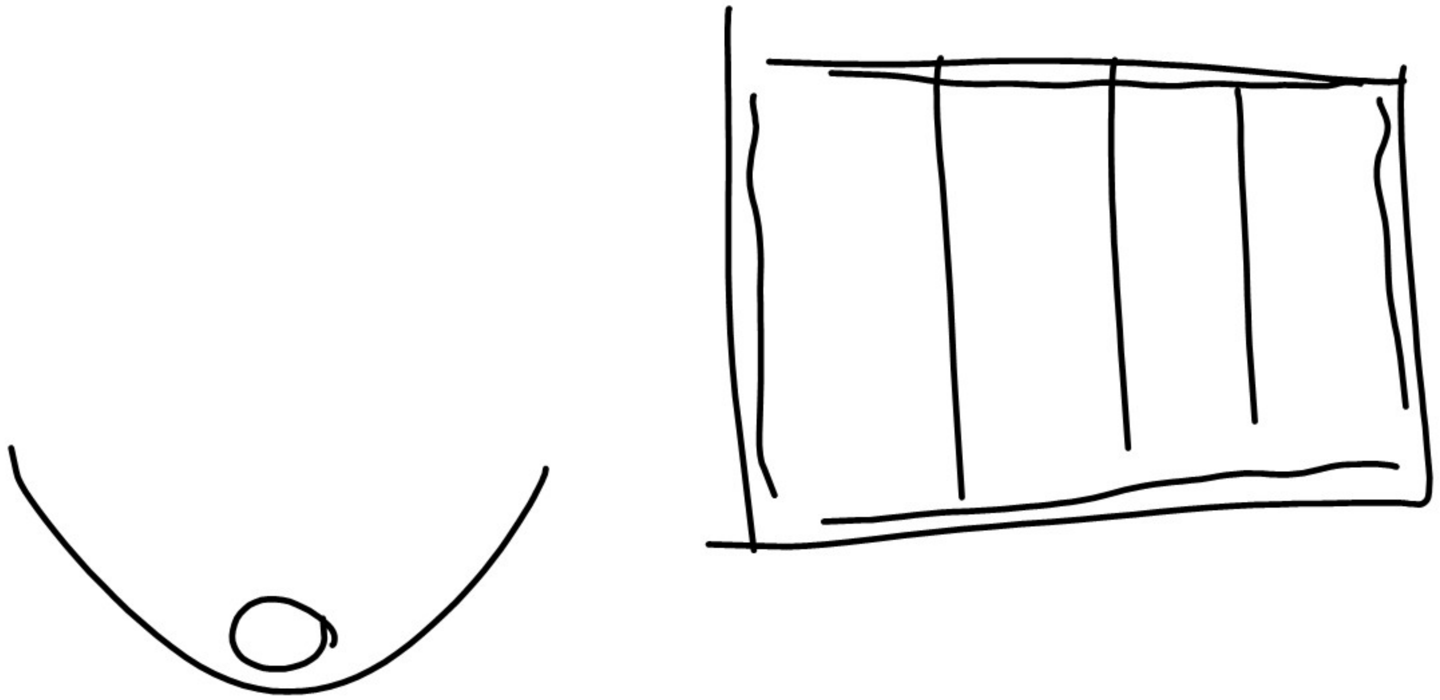


5.1. Regular systems

5.2. Ribbed slab systems

5.3. Two way slab systems

If time permits

5.4. Systems without vertical continuity

5.5. General shape building systems

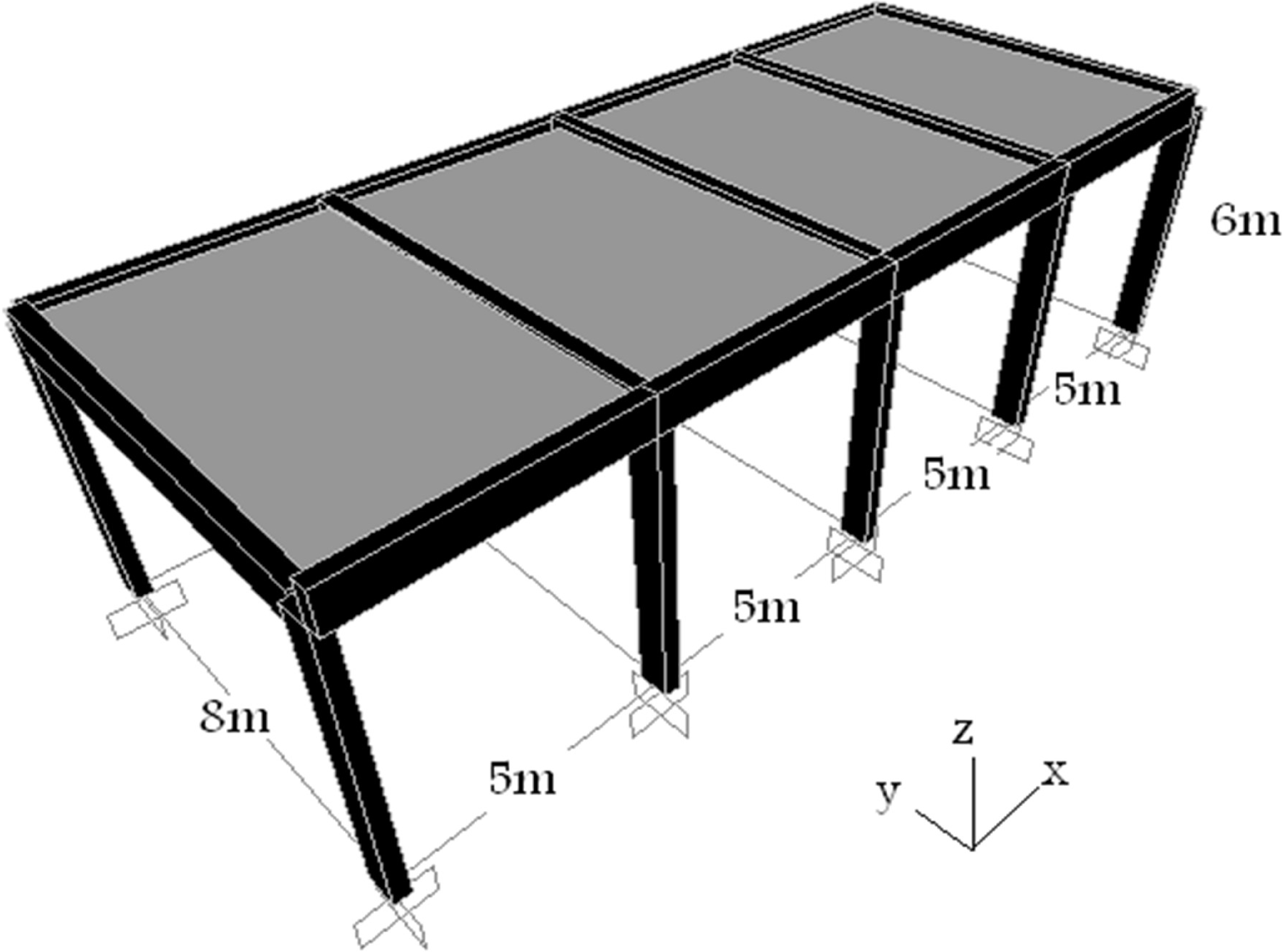
5.1 Regular systems

Regular systems are those which have one way solid slab and vertical continuity; i.e. load of slab is transferred to beams, from beams to columns and then to footings.

Analysis of all systems are done using either 1D, 2D or 3D modeling.

Regular systems: example

- 1-storey RC slab-beam factory structure shown next slide
- Fixed foundations, 4 spans 5m bays in x and a single 8m span in y, 6m elevation
- E=24GPa, μ=0.2, ρ=2.5t/m^3
- Cylinder concrete strength=25MPa, steel yield=420MPa
- superimposed loads=5kN/m^2, live load=9kN/m^2


6m
5m
5m
5m
8m
5m
z
y
x

Regular systems: example

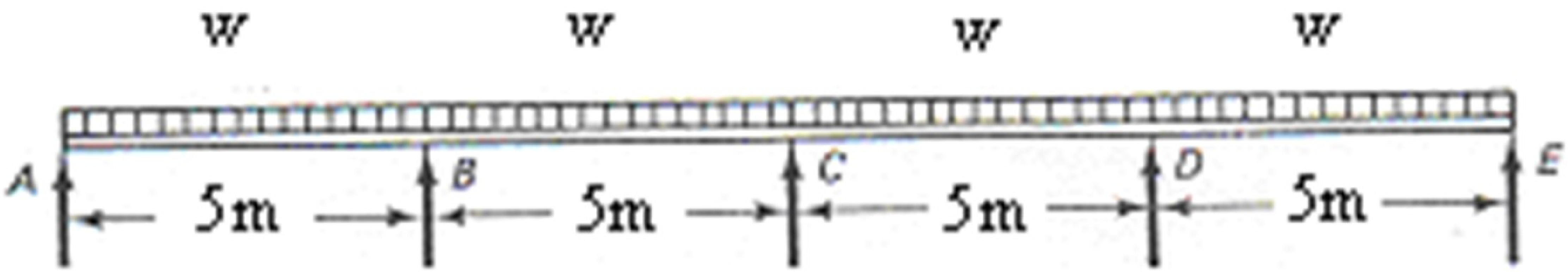
- Due to cracking of elements, use the following modifiers for gross inertia for 3D analysis (ACI R10.11.1):
  - Beam 0.35
  - Column 0.7
  - One way slab (0.35, 0.035)

Preliminary dimensioning

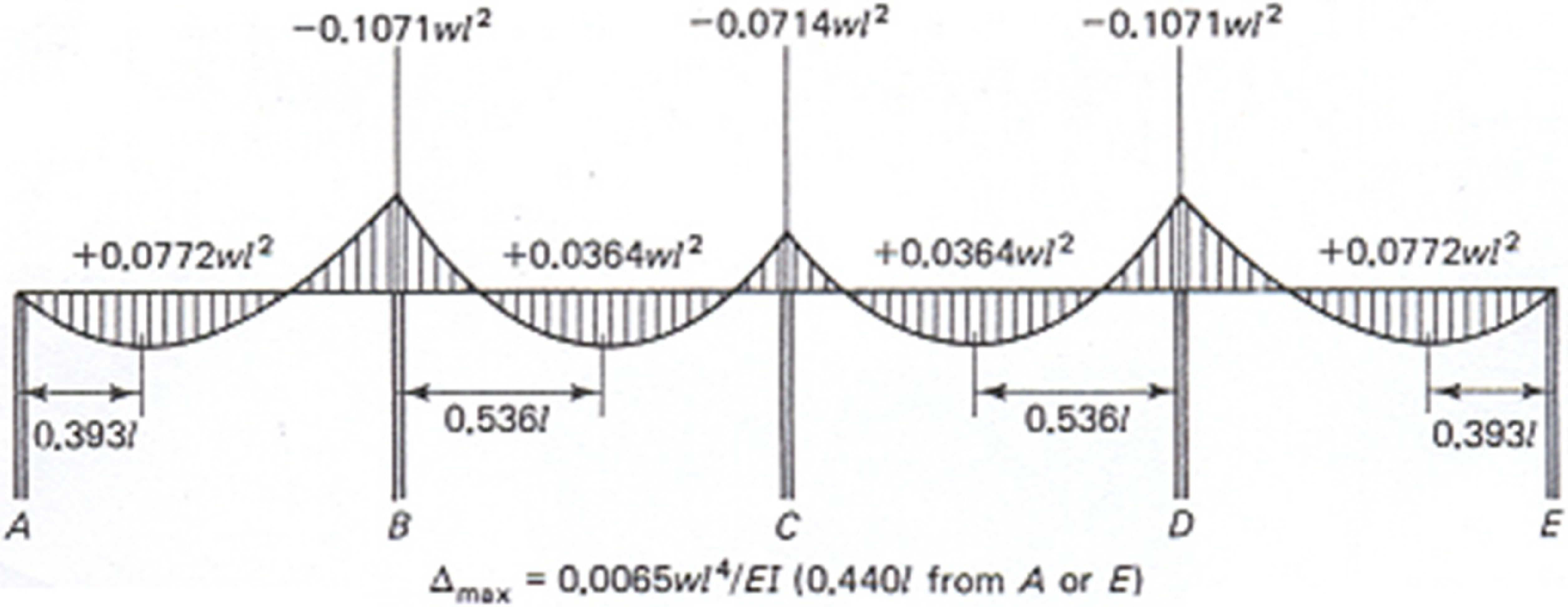
- Slab: According to ACI 9.5.2 thickness of slab=500/24=20.83cm, but considering that concentrated loads might be placed at middle of slab, use 25cm thickness
- Beam: 800/16=50cm, however beams fail by strength and not deflection, and because it is a factory use: drop beams 30cmX80cm (6cm cover)
- Columns: use 30X60cm reinforced on two faces (cover 4cm).

1D analysis and design: slab model

-



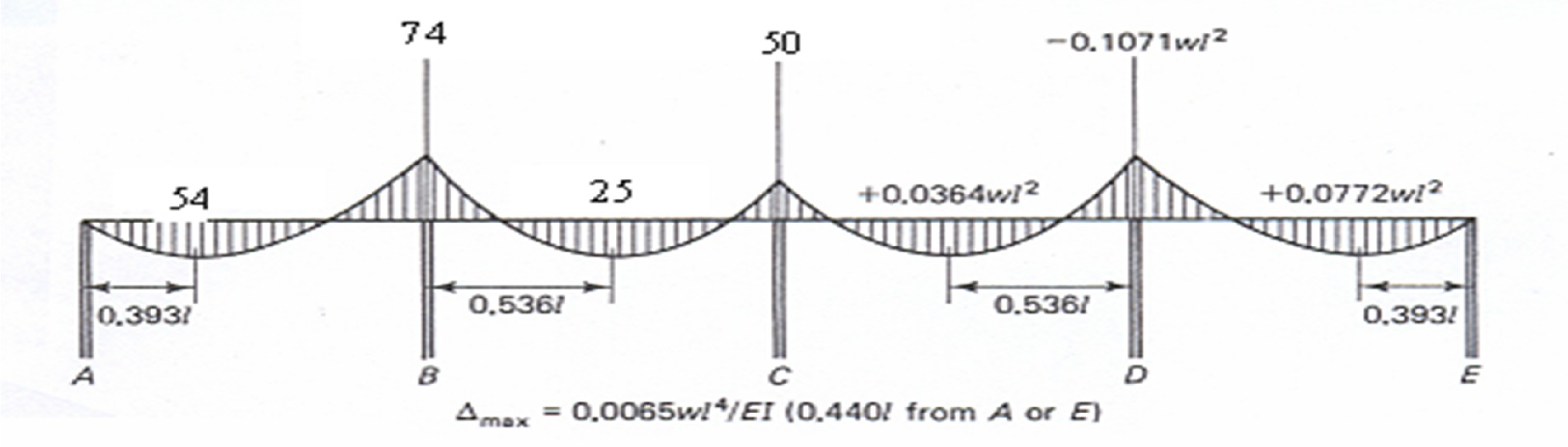
1D analysis and design: slab analysis

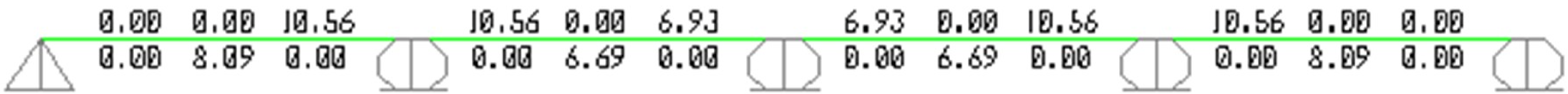


1D analysis and design: slab analysis

- $w_d=(.25*24.5+5)=11.125kN/m$
- $w_l=9kN/m$
- $w_u=1.2*11.125+1.6*9=27.75kN/m$

1D analysis and design: slab analysis, BM in KN.m, As in square cm

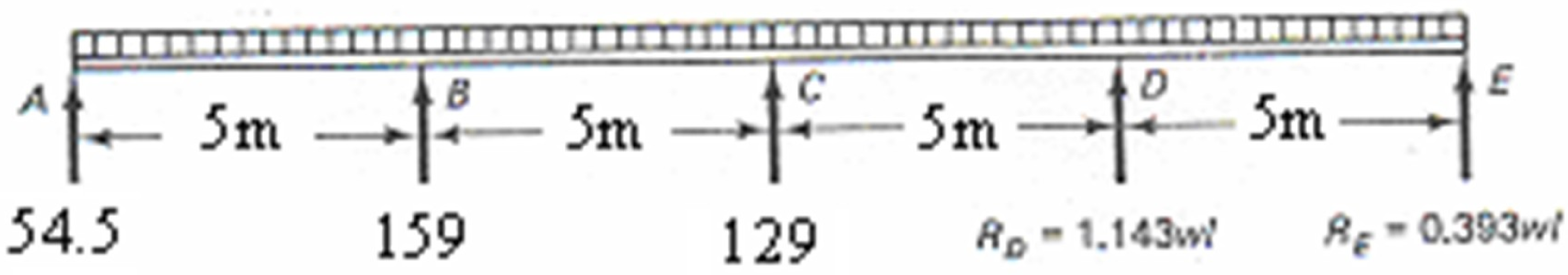




$$A_s \approx \frac{3M_u}{20} = 0.15M_u \geq \frac{1.4}{420}(100*20) = 6.67$$

1D analysis and design: slab analysis, values of reactions in KN

- Note: for slabs and footings of uniform thickness the minimum steel is that for temperature and shrinkage but with maximum spacing three times the thickness or 450mm. (ACI10.5.4)



1D analysis and design: beam analysis,

- Assume simply supported beam:

-Beam C, M_u=(129+1.2*0.3*.55*24.5)*8^2 /8=1070kN.m, As=43.4cm^2

-Beam B, M_u=(159+1.2*0.3*.55*24.5)*8^2 /8=1311kN.m, As=53.1cm^2

-Beam A, M_u=(54.5+1.2*0.3*.55*24.5)*8^2 /8=475kN.m, As=19.3cm^2

3D SAP

If same assumptions are used in 3D model, results should be the same

- Do not put secondary beams
- Set modifiers for slab $m_{12}=m_{22}=0.01$
- Set modifiers for beam torsion=0.01, flexure 3=100, weight=0.55/0.8
- Set modifiers for column: axial=100, flexure=torsion=0.01

3D SAP: Gravity equilibrium checks

D:

Slab=20X8X (0.25X24.5+5) =1780kN

Beams= (5X8) X.55X.3X24.5=161.7kN

Columns=10X6X.3X.6X24.5=264.6KN

Sum=2206.3kN

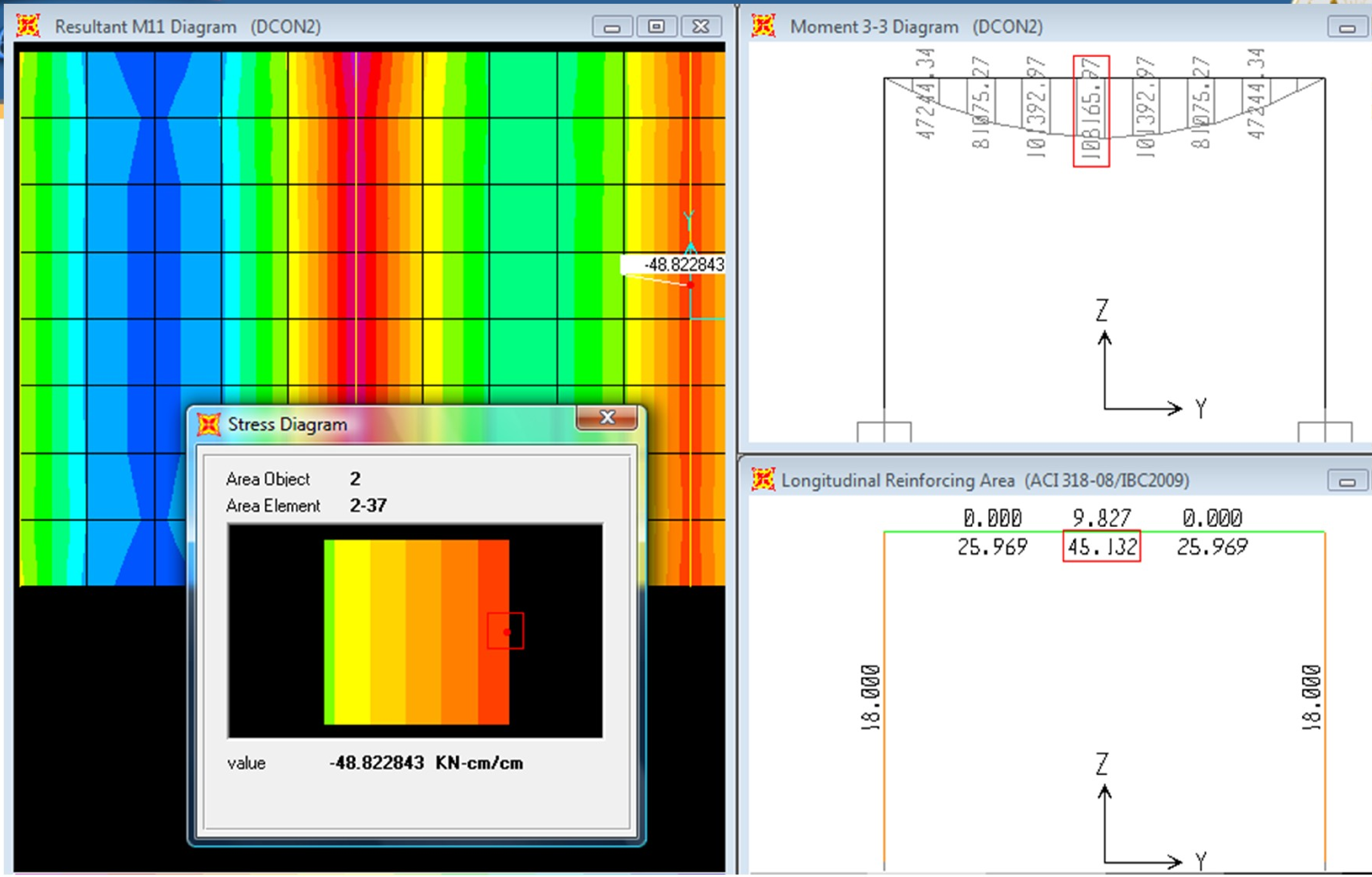
- L:

R =20X8X9=1440KN

Gravity equilibrium checks

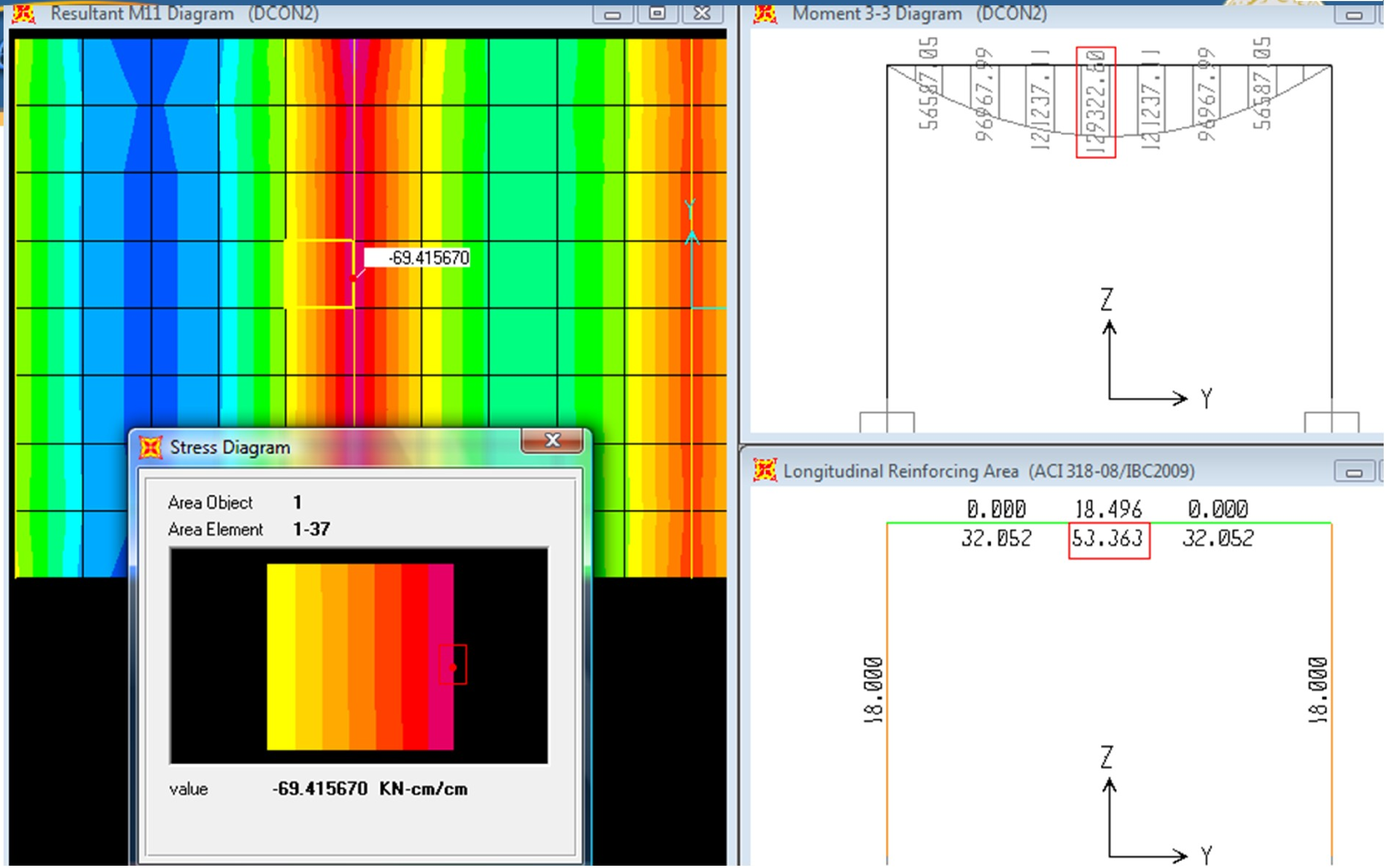
- SAP results:

	OutputCase Text	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-cm	GlobalMY KN-cm	GlobalMZ KN-cm	GlobalX cm
▶	DEAD	LinStatic	-8.327E-17	-5.117E-17	2206.3	000000001478	000000001137	-2.22E-14	0
	live	LinStatic	-4.163E-17	-3.686E-17	1440	000000004547	000000001478	2.776E-15	0

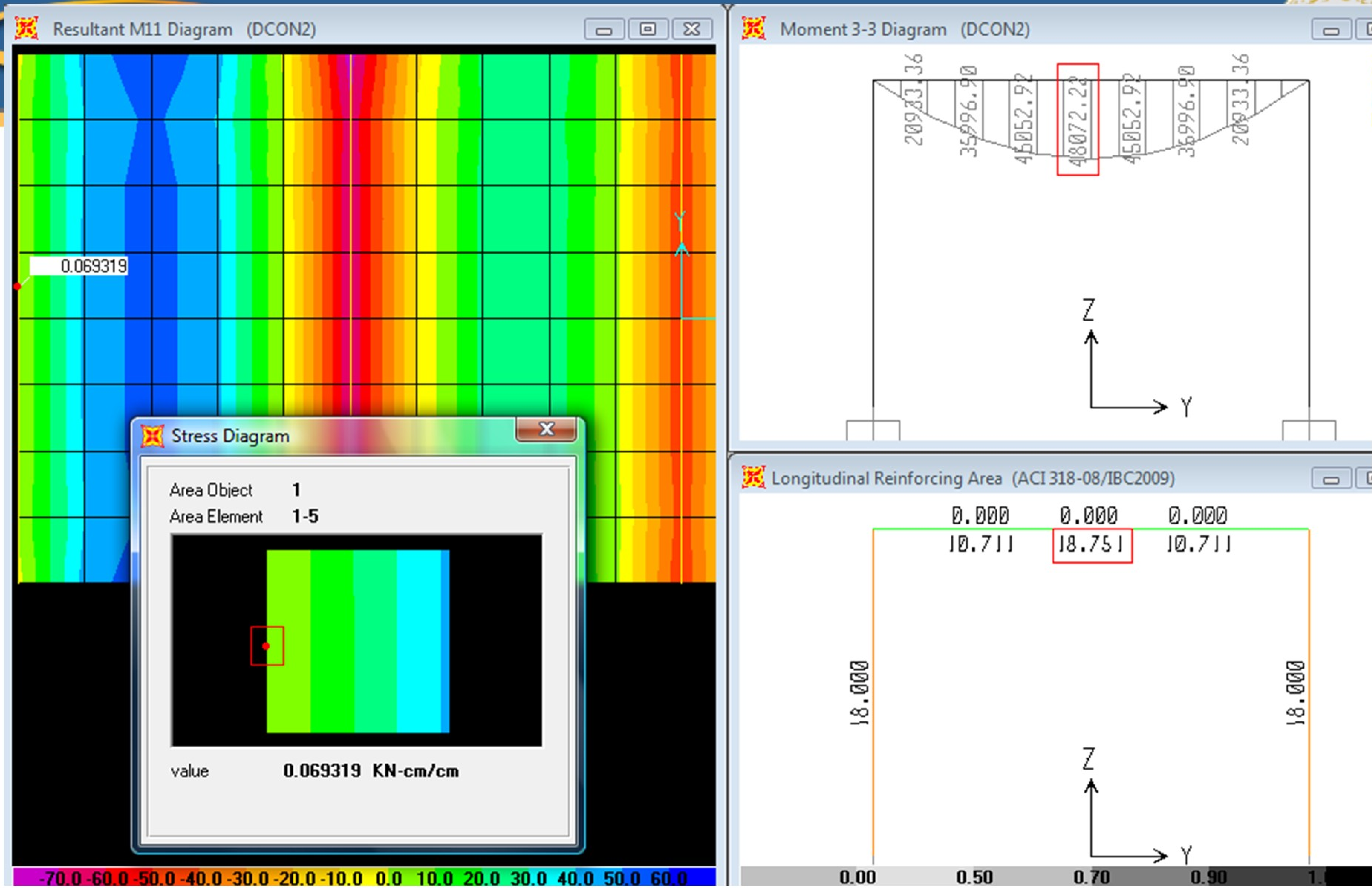


Left: bending moment in slab at point c 48.8kN.m/m

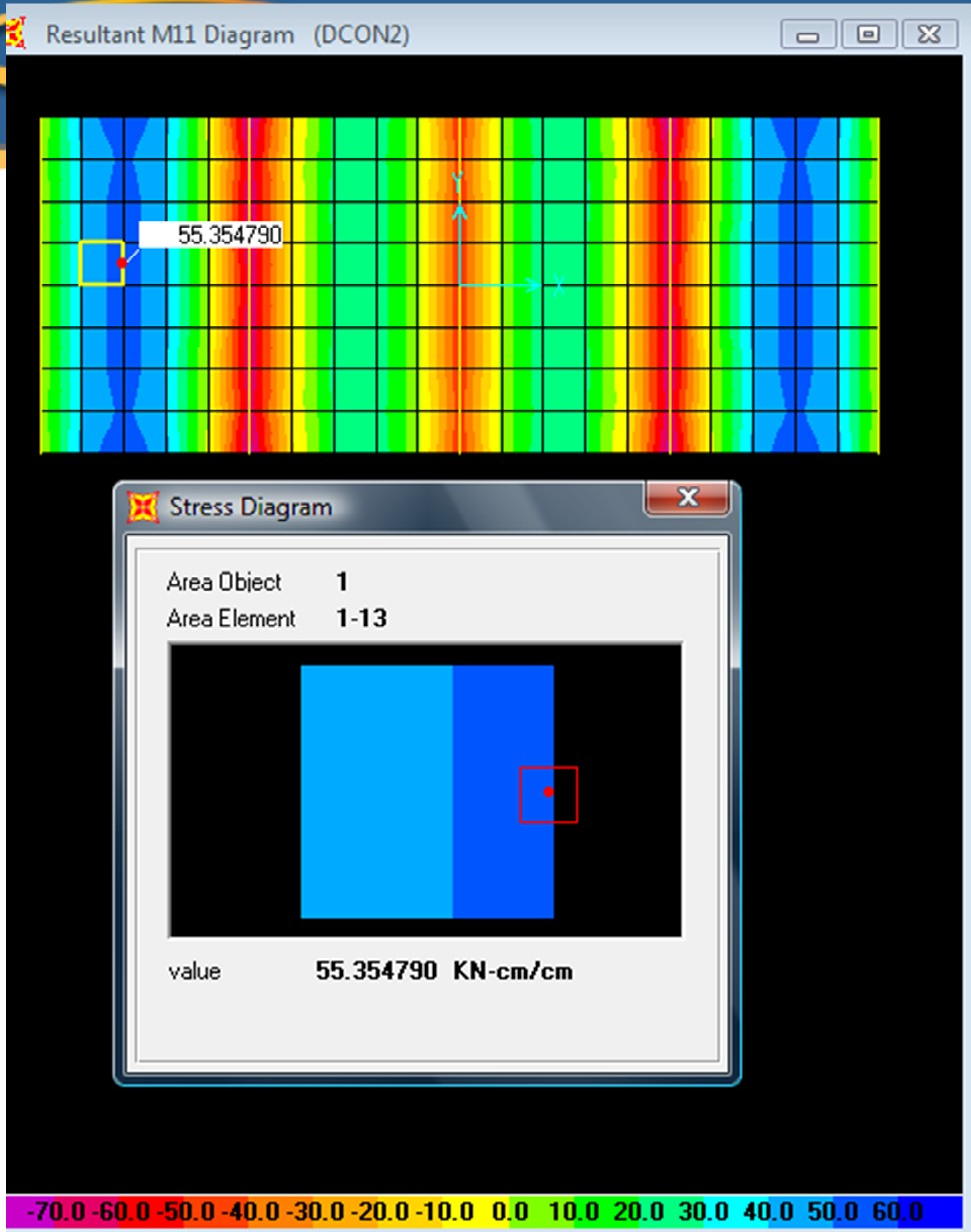
Right: top bending in beam C 1081kN.m, bottom area of steel 45cm^2.

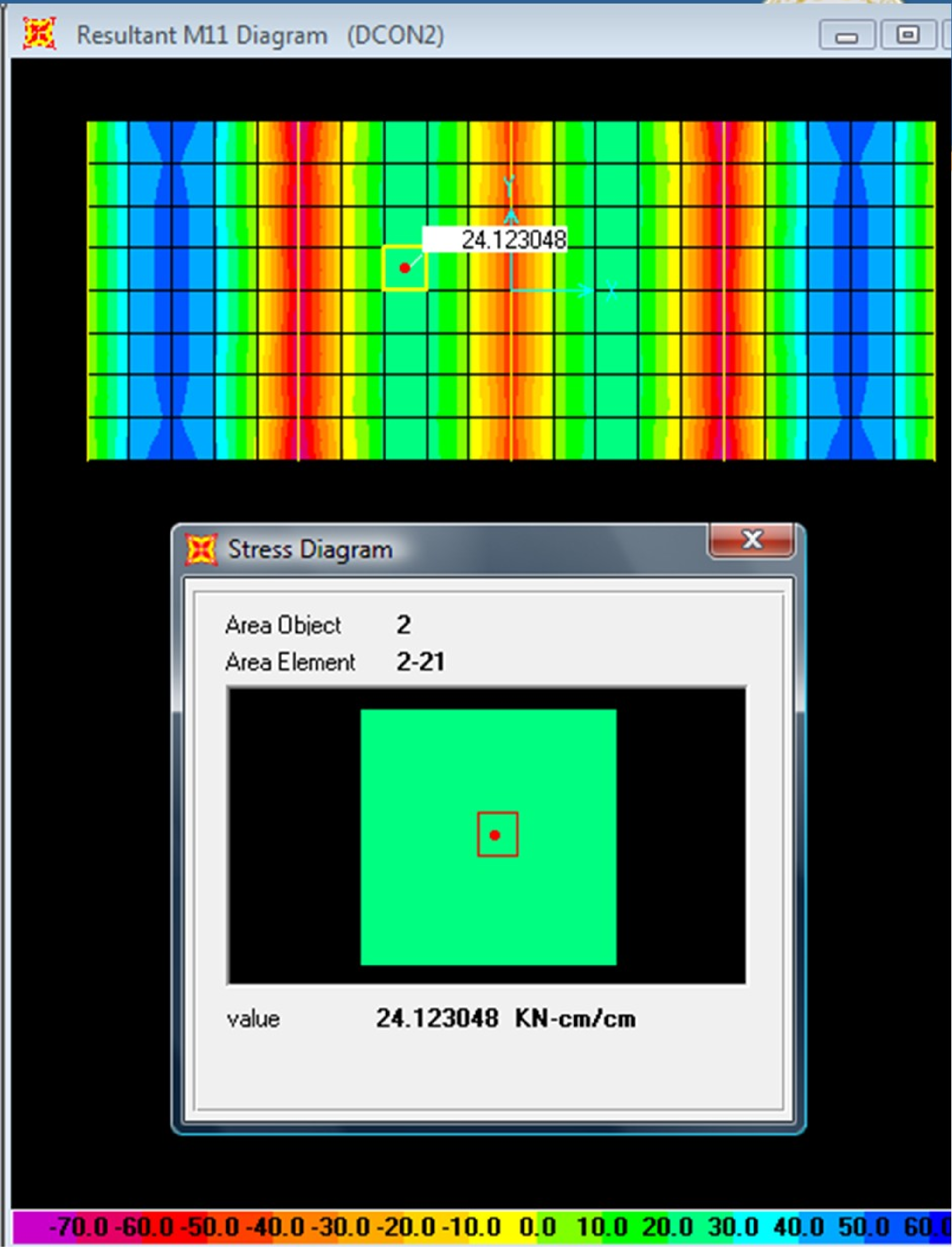


- Left: bending moment in slab at point B 69.4kN.m/m
- Right: top bending in beam B 1293kN.m, bottom area of steel 53cm^2



- Left: bending moment in slab at point A 0.0kN.m/m
- Right: top bending in beam A 480kN.m, bottom area of steel 18.8cm^2





Left: maximum bending moment in slab between A and B 55.4kN.m/m

- Right: maximum bending moment in slab between B and C 24.1kN.m/m

Item	1D	3D	%diff.	As eq.	As concp.	%diff.
Slab MA	0	0	0			
Exter M+	54	55.4	2.5			
Slab MB	74	69.4	6.6			
Inter M+	25	24.1	3.7			
Slab MC	50	48.8	2.5			
Beam Ma	1070	1081	1.0	44.4	45	1.3
Beam Mb	1311	1293	1.4	53.9	53	1.7
Beam Mc	475	480	1.0	18.5	18.8	1.6

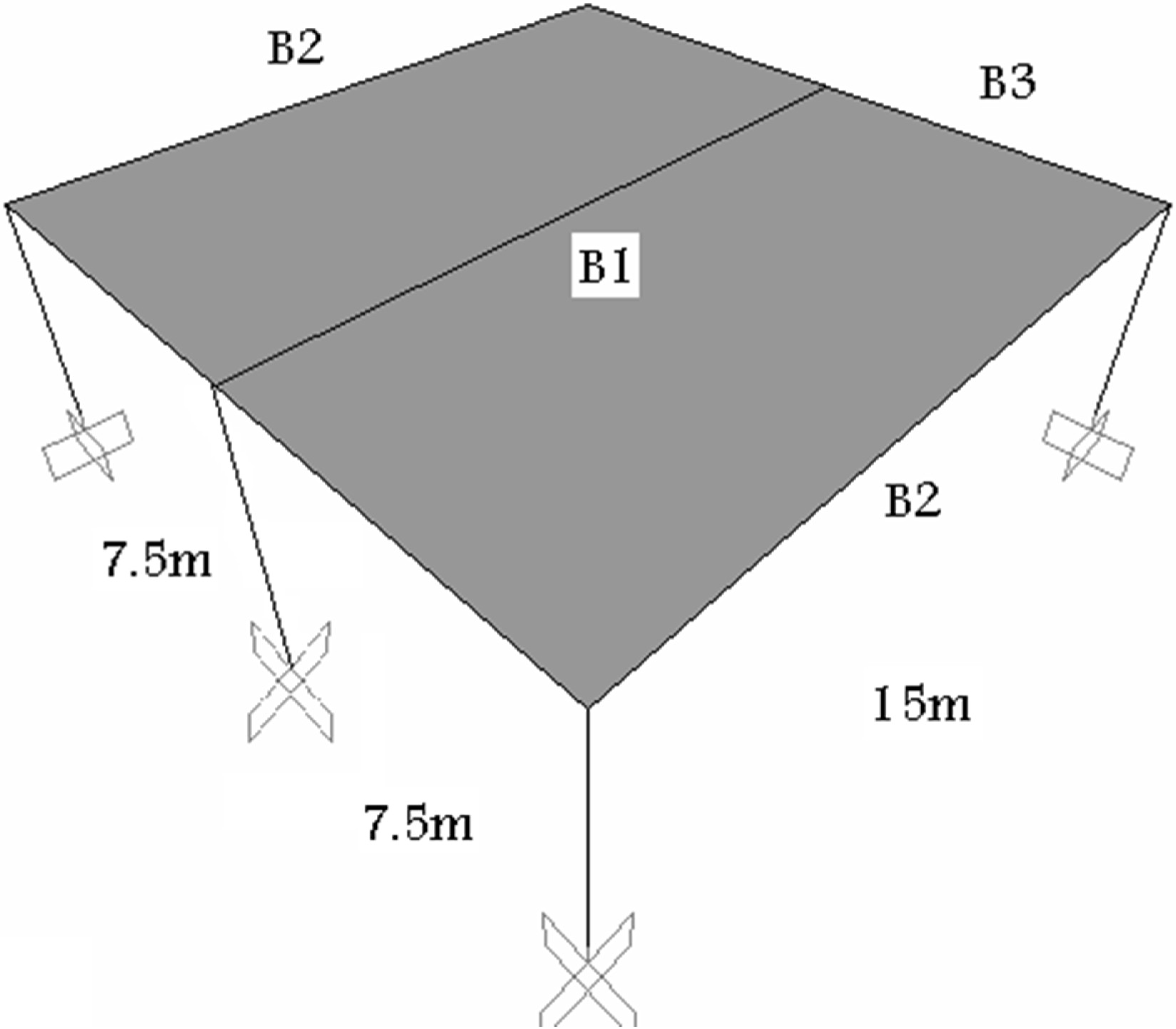
Comparison between results of 1D and 3D under similar assumptions.

Conclusion:

- Regular systems are conservatively designed as seen in attached file chapter6comp.doc

Problem set #6

- Analyze and design a one story reinforced concrete structure (entertainment hall) made of one way solid slab sitting on drop beams supported on six square columns 50cm dimensions. The superimposed and live loads are $3KN/m^2$ and $4KN/m^2$ respectively.


B2
B3
B1
B2
7.5m
15m
7.5m

End of section 5.1

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5.2 Ribbed slab systems

View of Pan Joist Slab from Below

Pan Joist Floor Systems

- Definition: The type of slab is also called a ribbed slab. It consists of a floor slab, usually 5-10cm thick, supported by reinforced concrete ribs. The ribs are usually uniformly spaced at distances that do not exceed 75cm. The space between ribs is usually filled with permanent fillers to provide a horizontal slab soffit.

Pan Joist Floor Systems

- ACI Requirements for Joist Construction
  (Sec. 8.13, ACI 318-08)
  - Slabs and ribs must be cast monolithically.
  - Ribs may not be less than 10cm in width
  - Depth of ribs may not be more than 3.5 times the minimum rib width
  - Clear spacing between ribs shall not exceed 750mm

  ** Ribbed slabs not meeting these requirements are designed as slabs and beams. **

Slab Thickness

– (ACI Sec. 8.13.6.1)

$t \geq 5cm$

$t \geq$ one twelfth the clear distance between ribs

Building codes give minimum fire resistance rating:

1-hour fire rating: 2cm cover, 7.5-9cm slab thick.

2-hour fire rating: 2.5cm cover, 12cm slab thick.

Shear strength

8.13.8 — For joist construction, V_c shall be permitted to be 10 percent more than that specified in Chapter 11.

Pan Joist Floor Systems

- Laying Out Pan Joist Floors (*cont.*)
  - Typically no stirrups are used in joists
  - Reducing Forming Costs:
    - Use constant joist depth for entire floor
    - Use same depth for joists and beams (not always possible)

Pan Joist Floor Systems

Distribution Ribs

- Placed perpendicular to joists*
- Spans < 6m.: None
- Spans 6-9m: Provided at midspan
- Spans > 9m: Provided at third-points
- At least one continuous #12mm bar is provided at top and bottom of distribution rib.

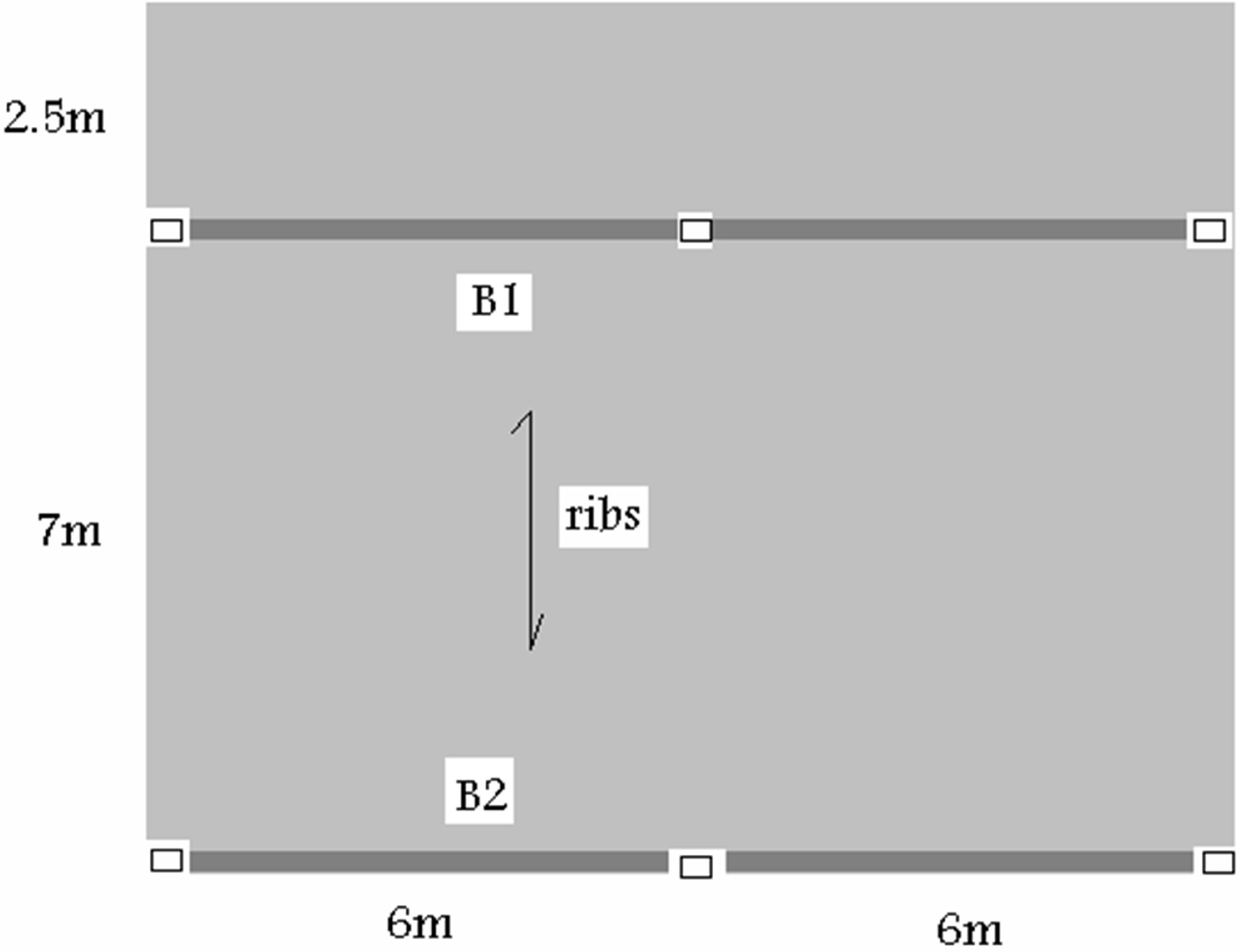
*Note: not required directly by ACI Code, but typically used in construction and required

indirectly in ACI 10.4.1:

10.4.1 — Spacing of lateral supports for a beam shall not exceed 50 times ***b***, the least width of compression flange or face.

Ribbed Slab example

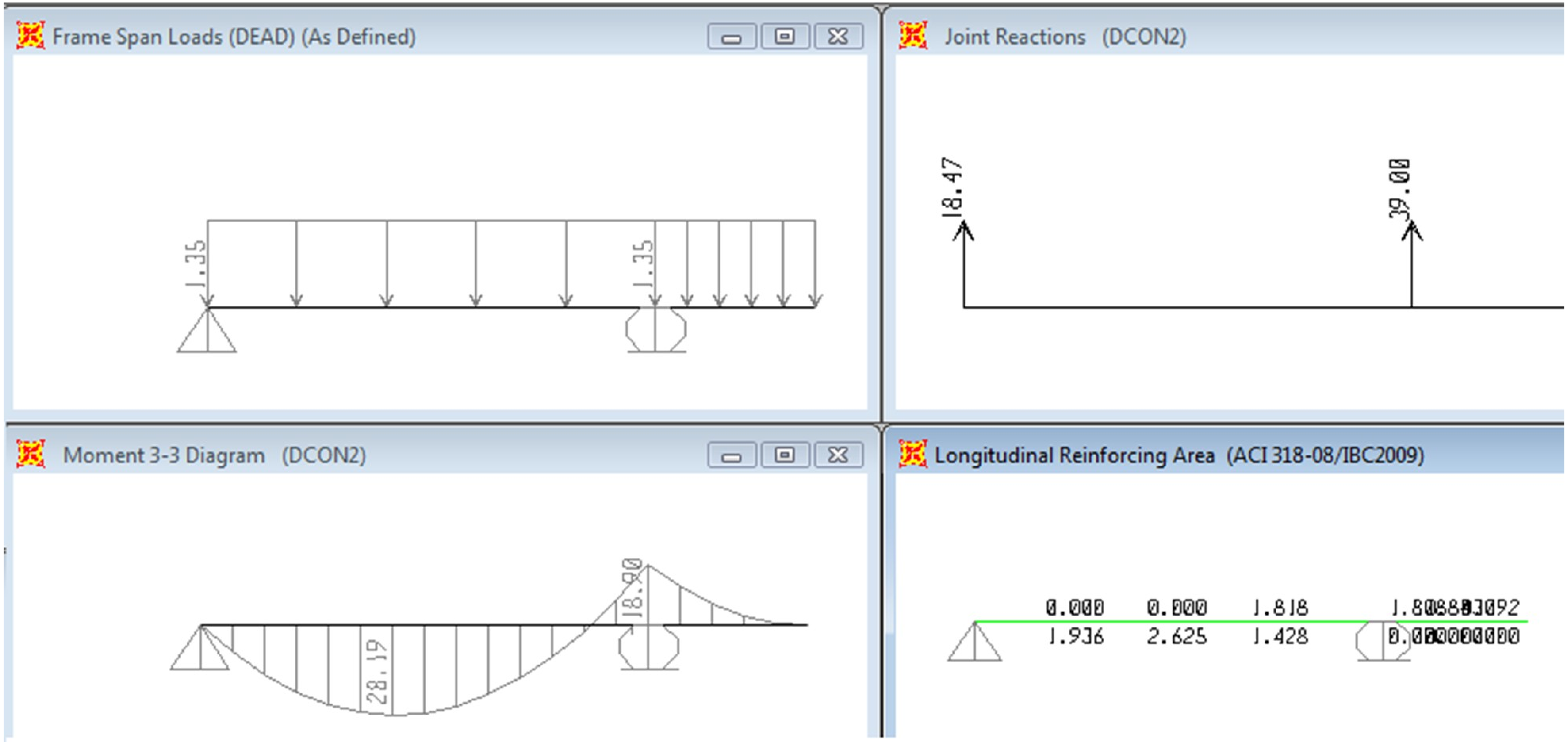
- Analyze and design (as a one-way ribbed slab in the 7m direction) the following one story structure (3m height) using 3D model (figure next page):
- A. Specifications: B250, fy=420MPa, superimposed= 0.7kN/m^2 , live loads= 2kN/m^2, ribs 34cm height/ 15cm width, blocks 40X25X24cm height (weight density=10kN/m^3), beam 25cm width by 50cm depth, column dimensions 25cmX25cm


2.5m
B1
ribs
7m
B2
6m
6m

Local practice: slab-beam-column construction

Slab: assume c=5cm

- w_d=[(0.15*.24+0.55*0.1)*24.5+0.4*0.24*10]/0.55+ 0.7=6.5kN/m^2
- w_u =[1.2*6.5+1.6*2]*0.55=6.05kN/m/rib
- M_u^- =6.05(2.5)^2 /2=18.9kN.m, As≈1.96cm^2.
- M_u^+ ≈6.05 (7)^2/8-18.9/2=27.6kN.m, As≈2.85cm^2


Frame Span Loads (DEAD) (As Defined)
1.35
1.35
Joint Reactions (DCON2)
18.47
39.00
Moment 3-3 Diagram (DCON2)
18.90
28.19
Longitudinal Reinforcing Area (ACI 318-08/IBC2009)
0.000
0.000
1.818
1.936
2.625
1.428

Beam analysis and design

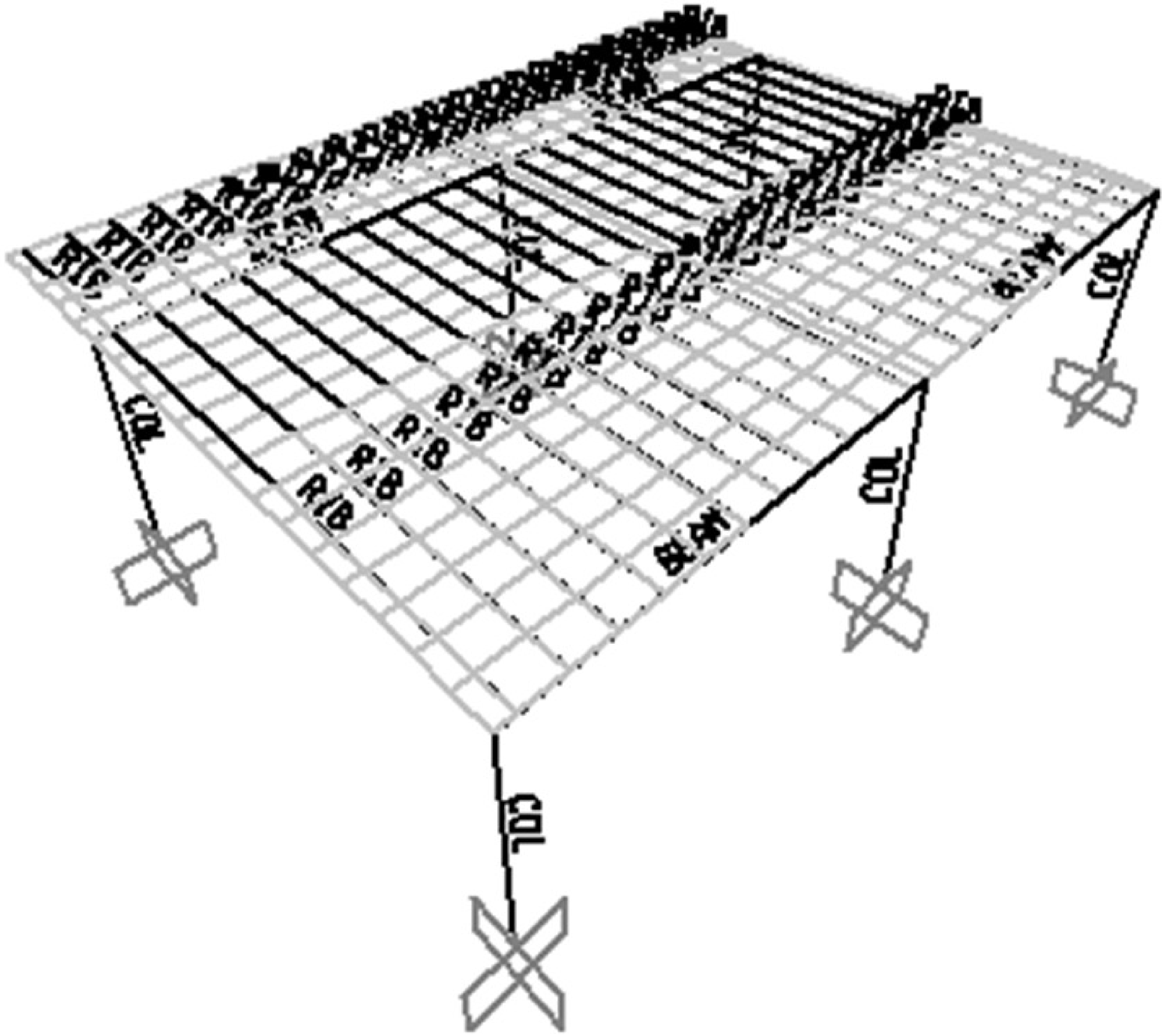
Beam B1: (interior frame)

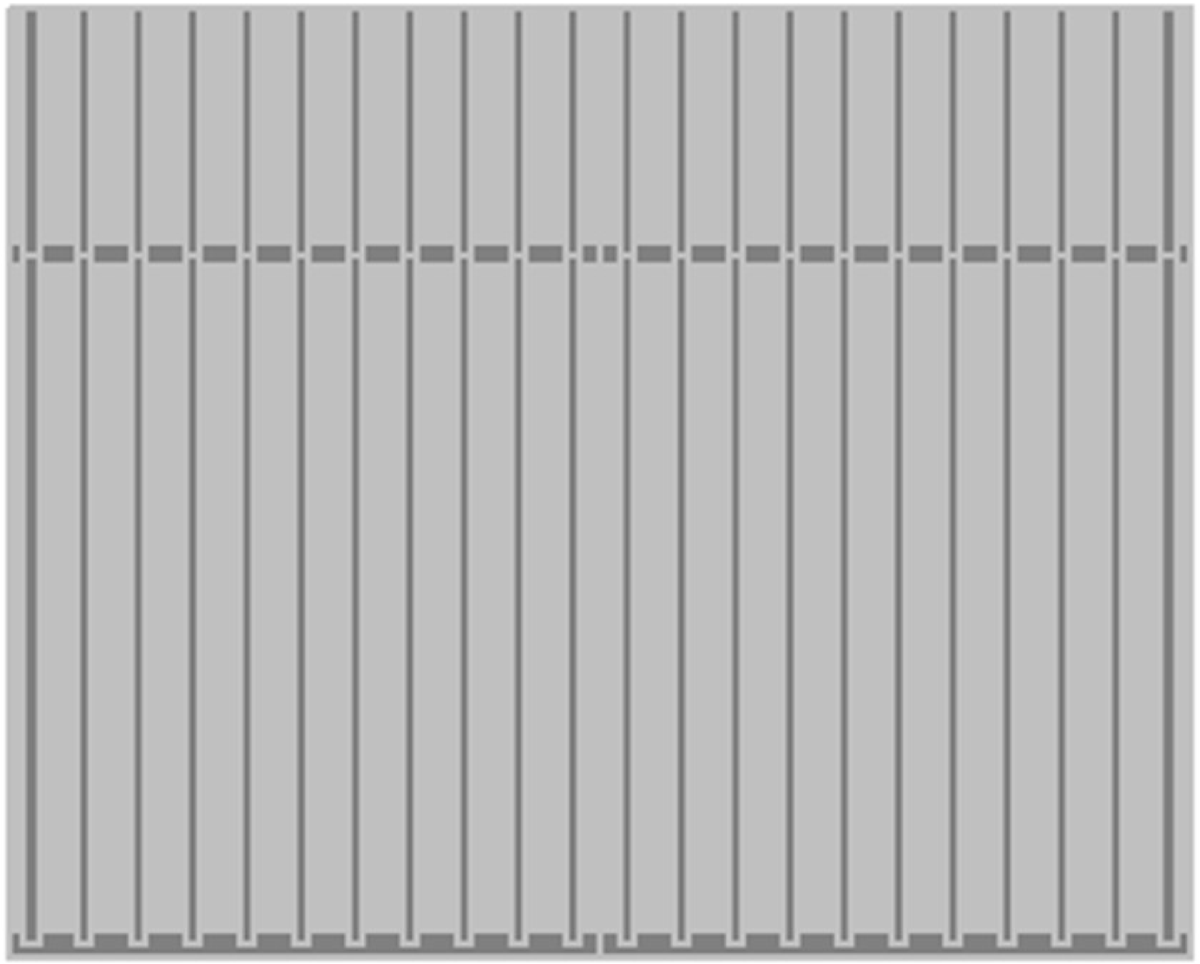
- w_u =(39/0.55)+0.25*0.4*24.5*1.2 =73.8kN/m
- M_u^- =73.8(6)^2 /8=332kN.m, As=332X3/45=22.1cm^2
- M_u^+ =73.8(6)^2 /14.2=187kN.m, As=187X3/45=12.5cm^2
-

Beam B2: (exterior frame)

- w_u =(18.5/0.55)+0.25*0.4*24.5*1.2 =36.6kN/m
- M_u^- =36.6(6)^2 /8=165kN.m, As=165X3/45=11cm^2
- M_u^+ =36.6(6)^2 /14.2=92.8kN.m., As=92.8X3/45=6.2cm^2

3D Model





3D SAP: if same assumptions are used in 3D model, results should be the same

A. Set modifiers for slab $M_{22} = M_{12} = 0.01$
B. Set modifiers for rib torsion=0.01, weight=0.24/0.34
C. Set modifiers for beam torsion=0.01, flexure 3=10 (do not put 100), weight=0.4/0.5=0.8
D. Set modifiers for column: axial=100, flexure=torsion=0

Gravity equilibrium checks

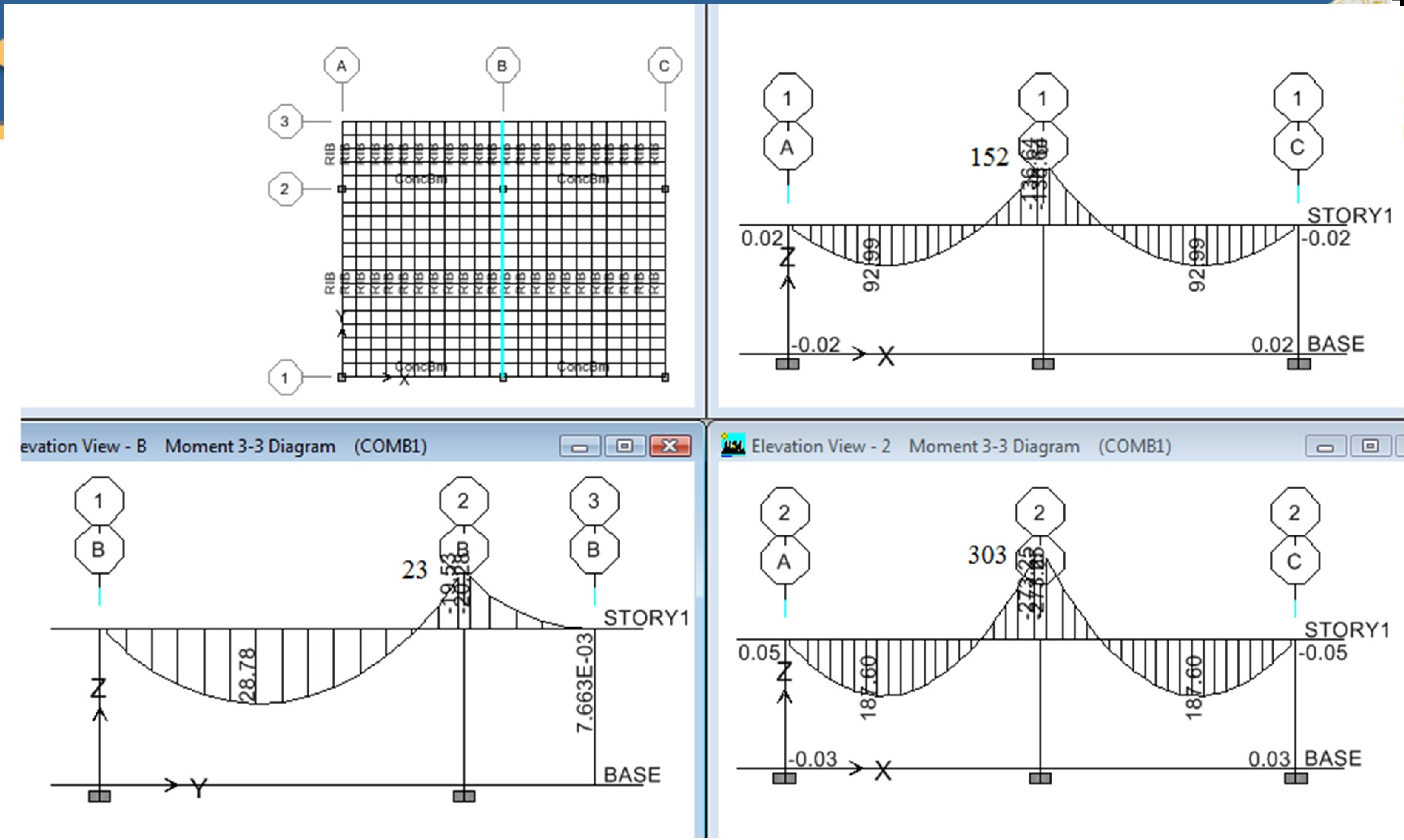
D:

- Slab=12X9.5X 0.1X24.5 =279kN
- Superimposed+blocks=12X9.5 ((0.24 X0.4 X10/0.55) +0.7)= 12X9.5X2.45 =279kN
- Ribs=9.5X23X.15X0.24X 24.5=193kN
- Beams= (2X12) X.25X.4X24.5=58.8kN
- Columns=6X.25X.25X3 X 24.5=27.6KN
- Sum=837.4kN

- L:
  - R =12X9.5X2=228kN

Support Reactions

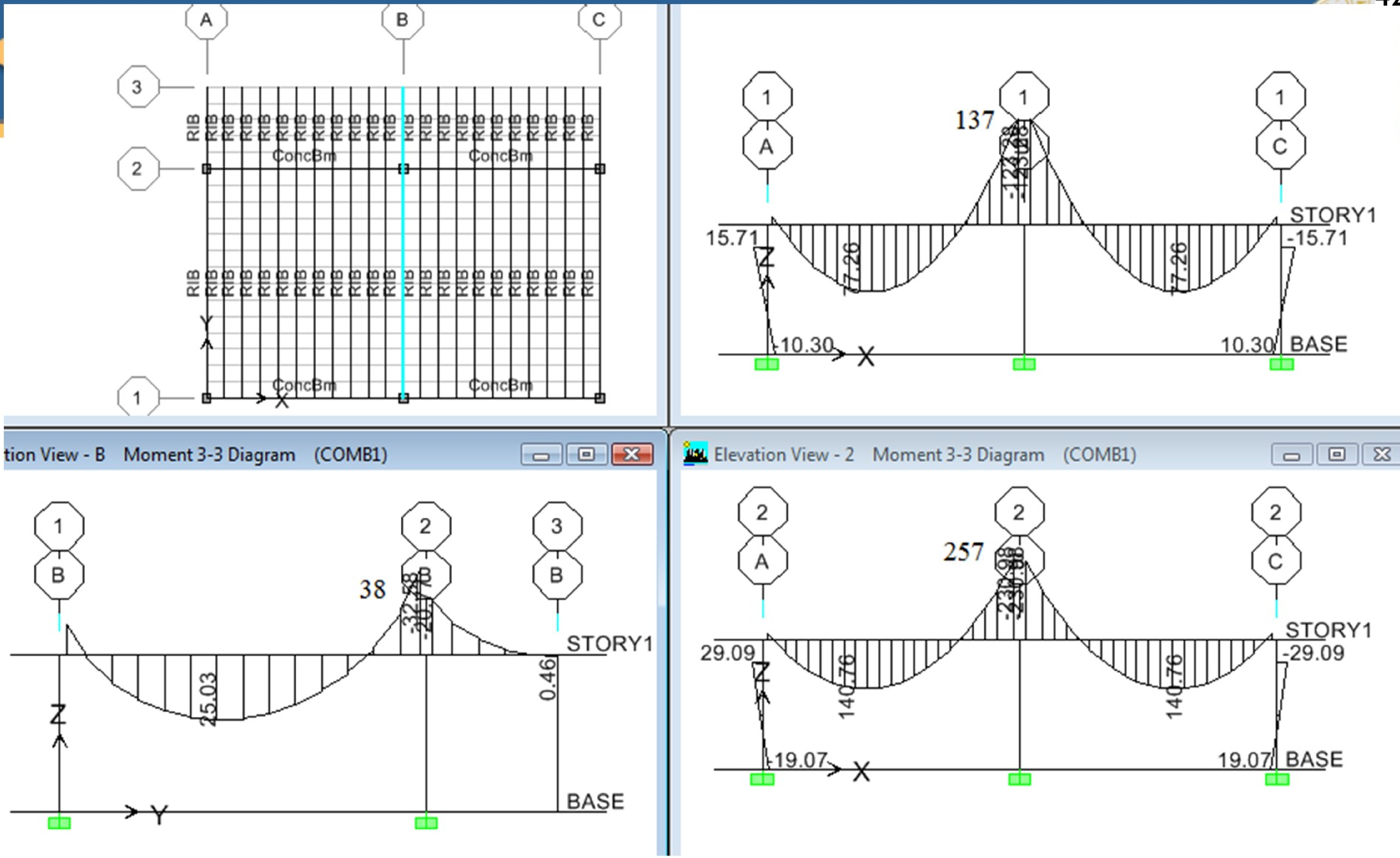
	Story	Point	Load	FX	FY	FZ	MX	MY	MZ
	Summation	0, 0, Base	DEAD	0.00	0.00	837.68	3871.025	-5026.077	0.000
	Summation	0, 0, Base	LIVE	0.00	0.00	228.00	1083.000	-1368.000	0.000



22/3/2015

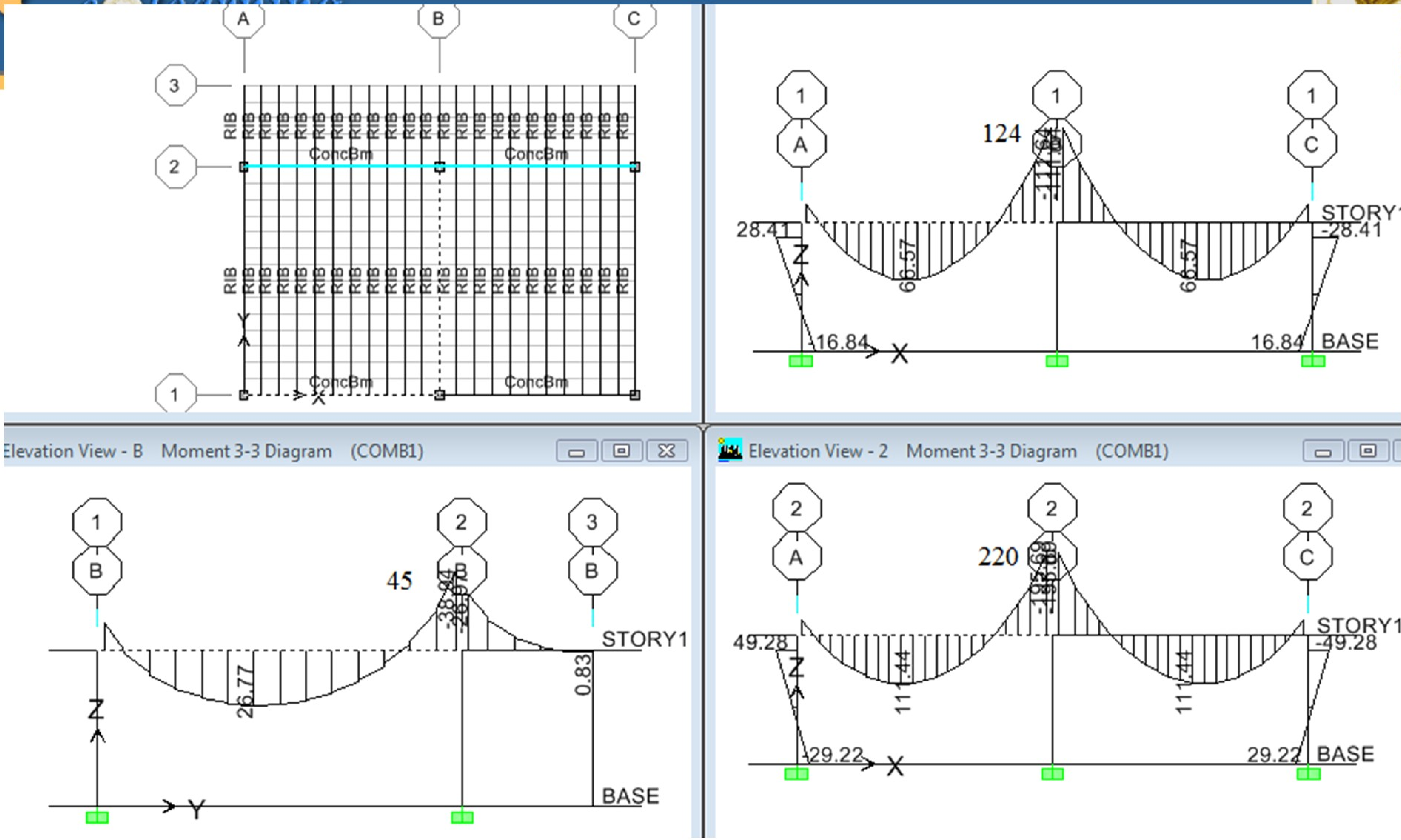
- Left bottom: bending moment in rib at grid B

Right: top bending moment in beam B1, bottom bending moment in beam B2. Figure with modifiers



Left bottom: bending moment in rib at grid B
Right: top bending moment in beam B1, bottom bending moment in beam B2.
Figure without modifiers

- Repeat previous example but if the beams are 34cm depth by 37cm width .(to preserve beam weight). Draw conclusions



22/3/2015

- Left bottom: bending moment in rib at grid B

Right: top bending moment in beam B1, bottom bending moment in beam B2.

Figure for hidden beam without modifiers

Conclusions:

Ribs

- Moments increased on interior column strip and reduced on interior middle strip, which increases the difference existed previously. Why?
- Do you expect problems in local practice, why?

beams

- All moments are reduced (except at exterior, almost the same), why?
- Exterior moment increases for hidden, why?
- Do you expect problems in local practice?.
- Is it now necessary to change local practice?

•

End of section 5.2

Let Learning Continue