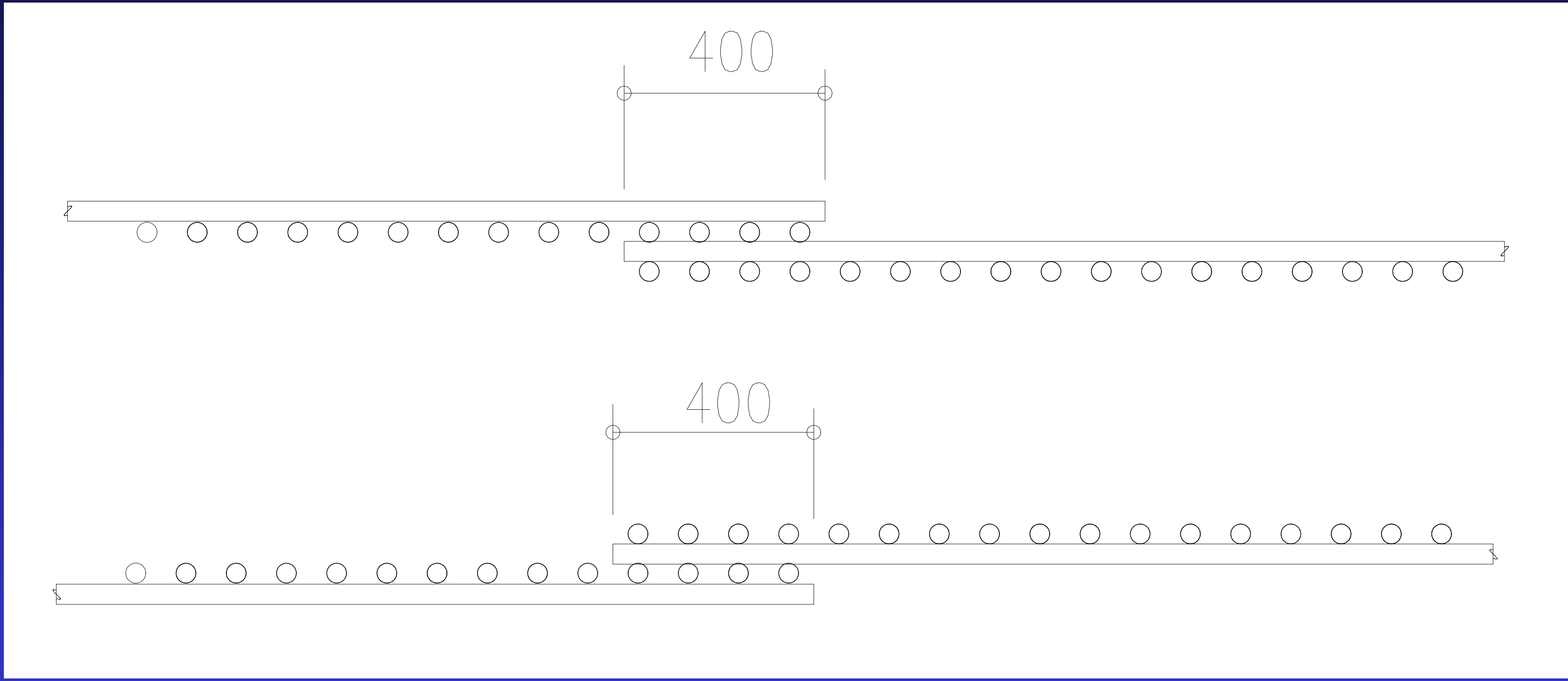

F - Mesh
Main Wire
Cross Wire


F - Mesh
Main Wire
Cross Wire

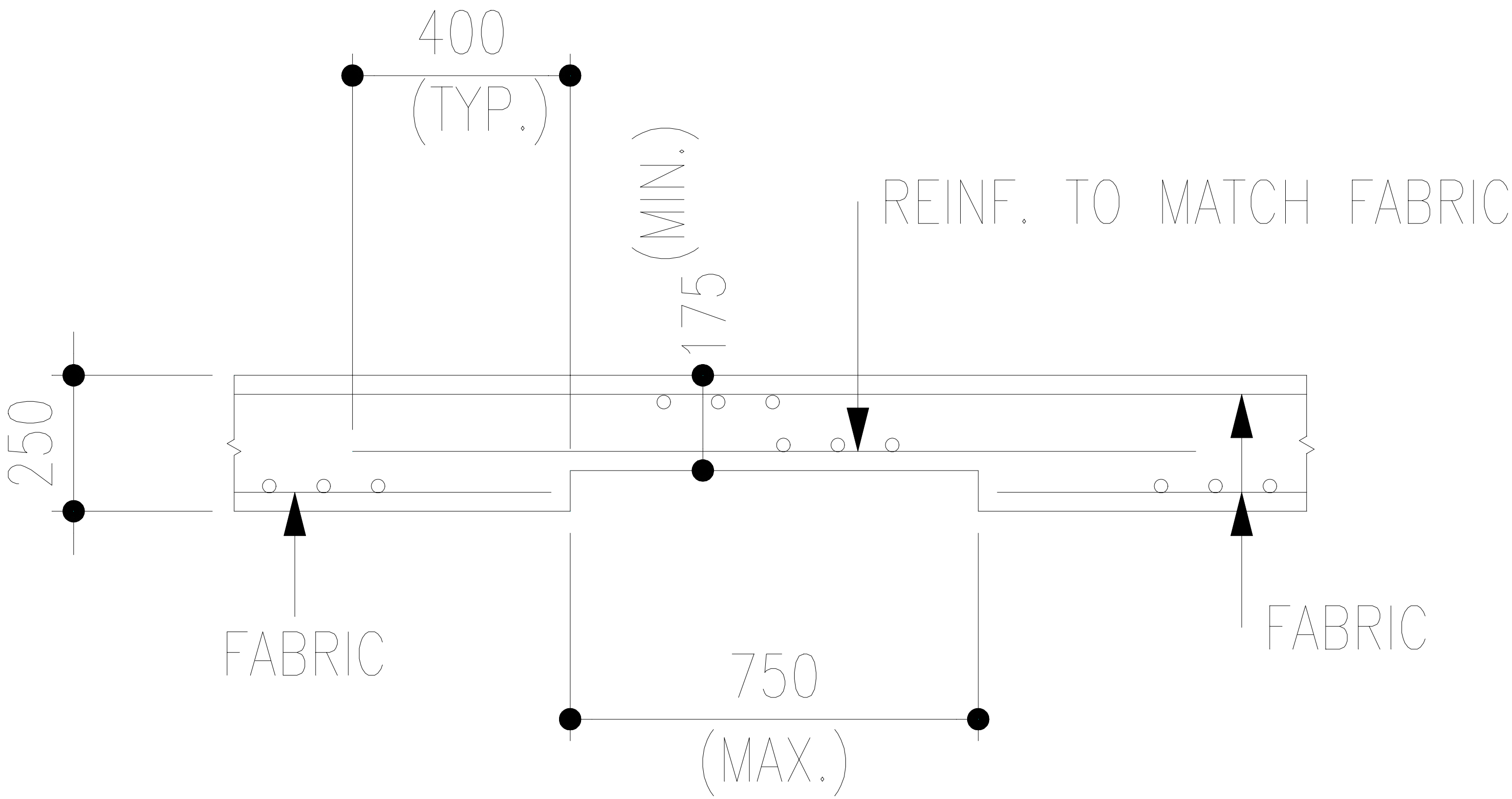
REINFORCEMENT FOR INTERNAL PANELS

- 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

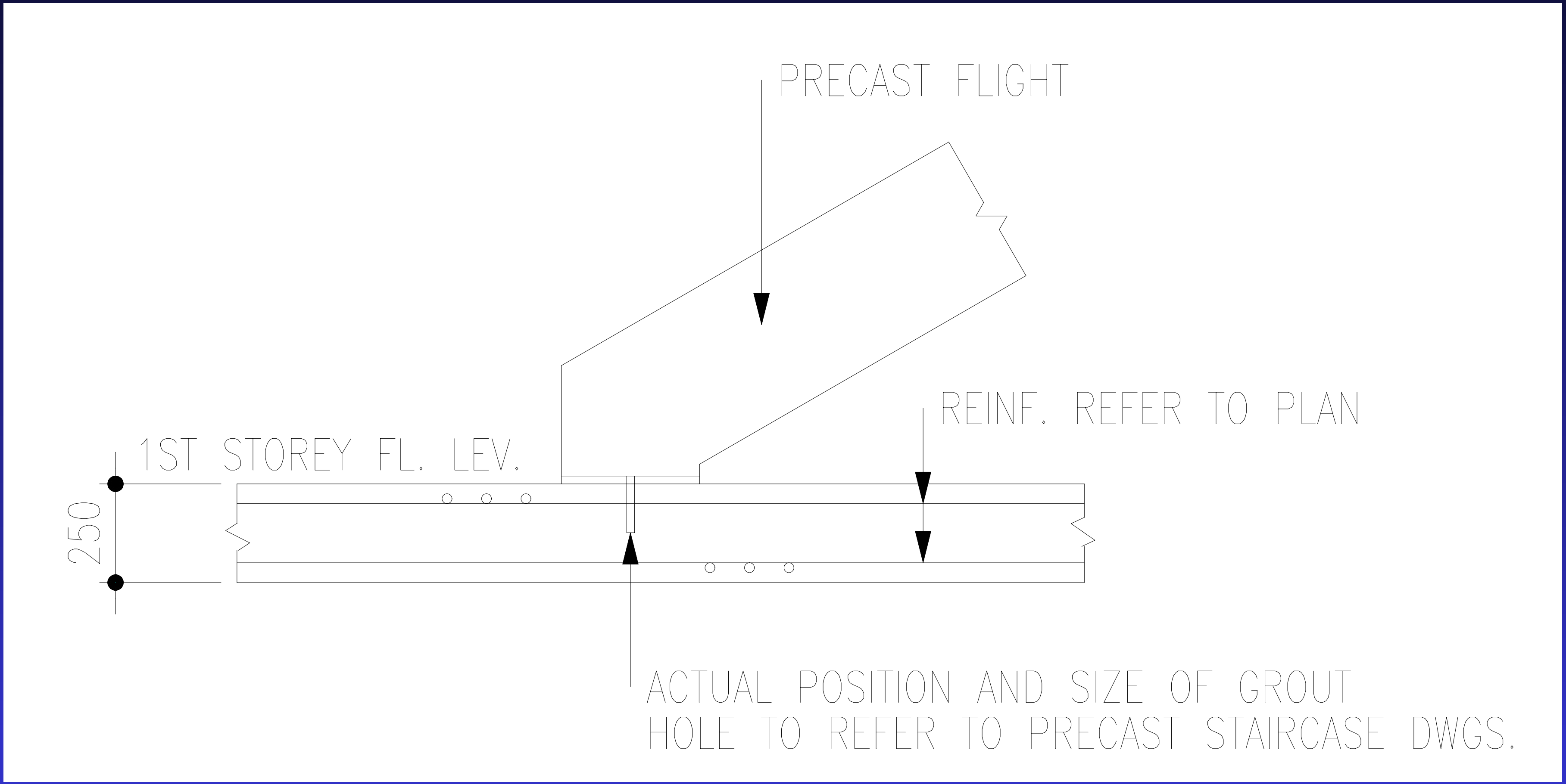
STANDARD LAPPING OF MESH (FOR FLAT SLAB)



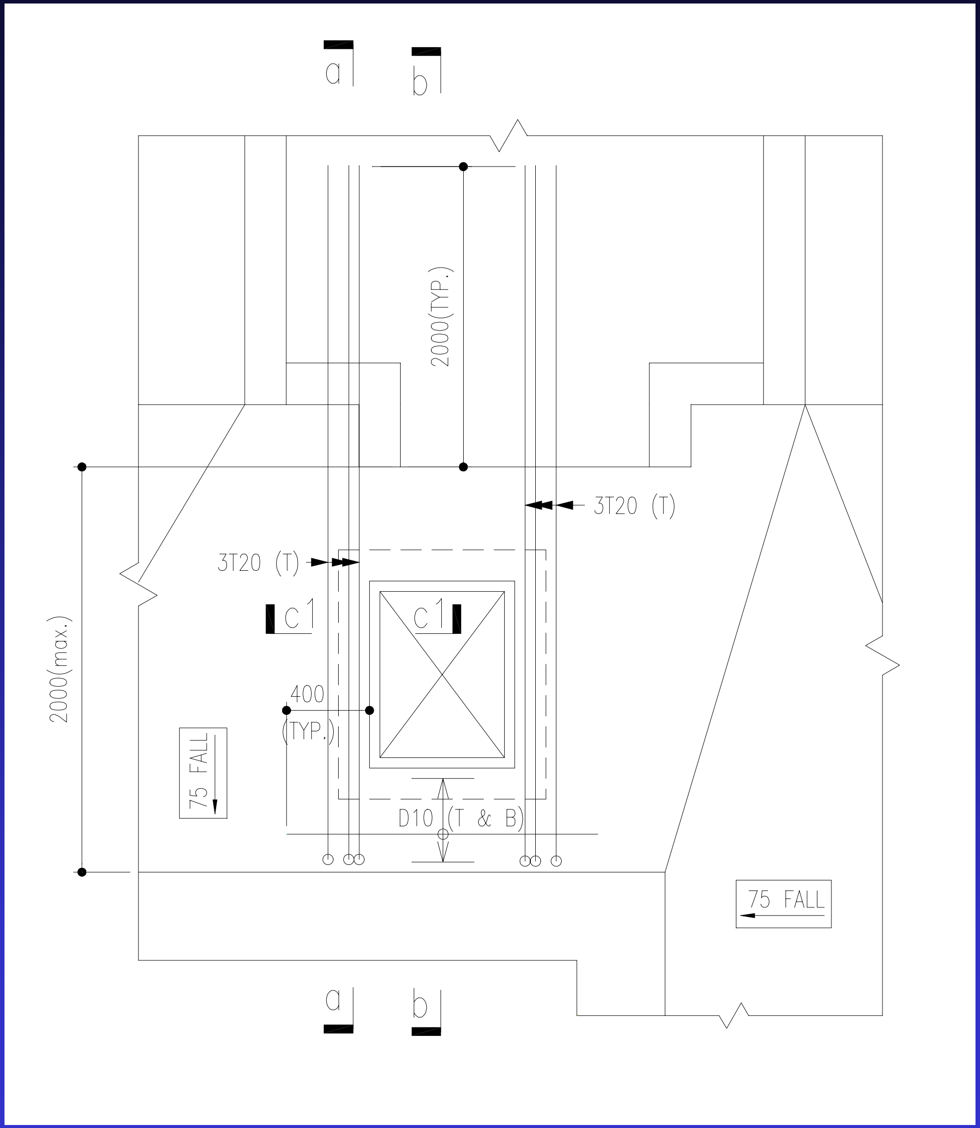
TYPICAL DETAIL SHOWING RECESS AT SLAB SOFFIT FOR SERVICES



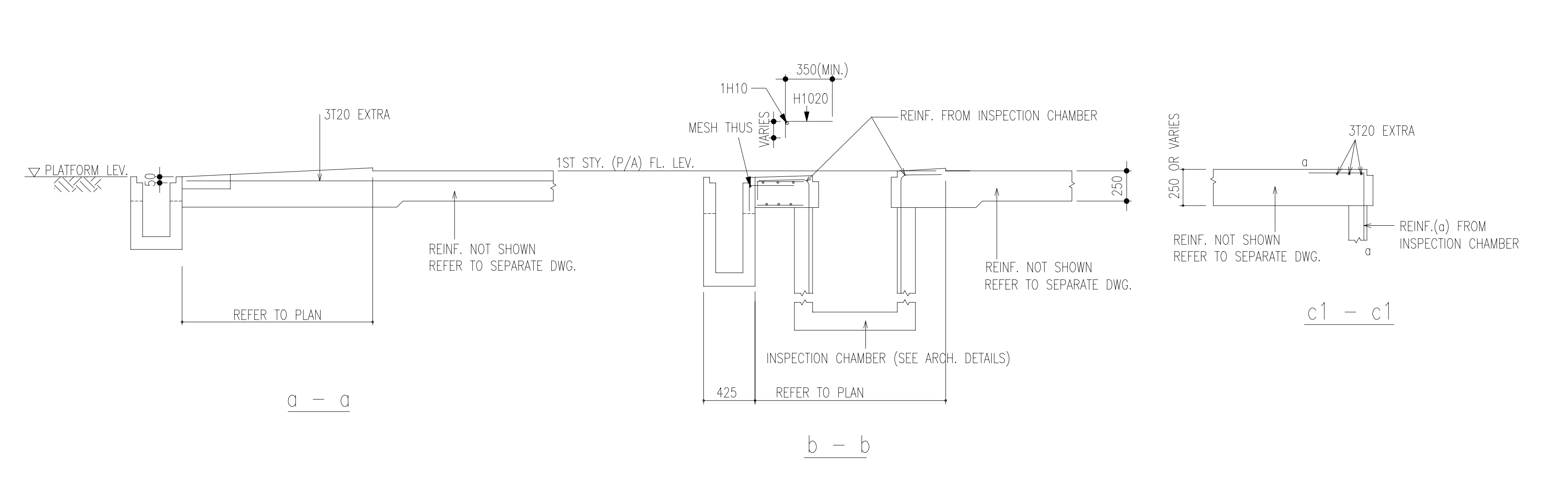
TYPICAL SECTION AT STAIRCASE



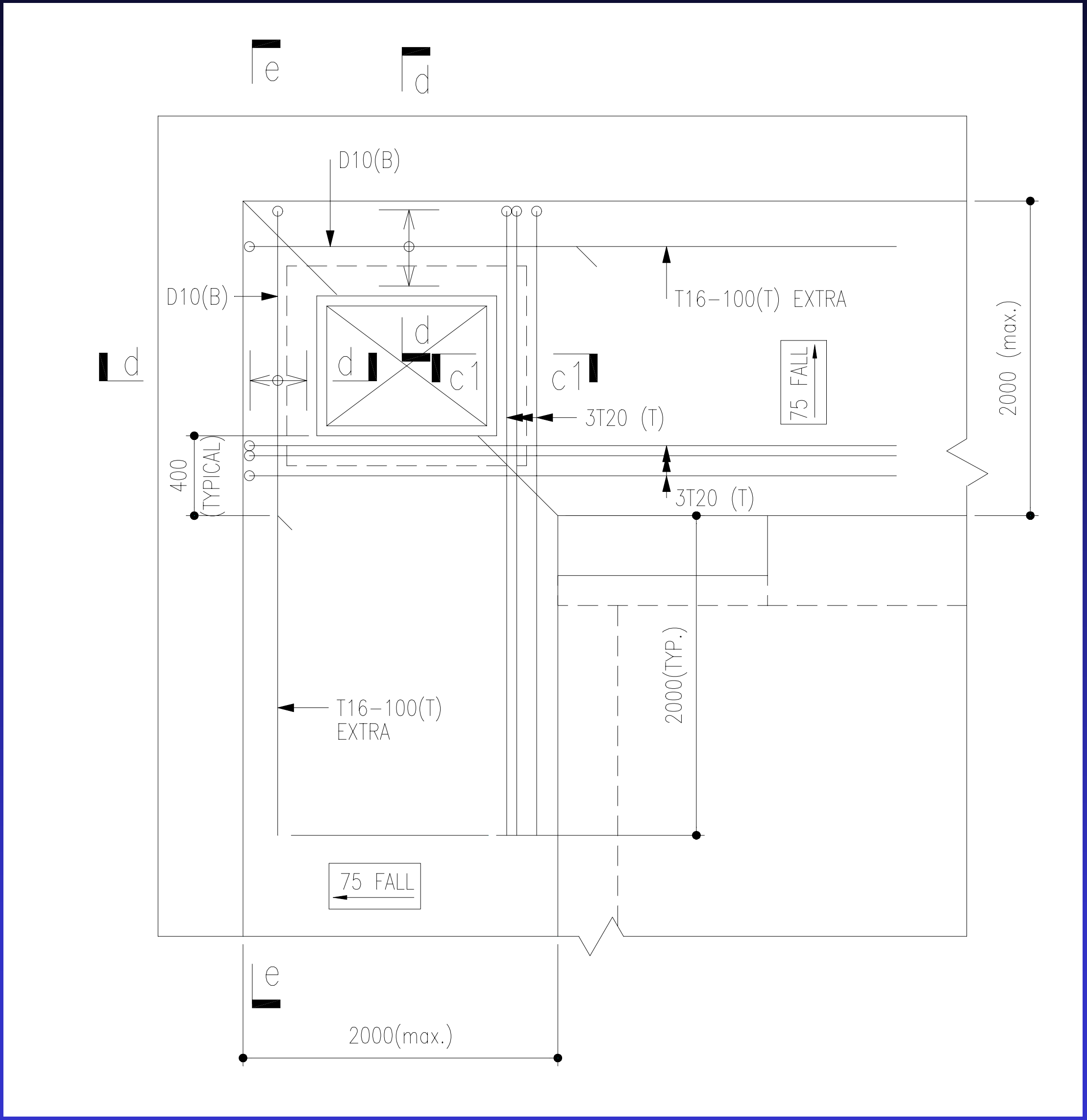
DETAILS OF INSPECTION CHAMBER AT APRON



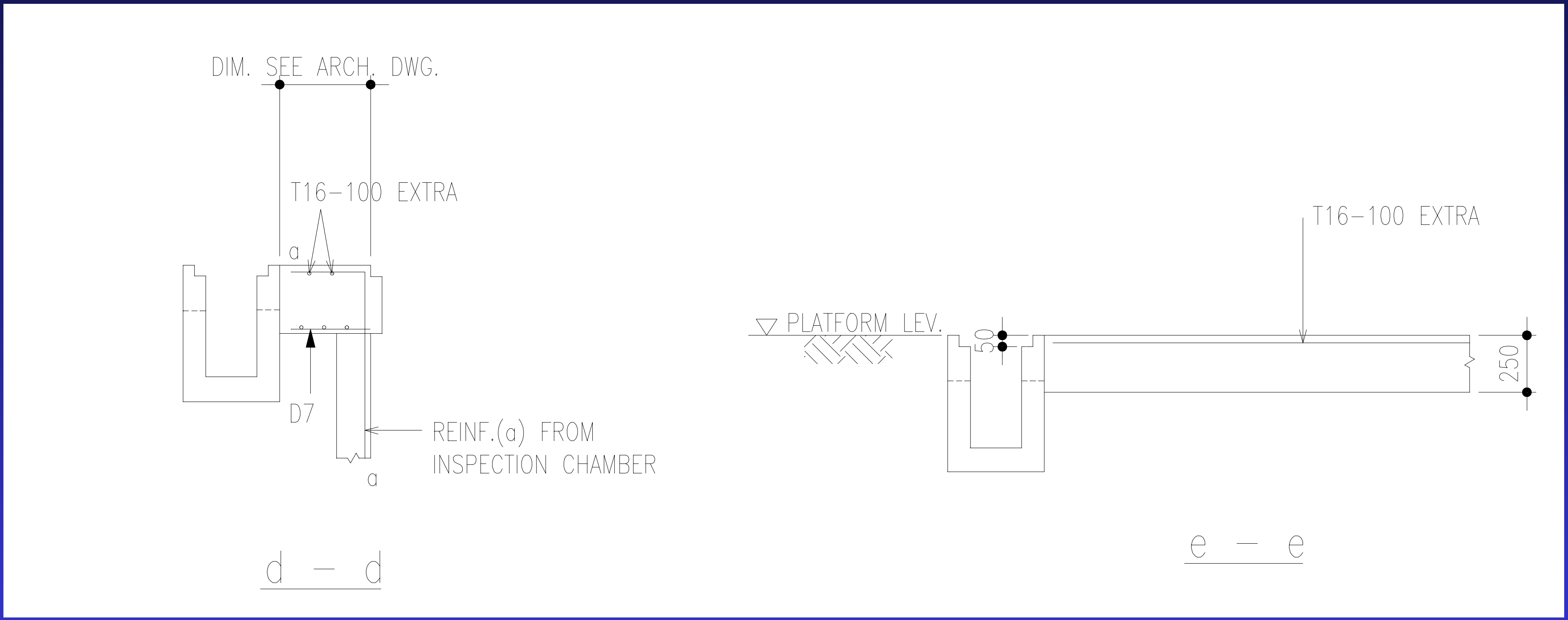
DETAILS OF INSPECTION CHAMBER AT APRON



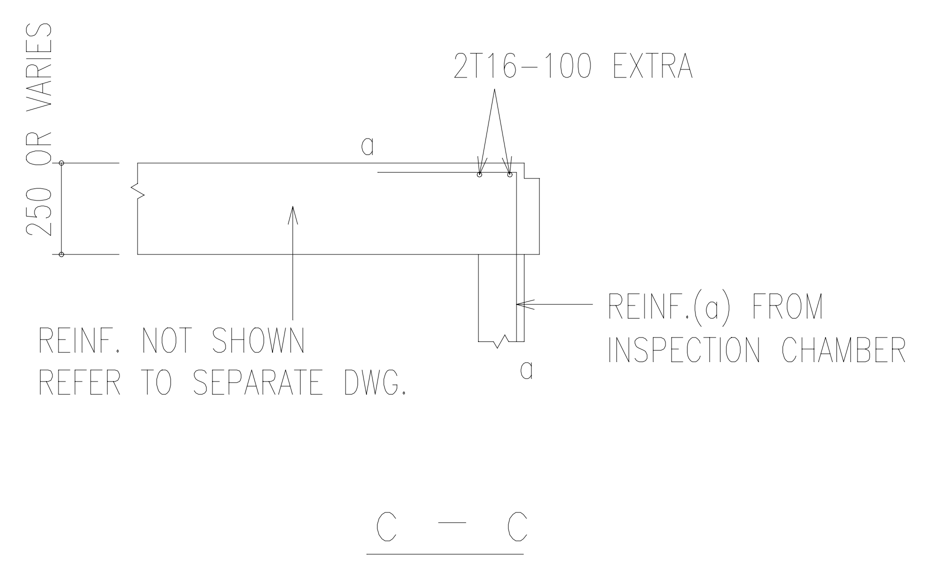
DETAILS OF INSPECTION CHAMBER AT APRON



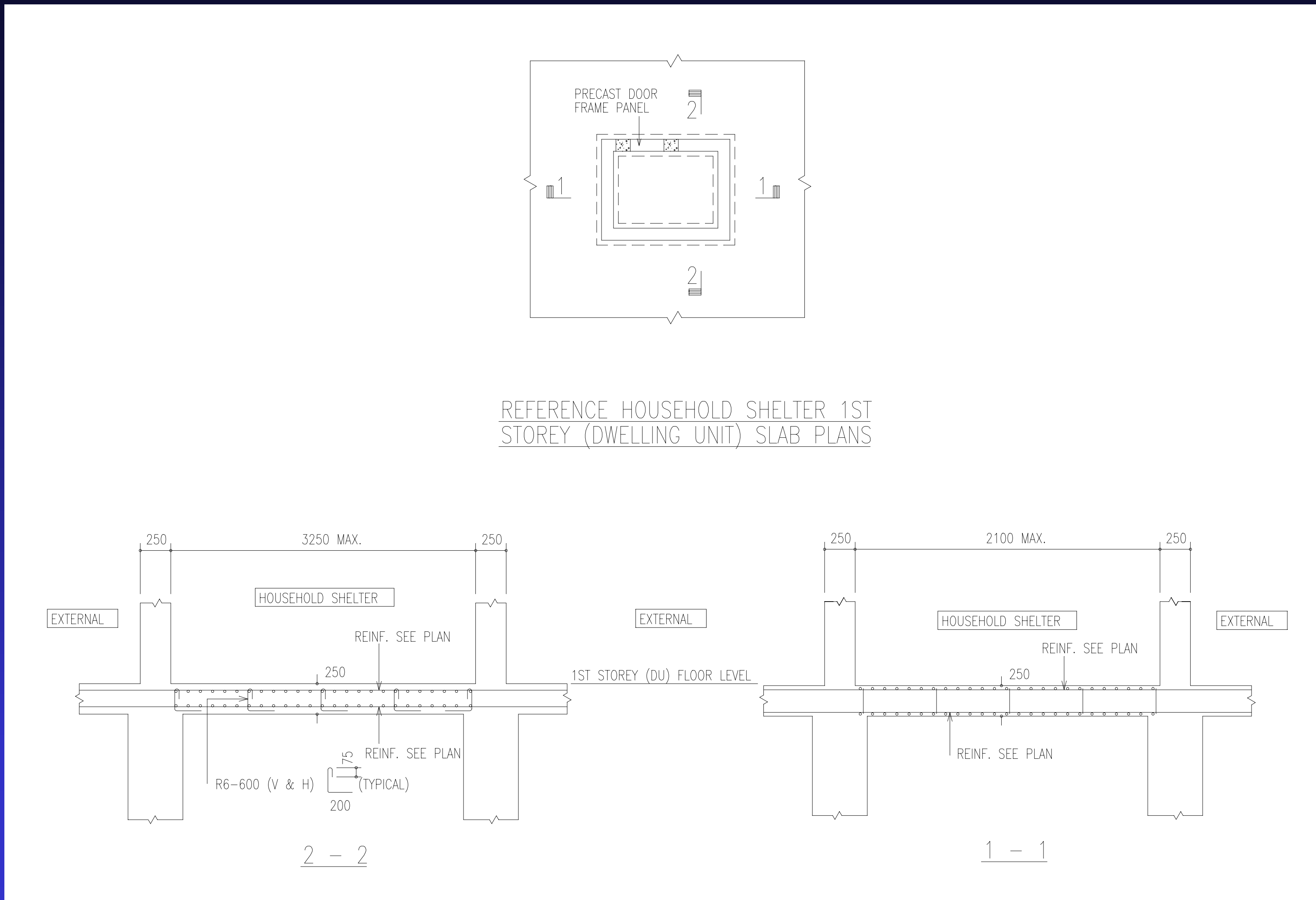
DETAILS OF INSPECTION CHAMBER AT APRON



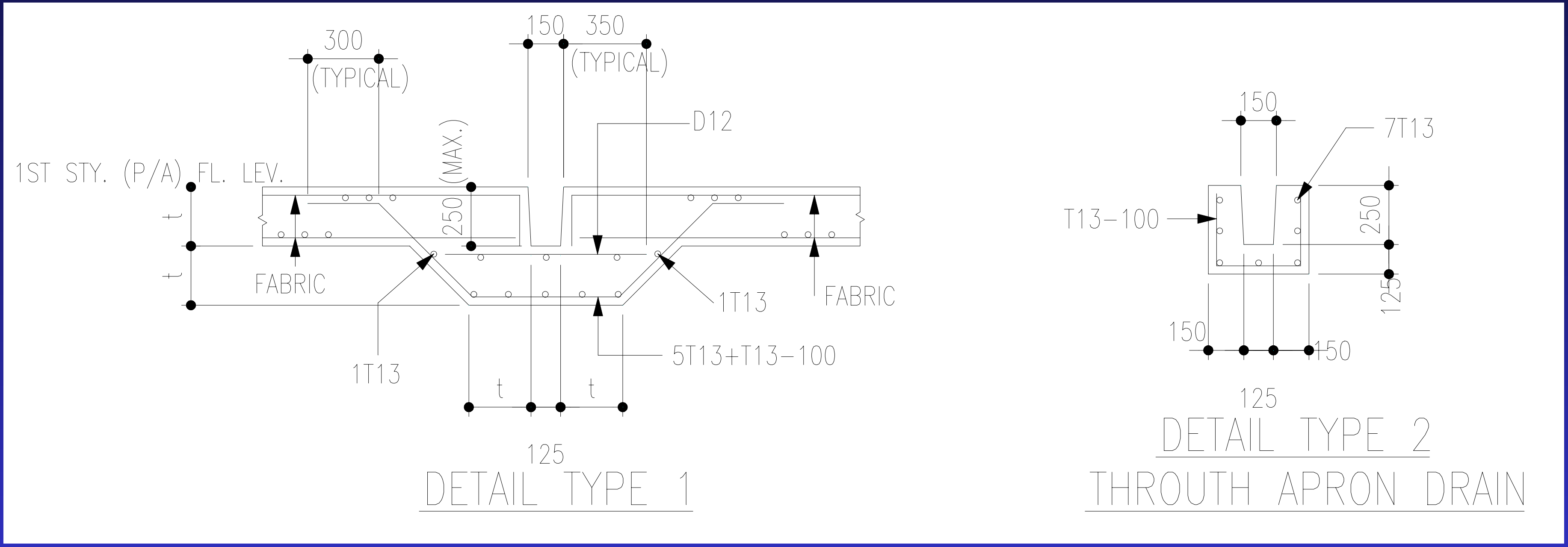
DETAILS OF INSPECTION CHAMBER AT PLAY AREA



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



TYPICAL DETAILS OF 125X250 RC CHANNEL FOR GAS PIPE ENTRY



TYPICAL SECTION
THRU' COVERED HOUSEDRAIN (PRECAST)