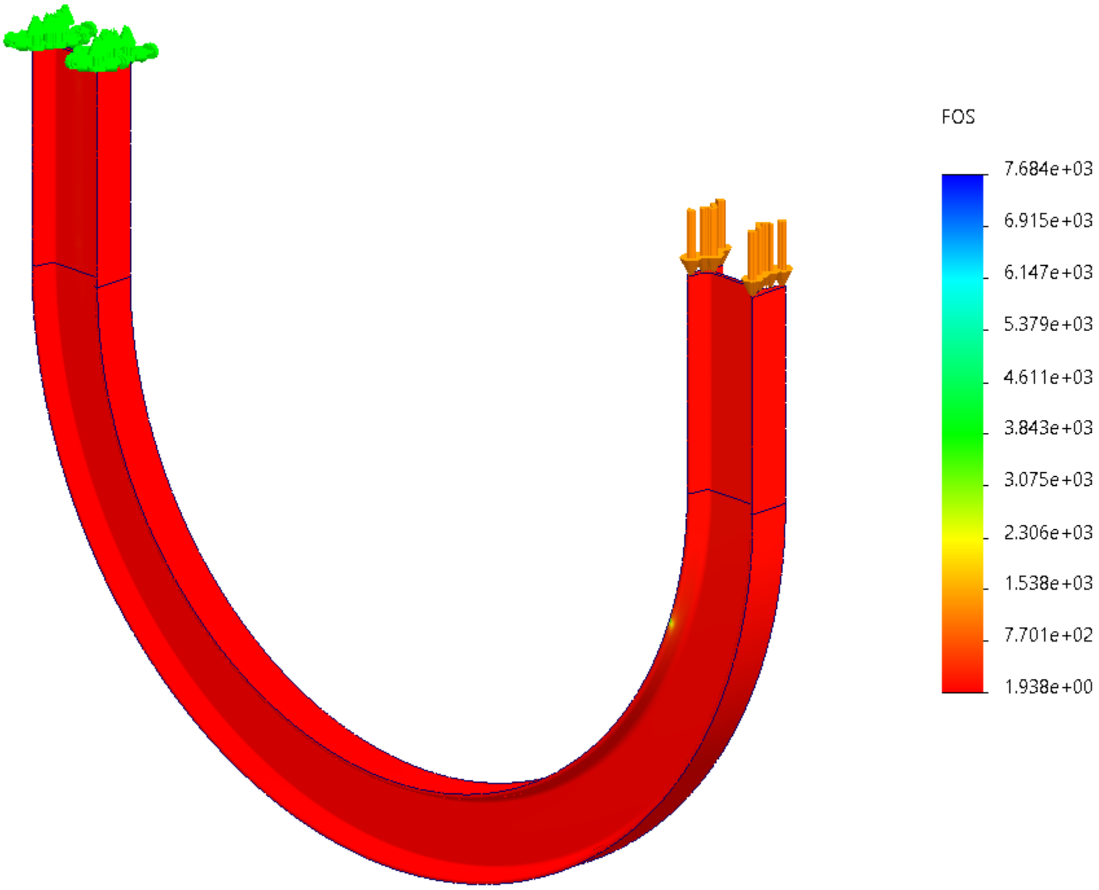
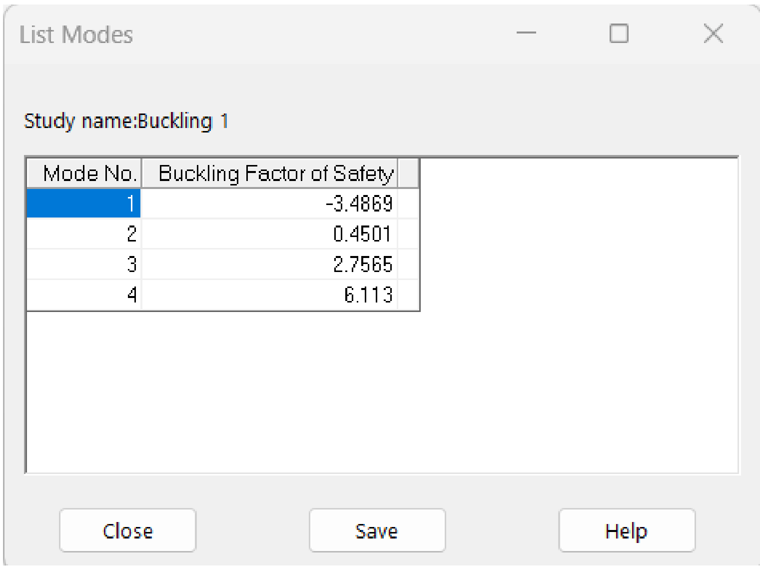
Problem 1:

a. Factor of safety related to the yield stress is minimum of **1.938** as shown below in the result for static study with given loading conditions.



b. Factor of safety related to buckling is **0.4501** from the results of buckling simulation. As seen below we select the minimum positive Buckling Factor of Safety from first 4 buckling modes as the FOS related to buckling.


List Modes

Study name:Buckling 1

Mode No.	Buckling Factor of Safety
1	-3.4869
2	0.4501
3	2.7565
4	6.113

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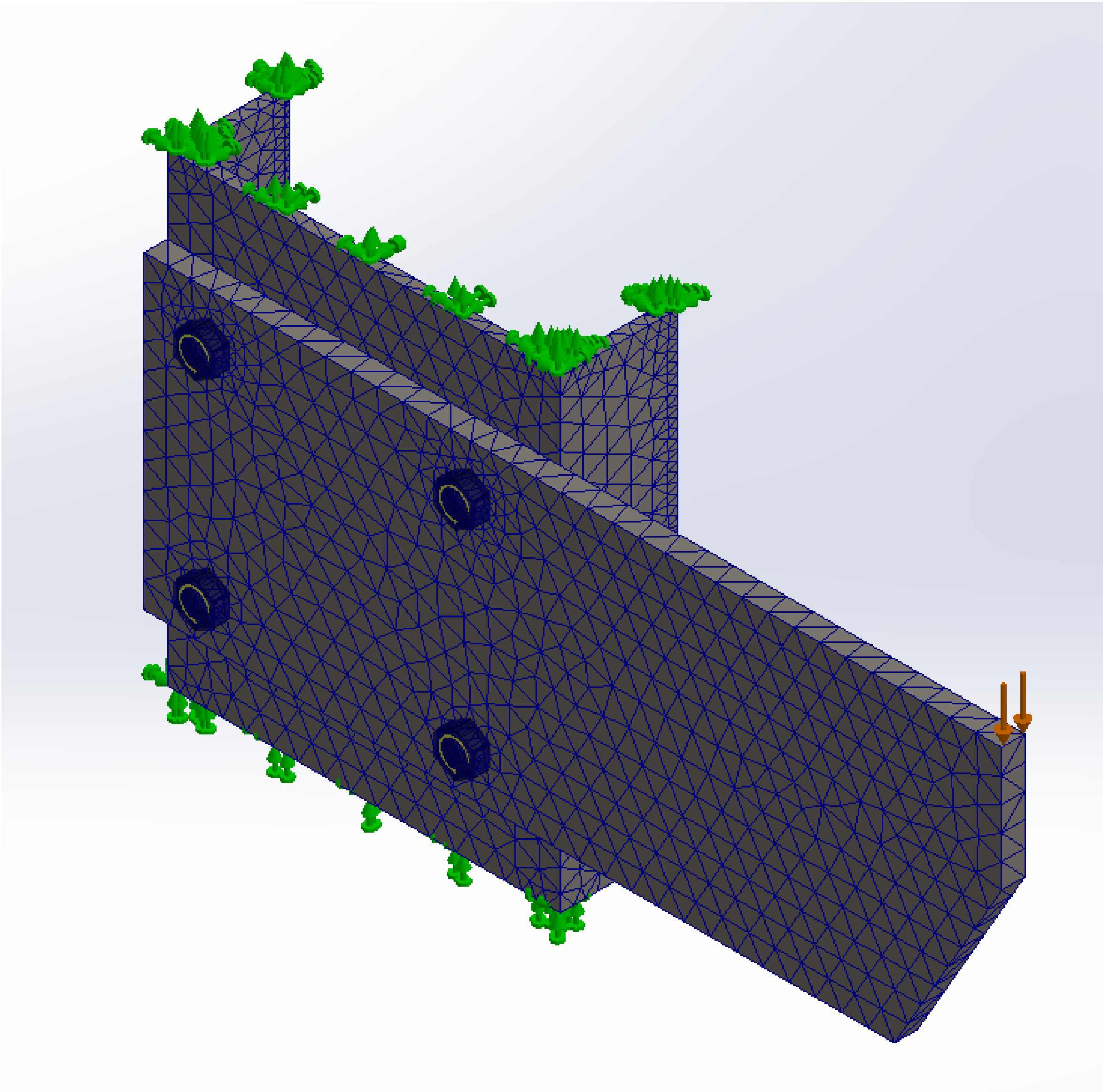
c. Critical buckling load = Load x FOS for buckling = 5000 x 0.4501 = **2250.5 N**

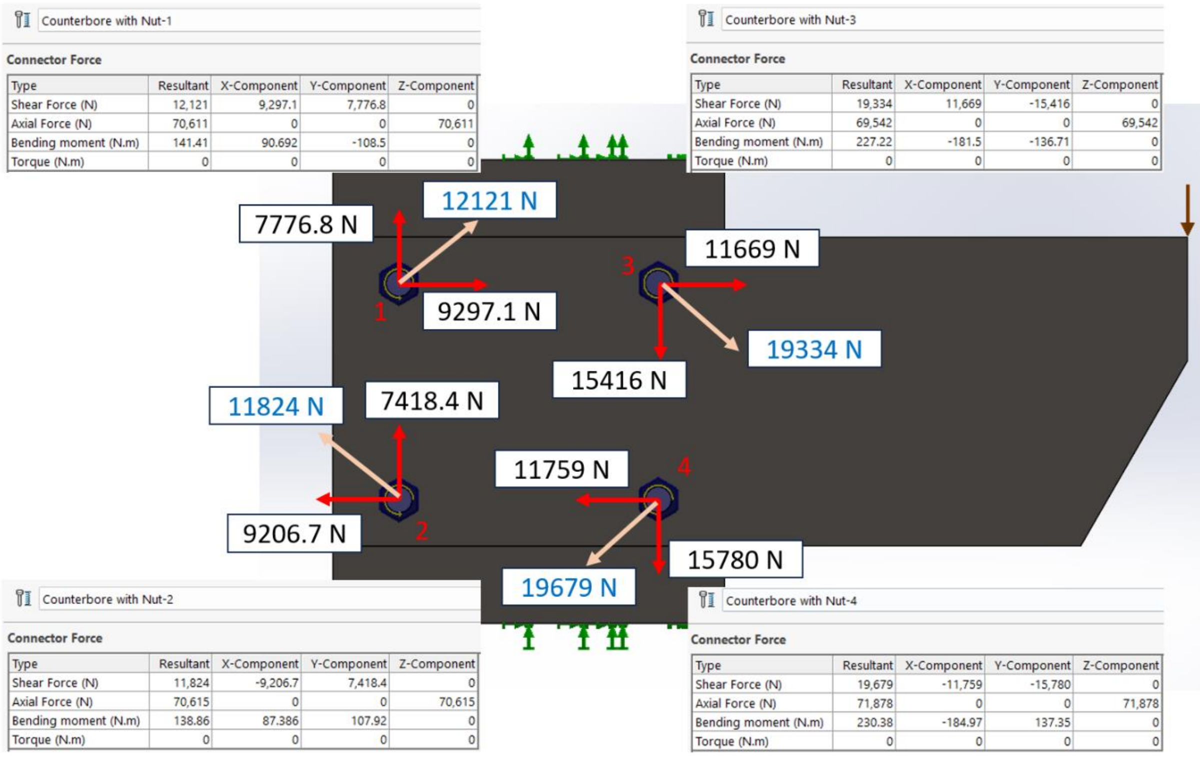
d. If we look at minimum FOS for yielding (1.938) & for buckling (0.4501). It is clear that **FOS for yielding (1.938) > 1** which means the design does not fail due to yielding. While, **FOS for buckling (0.4501) < 1** which means the design will fail due to buckling. Thus, the cause of failure is **buckling**.

Problem 2:

a. Isometric screenshot of the model showing all boundary conditions below:



b. The shear force components at each bolt location shown below:


Counterbore with Nut-1

Connector Force

Type	Resultant	X-Component	Y-Component	Z-Component
Shear Force (N)	12,121	9,297.1	7,776.8	0
Axial Force (N)	70,611	0	0	70,611
Bending moment (N.m)	141.41	90.692	-108.5	0
Torque (N.m)	0	0	0	0

Counterbore with Nut-3

Connector Force

Type	Resultant	X-Component	Y-Component	Z-Component
Shear Force (N)	19,334	11,669	-15,416	0
Axial Force (N)	69,542	0	0	69,542
Bending moment (N.m)	227.22	-181.5	-136.71	0
Torque (N.m)	0	0	0	0

Counterbore with Nut-2

Connector Force

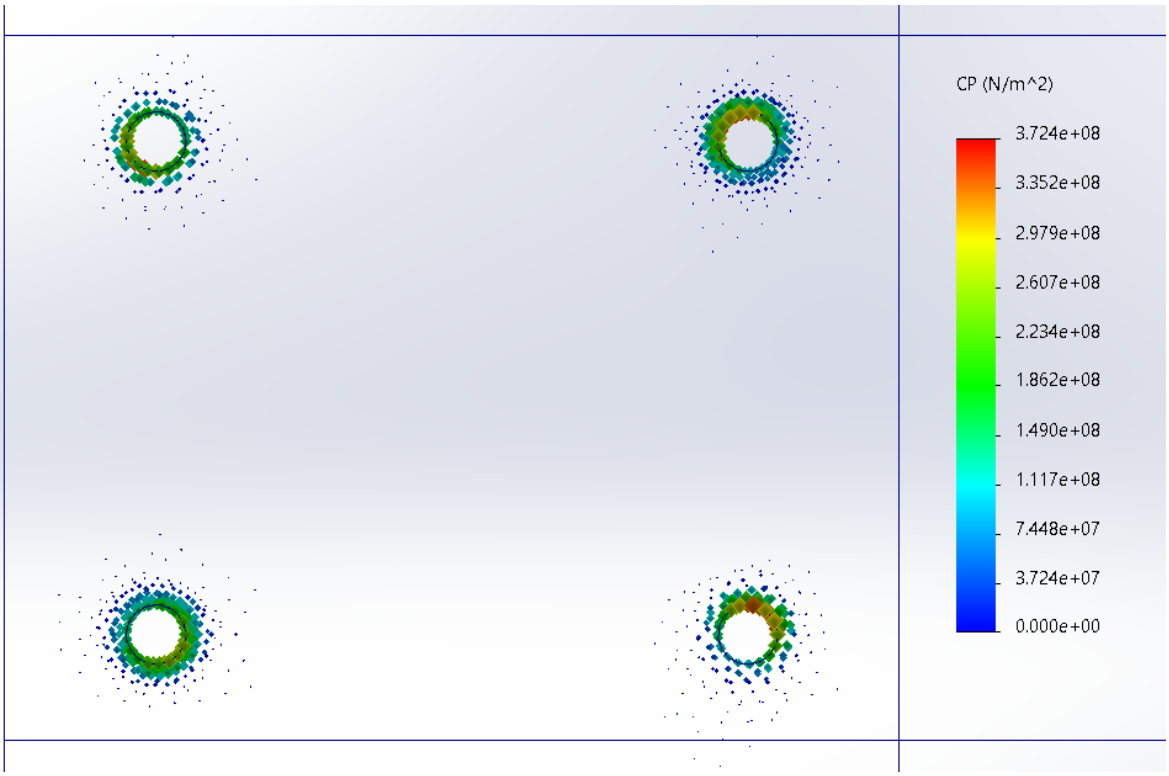
Type	Resultant	X-Component	Y-Component	Z-Component
Shear Force (N)	11,824	-9,206.7	7,418.4	0
Axial Force (N)	70,615	0	0	70,615
Bending moment (N.m)	138.86	87.386	107.92	0
Torque (N.m)	0	0	0	0

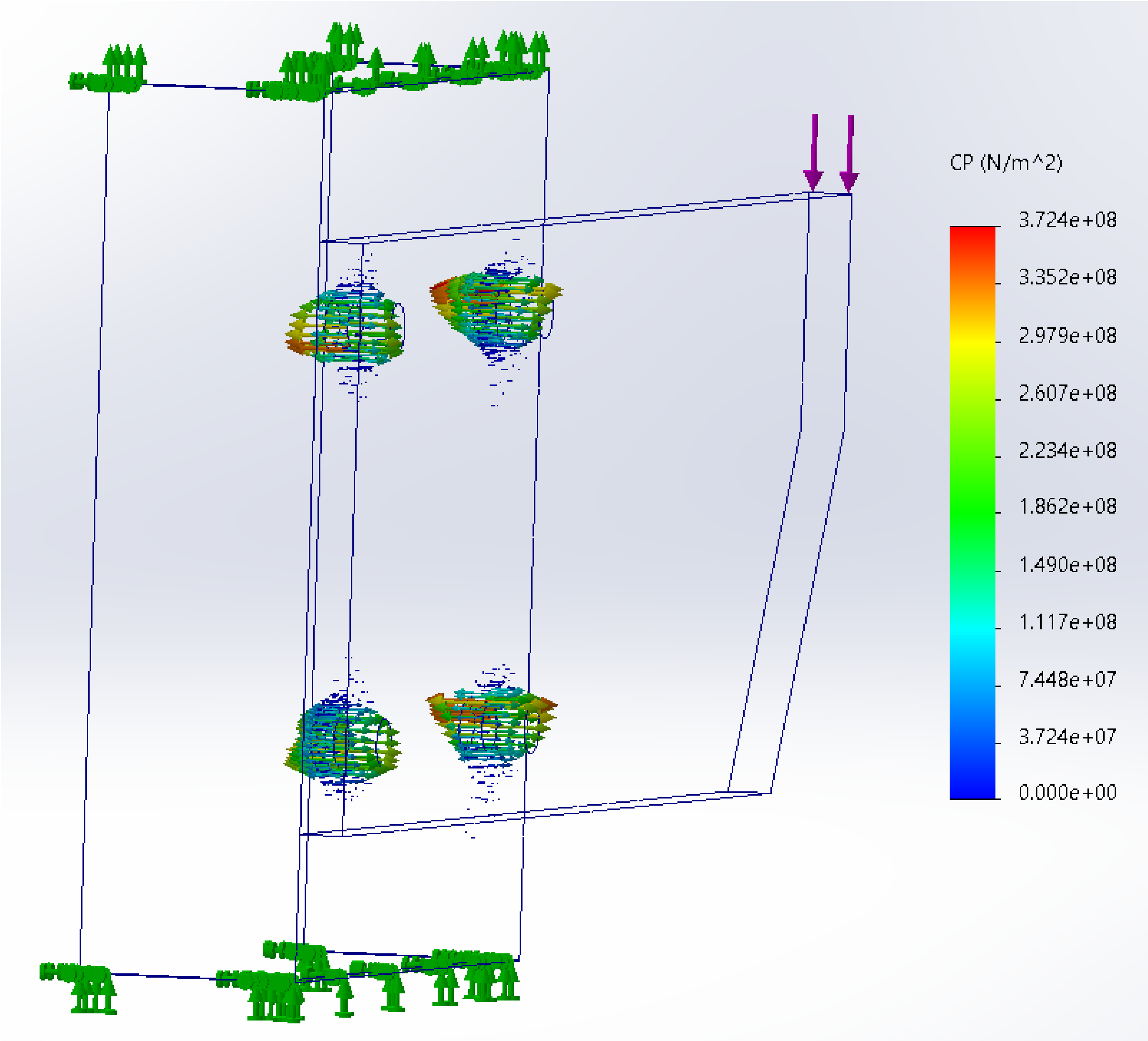
Counterbore with Nut-4

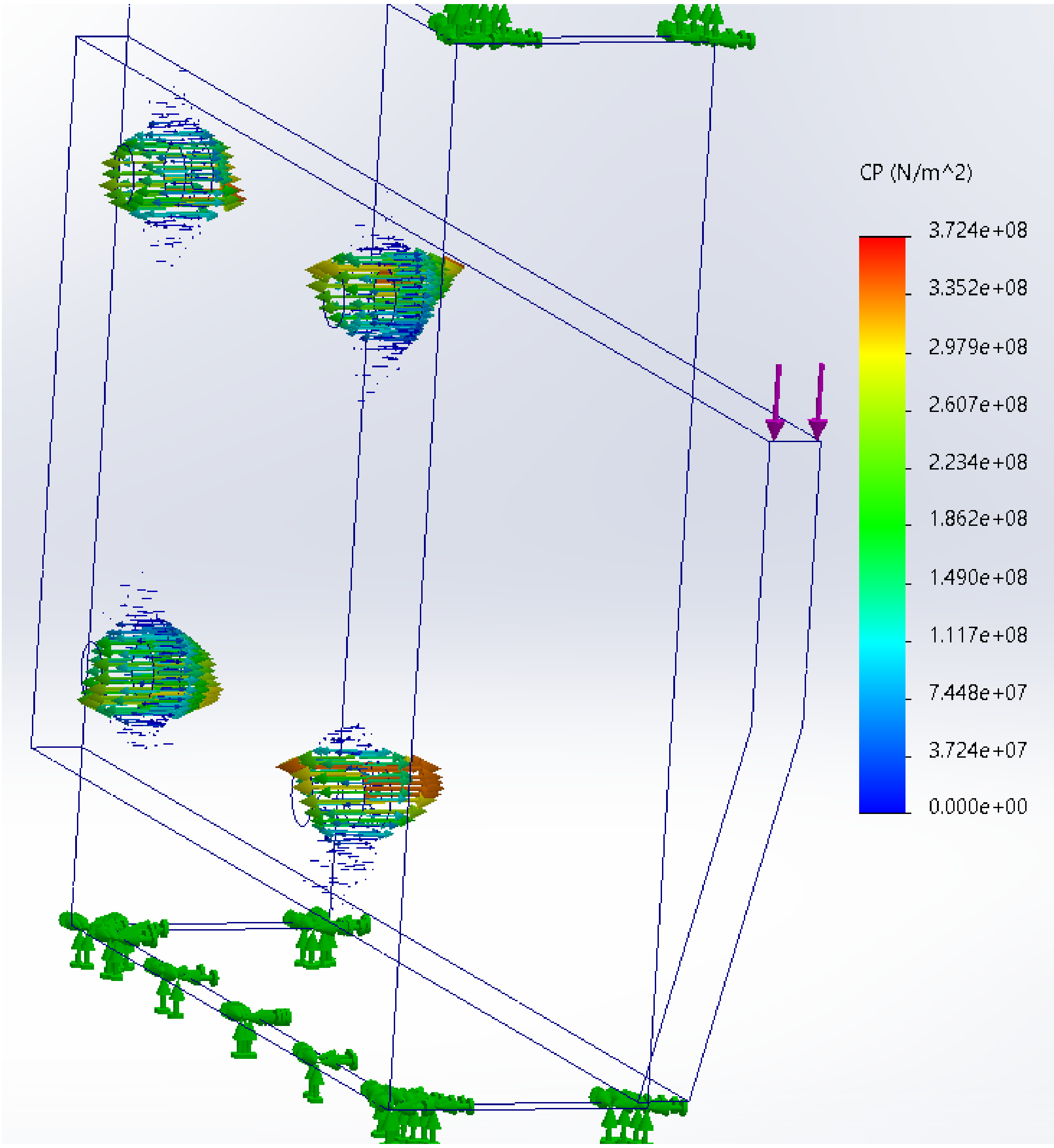
Connector Force

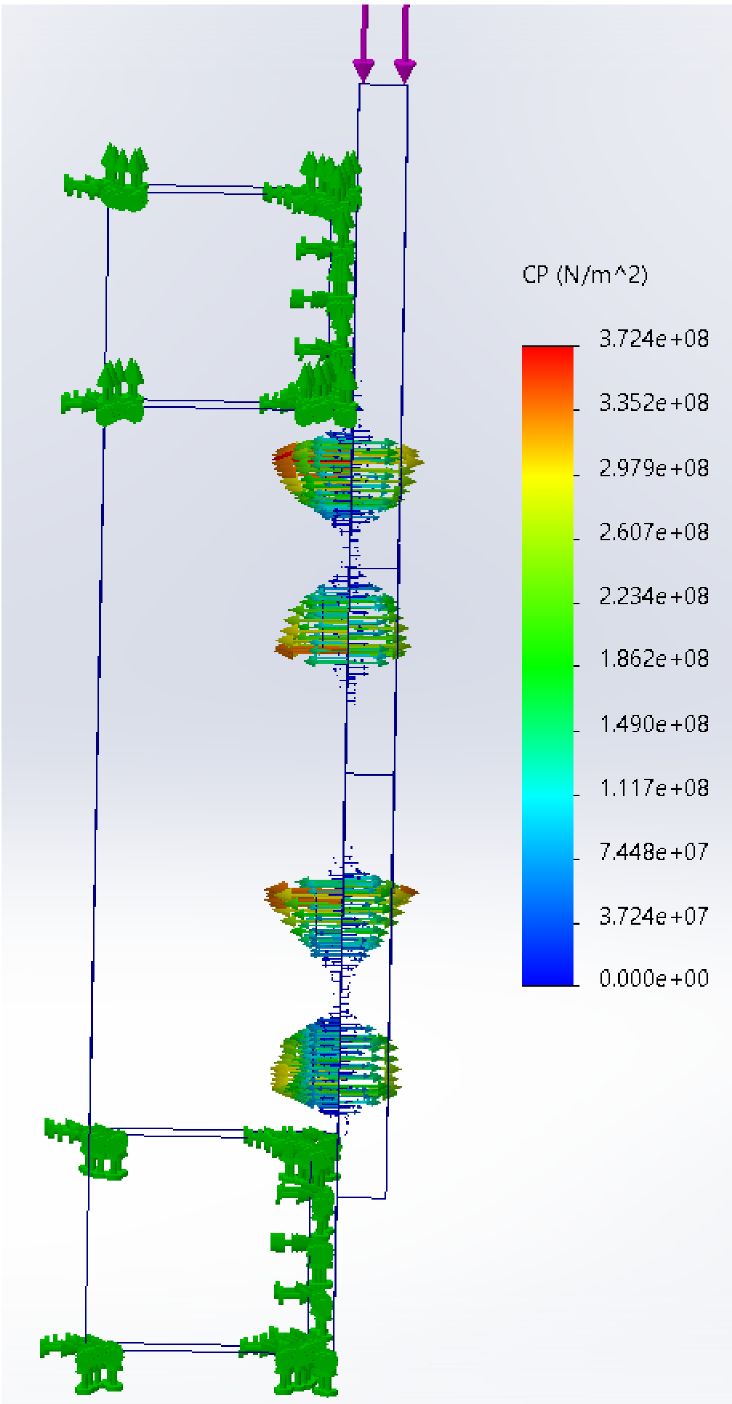
Type	Resultant	X-Component	Y-Component	Z-Component
Shear Force (N)	19,679	-11,759	-15,780	0
Axial Force (N)	71,878	0	0	71,878
Bending moment (N.m)	230.38	-184.97	137.35	0
Torque (N.m)	0	0	0	0

c. Vector plot of contact pressure (CP) between the column and plate in 4 different views shown below:



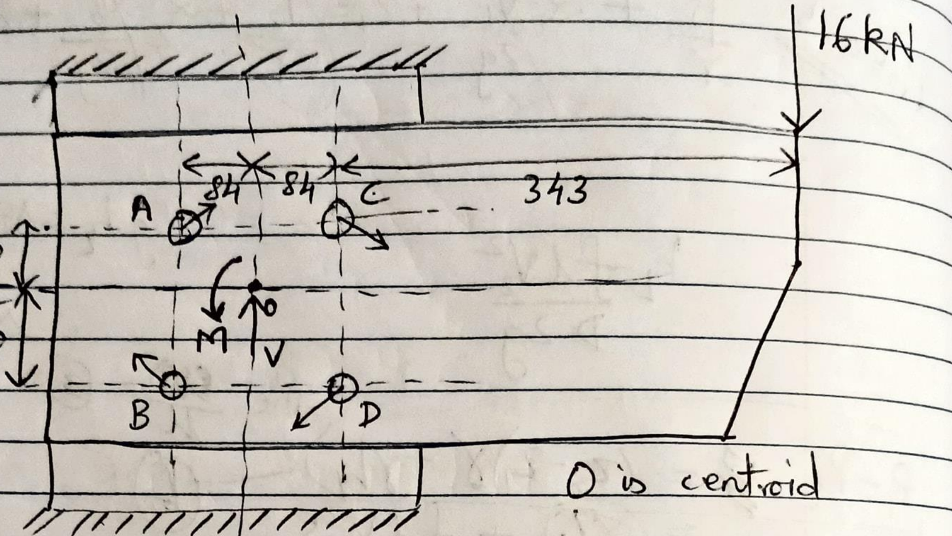

CP (N/m^2)
3.724e+08
3.352e+08
2.979e+08
2.607e+08
2.234e+08
1.862e+08
1.490e+08
1.117e+08
7.448e+07
3.724e+07
0.000e+00


CP (N/m^2)
3.724e+08
3.352e+08
2.979e+08
2.607e+08
2.234e+08
1.862e+08
1.490e+08
1.117e+08
7.448e+07
3.724e+07
0.000e+00


CP (N/m^2)
3.724e+08
3.352e+08
2.979e+08
2.607e+08
2.234e+08
1.862e+08
1.490e+08
1.117e+08
7.448e+07
3.724e+07
0.000e+00

d. Manual calculations for bolt shear forces:

Q.2.) d.)



O is centroid

Shear reaction, $V = 16\ kN$

Primary shear load per bolt is,

$$F_P = \frac{V}{n} = \frac{16}{4} = 4\ kN \quad \text{—— (1)}$$

Moment reaction, $M = 16 \times (343 + 84)$

$\therefore M = 6832\ N.m$

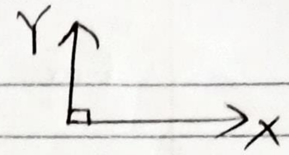
Distance from centroid to center of each bolt,

$$r = \sqrt{70^2 + 84^2} = 109.34\ mm$$

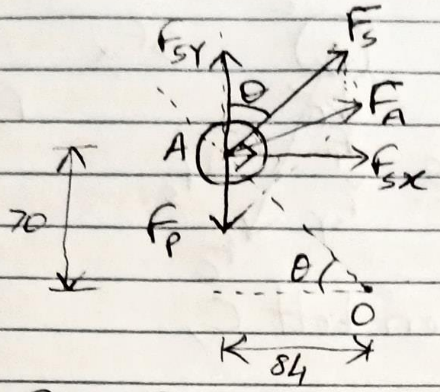
Secondary shear load per bolt is,

$$F_S = \frac{Mr}{4r^2} = \frac{M}{4r} = \frac{6832}{4 \times 109.34} = 15.62\ kN \quad \text{(2)}$$

Coordinate system for all bolts



For bolt A,



$\theta = \tan^{-1}\left(\frac{70}{84}\right) = 39.8^\circ$

$F_{SY} = F_S \cos\theta = 15.62 \cos 39.8 = 12 \text{ kN}$ — (3)

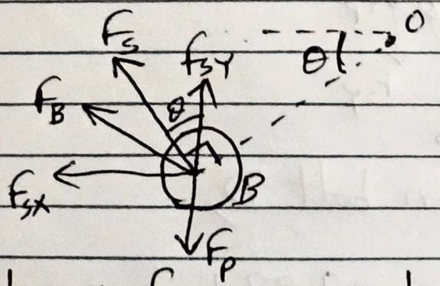
$F_{SX} = F_S \sin\theta = 15.62 \sin 39.8 = 9.99 \text{ kN}$ — (4)

Shear forces on bolt A,

$F_{AX} = F_{SX} = 9.99 \text{ kN}$ — (5)

$F_{AY} = F_{SY} - F_P = 12 - 4 = 8 \text{ kN}$ — (6)

For bolt B,



$F_{SY} = F_S \cos\theta = 12 \text{ kN}$

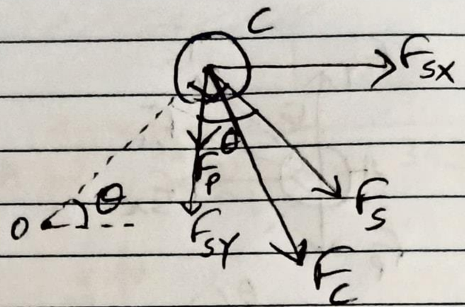
$F_{SX} = F_S \sin\theta = -9.99 \text{ kN}$

Shear forces on bolt B,

$F_{BX} = F_{SX} = -9.99 \text{ kN}$ — (7)

$F_{BY} = F_{SY} - F_P = 12 - 4 = 8 \text{ kN}$ — (8)

For bolt C,



$F_{SX} = F_S \sin\theta = 9.99$ kN

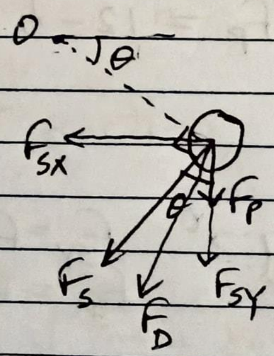
$F_{SY} = F_S \cos\theta = -12$ kN

Shear forces on bolt C,

$F_{CX} = F_{SX} = 9.99$ kN —— (9.)

$F_{CY} = F_{SY} + F_P = -12 - 4 = -16$ kN —— (10.)

For bolt D,



$F_{SX} = F_S \sin\theta = -9.99$ kN

$F_{SY} = F_S \cos\theta = -12$ kN

Shear forces on bolt D,

$F_{DX} = F_{SX} = -9.99$ kN —— (11.)

$F_{DY} = F_{SY} + F_P = -12 - 4 = -16$ kN —— (12.)

Comparing FEA & manually calculated shear forces on bolts, along with % error for resultant forces in the table below:

Calculated shear forces on each bolt (all forces in kN):				Resultant shear force from FEA (kN)	% Error
Bolt no.	Force in X	Force in Y	Resultant Force		
A	9.99	8	12.7984	12.121	5.3%
B	-9.99	8	12.7984	11.824	7.6%
C	9.99	-16	18.8627	19.334	2.5%
D	-9.99	-16	18.8627	19.679	4.3%

We can see that there is a difference between the manual calculations and FEA but it is not too large and this validates our FEA simulation.