Validation Problem for Joint Checks as per ACI 318M-2014

Introduction:

As per clause 18.3.7.1 of ACI 318M-2014, it is suggested to perform column beam joint check. The capacity of the column should be 1.2 times more than that of beam framing into it. It is the same concept of strong column weak beam check for special frames of ductile design and detailing. Clause 18.8 is Applicable for joints of special moment resisting frames.

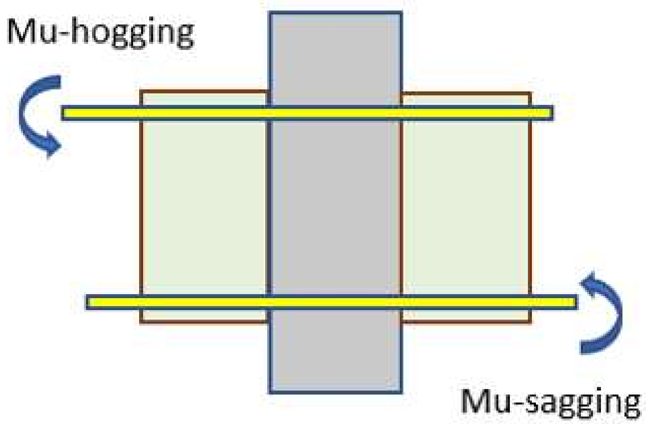
Content:

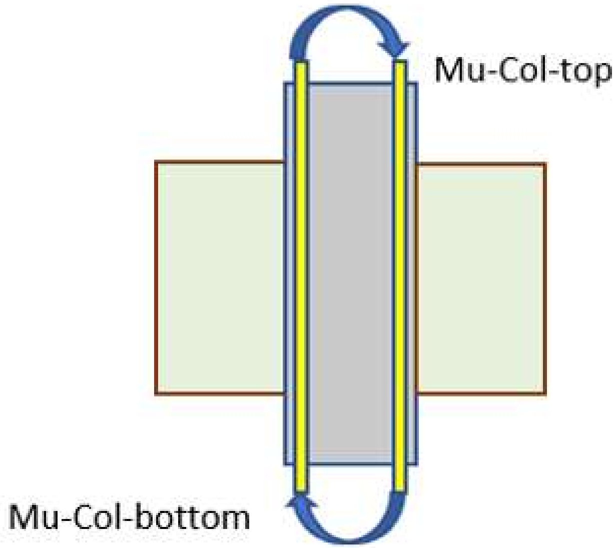
1. Design concept of Strong column weak beam check
2. Reference from ACI code
3. Critical Issues of Performing Joint Check
4. Advantages Of RCDC
5. PM curve explanation
6. Flexural Joint Check
7. Design of Beam Column Joint for Shear
8. Sample STAAD files used for validation

1. Design concept of Strong column weak beam check

Since last 30 years various seismic loading test are performed on a beam column joint of a reinforced concrete moment resisting frame, the importance of the design of beam-column joints has been recognized in the seismic design recommendations in different building codes. Recent earthquakes have strengthened the need for properly reinforcing beam column joints to avoid partial or total structural collapse in large events and to avoid irreparable damage in moderate events.

The Idea of Strong column-weak beam concept is to prevent total collapse of the building while resisting the lateral loads (especially the seismic loads/EQ). Strong column-weak beam' means that the actual flexural capacity of beam end Mb and Mc of column end at the node should meet the following equation: 1.2 ΣMc > ΣMb. The aim of the design is to ensure satisfactory performance of joints during a strong earthquake.





Mu-Col-Total >= Mu-Beam-Total

2. Reference from ACI code

Relative Strength of Beams and Column at a Joint

18.7.3 *Minimum flexural strength of columns*

18.7.3.1 Columns shall satisfy 18.7.3.2 or 18.7.3.3.

18.7.3.2 The flexural strengths of the columns shall satisfy

$$\sum M_{nc} \geq (6/5)\sum M_{nb} \qquad (18.7.3.2)$$

where

$\sum \boldsymbol{M}_{nc}$ is sum of nominal flexural strengths of columns framing into the joint, evaluated at the faces of the joint. Column flexural strength shall be calculated for the factored axial force, consistent with the direction of the lateral forces considered, resulting in the lowest flexural strength.

$\sum \boldsymbol{M}_{nb}$ is sum of nominal flexural strengths of the beams framing into the joint, evaluated at the faces of the joint. In T-beam construction, where the slab is in tension under moments at the face of the joint, slab reinforcement within an effective slab width defined in accordance with 6.3.2 shall be assumed to contribute to $\boldsymbol{M}_{nb}$ if the slab reinforcement is developed at the critical section for flexure.

Flexural strengths shall be summed such that the column moments oppose the beam moments. Equation (18.7.3.2) shall be satisfied for beam moments acting in both directions in the vertical plane of the frame considered.

18.7.3.3 If 18.7.3.2 is not satisfied at a joint, the lateral strength and stiffness of the columns framing into that joint shall be ignored when calculating strength and stiffness of the structure. These columns shall conform to 18.14.

R18.7.3 *Minimum flexural strength of columns*—The intent of 18.7.3.2 is to reduce the likelihood of yielding in columns that are considered as part of the seismic-force-resisting system. If columns are not stronger than beams framing into a joint, there is increased likelihood of inelastic action. In the worst case of weak columns, flexural yielding can occur at both ends of all columns in a given story, resulting in a column failure mechanism that can lead to collapse.

In 18.7.3.2, the nominal strengths of the beams and columns are calculated at the joint faces, and those strengths are compared directly using Eq. (18.7.3.2). The 1995 and earlier Codes required design strengths to be compared at the center of the joint, which typically produced similar results but with added calculation effort.

In determining the nominal moment strength of a beam section in negative bending (top in tension), longitudinal reinforcement contained within an effective flange width of a top slab that acts monolithically with the beam increases the beam strength. French and Moehle (1991), on beam-column subassemblies under lateral loading, indicates that using the effective flange widths defined in 6.3.2 gives reasonable estimates of beam negative moment strengths of interior connections at story displacements approaching 2 percent of story height. This effective width is conservative where the slab terminates in a weak spandrel.

Design of Beam Column Joint for Shear

18.8—Joints of special moment frames

18.8.1 *Scope*

18.8.1.1 This section shall apply to beam-column joints of special moment frames forming part of the seismic-force-resisting system.

18.8.2 *General*

18.8.2.1 Forces in longitudinal beam reinforcement at the joint face shall be calculated assuming that the stress in the flexural tensile reinforcement is $\mathbf{1.25}f_y$.

R18.8—Joints of special moment frames

R18.8.2 *General*—Development of inelastic rotations at the faces of joints of reinforced concrete frames is associated with strains in the flexural reinforcement well in excess of the yield strain. Consequently, joint shear force generated by the flexural reinforcement is calculated for a stress of $\mathbf{1.25}f_y$ in the reinforcement (refer to 18.8.2.1). A detailed explanation of the reasons for the possible development of stresses in excess of the yield strength in beam tensile reinforcement is provided in ACI 352R.

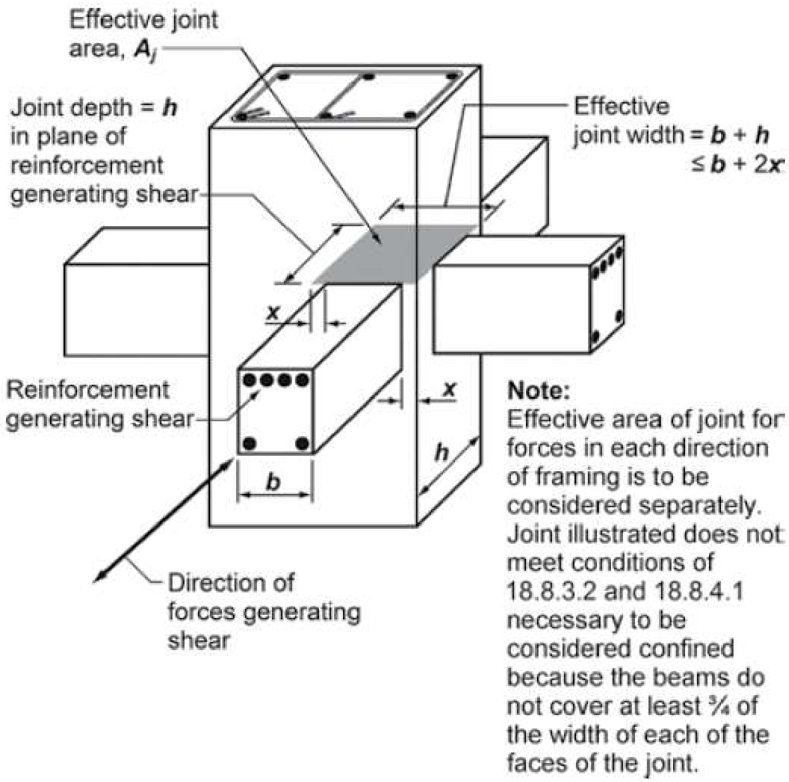
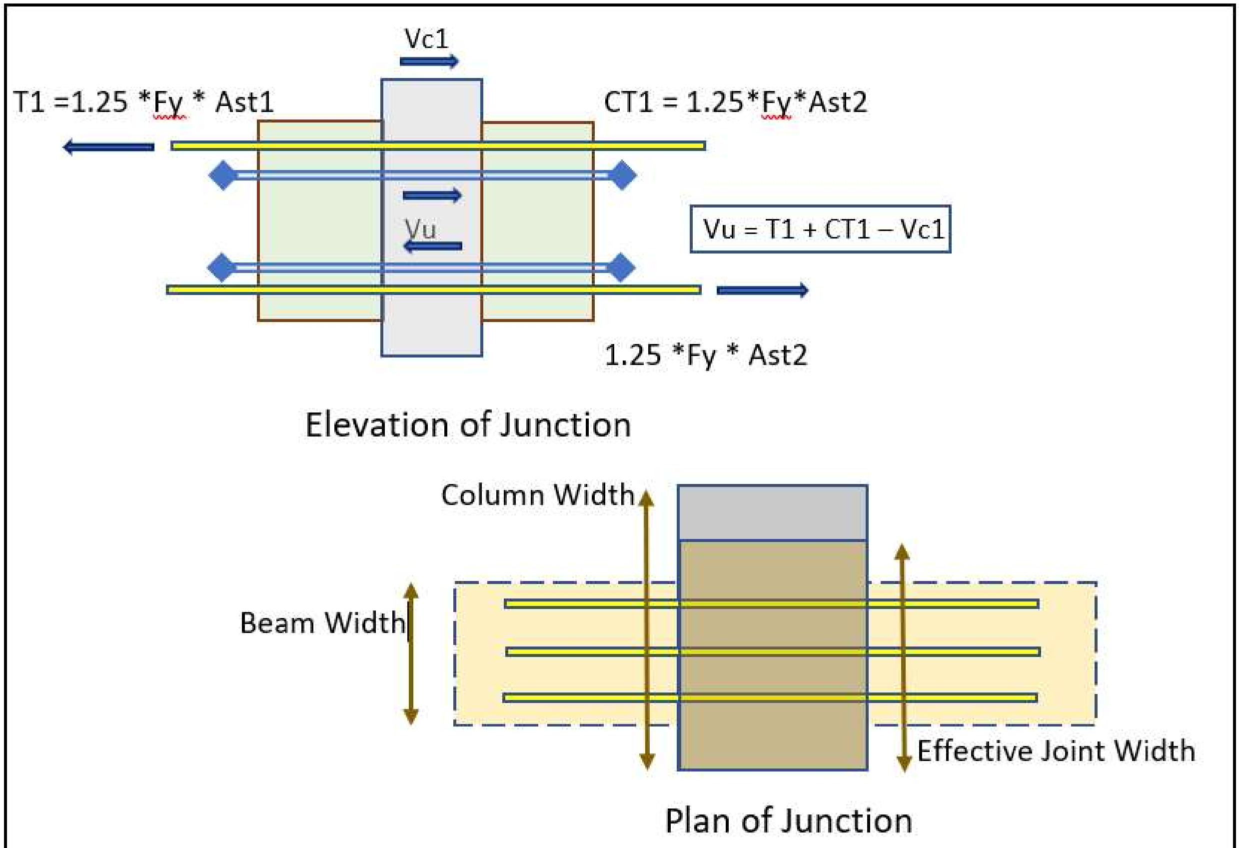


Fig. R18.8.4—Effective joint area.

18.8.4.1 V_n of the joint shall be in accordance with Table 18.8.4.1.

Table 18.8.4.1—Nominal joint shear strength V_n

Joint configuration	V_n
For joints confined by beams on all four faces[1]	$1.7\lambda\sqrt{f'_c}A_j$ [2]
For joints confined by beams on three faces or on two opposite faces[1]	$1.2\lambda\sqrt{f'_c}A_j$ [2]
For other cases	$1.0\lambda\sqrt{f'_c}A_j$ [2]



Joint Shear Check

3. Critical Issues of Performing Joint Check

- Each Joint of Ductile Columns Needs to Be Checked
- PM Curve of The Provided Rebar Diameter and Arrangement Required for Column Flexure Check
- Beam location w.r.t column axis become critical in joint check
- Dependency of the adjacent floor beam design
- Joints Checks Required Finalization of Beam and Column Reinforcement
- Distortional Shear Check is Depend on Member Meetings at Joint, its location and angle which is forming effective shear area of column.

4. Advantages Of RCDC

- Time and Resource Saving
- Compilation of All Clauses
- Column Design Satisfying Joints Checks
- Column geometry is considered from Base to top level and optimizing the reinforcement.
- Any geometry changes are handled, and joint check is performed
- All Checks Are Performed as Per Provided Reinforcement
- Detailing Modifications Accepted Only After All the Checks Are Performed
- All Checks Are Available in Report Format Along with All Values
  Redesign option is available and Joint check can be performed with revised reinforcement

5. PM curve explanation:

The principle used in RCDC for column design is to check the capacity of a section of given size with given reinforcement arrangement against the design-demand. For a given size of column with specific arrangement of reinforcement (in terms of location and size), for given grades of concrete and reinforcement, the P-M curves are generated as 'section capacity' curves to create the interaction surface. For all design load combinations, values of Pu, Mux and Muy (from analysis) are used and after checking of minimum eccentricity, slenderness and other relevant checks, final design values are worked out as Pu-d, Mux-d and Muy-d. Now each value of this Pu-d, Mux-d and Muy-d is checked against capacity available as per the P-M surface.

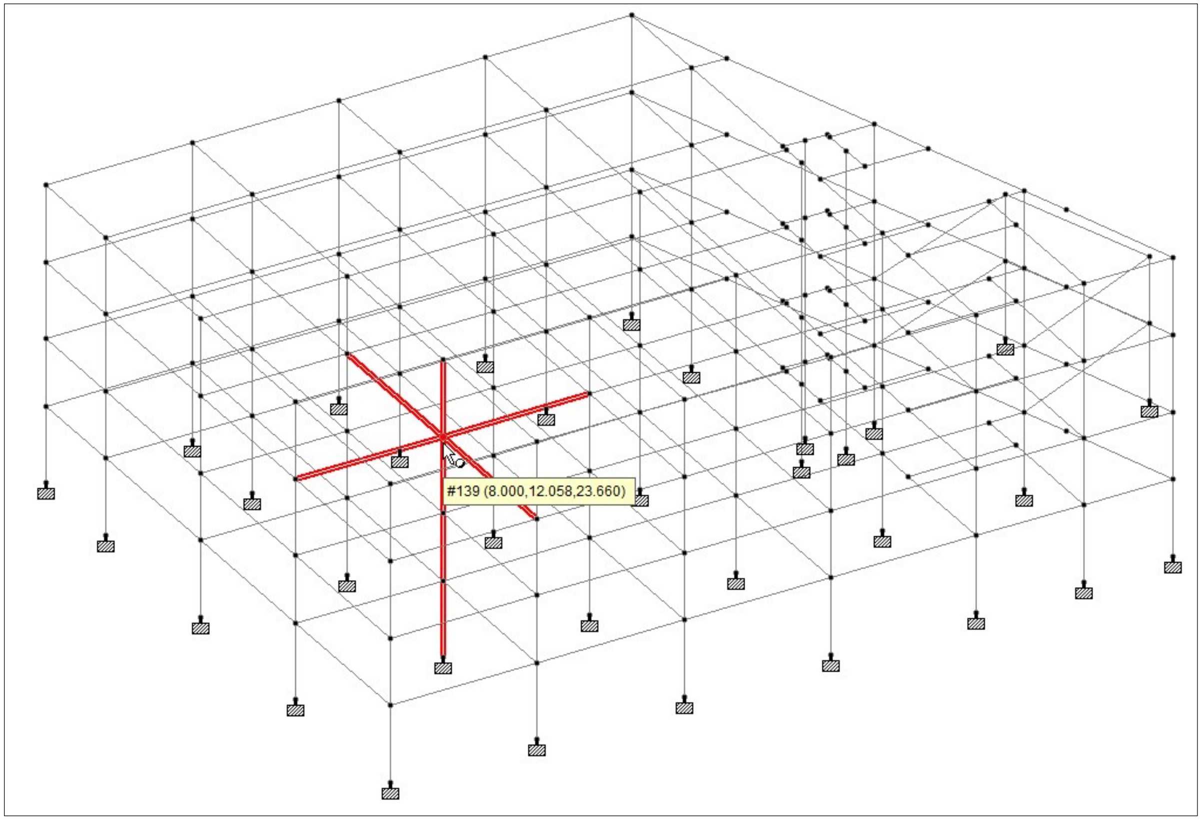
6. Flexural Joint Check

Steps,

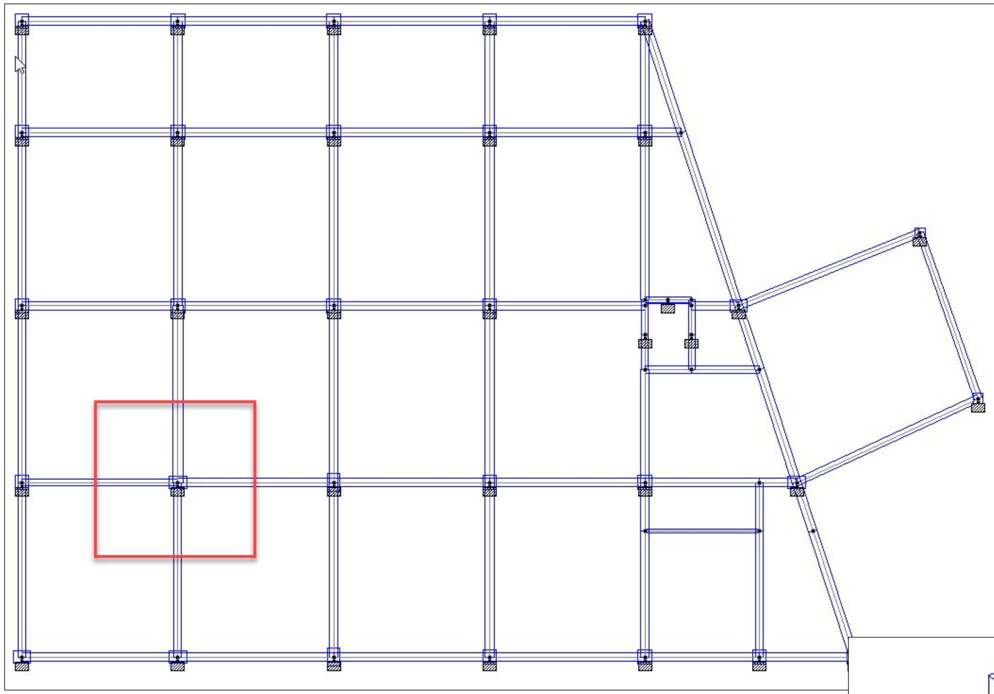
A. Input Data
B. RCDC Output
C. Calculation of column capacity
D. Calculation of Beam capacity

A. Input Data:

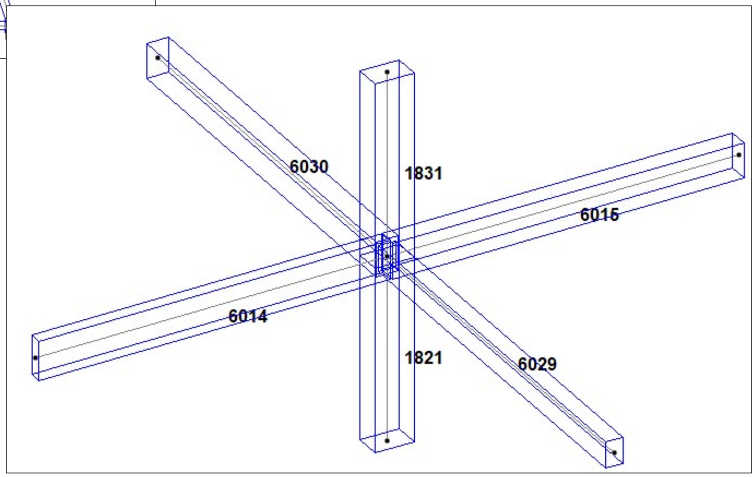
STAAD file	= RCDC-Staad-Demo -with RCC wall
Joint level	= 12.058 m
Column No. (RCDC)	= C22
Column Member no. (below joint)	= 1821
Column Member no.(above joint)	= 1831
Column Size	= 600 x 900
Height of column below Joint	= 4200 mm
Height of column Above Joint	= 4200 mm



3D View



Top View



Element Numbers at Joint at 12.058m level

Note: STAAD command file is available at end of this document

B. RCDC Output

General Data:

Column No. : C22

Joint at Level : 12.058 m

	Column Below	Column Above
Member Number	1821	1831
Concrete Grade,fck (N/sqmm)	C25	C25
Steel Grade,fy (N/sqmm)	Fy420	Fy420
Column Size (mm)	600 X 900	600 X 900

Check At Beam-Column Joints:

1. Flexure Strength Of Joint:

Moment Capacity Calculations for Beam

Concrete Grade,fck = C25 N/sqmm

Steel Grade,fy = Fy420 N/sqmm

Beam Size	Beam angle w.r.t. column Ly	Torsion moment	Moment Capacity for Top Reinforcement				Moment Capacity for Bottom Reinforcement				Resultant Moment			
(mm)	(deg)	(kNm)	Mu (kNm)	Ast Req (sqmm)	Ast Pro (sqmm)	Mu Cap (kNm)	Mu (kNm)	Ast Req (sqmm)	Ast Pro (sqmm)	Mu Cap (kNm)	Top @ D (kNm)	Top @ B (kNm)	Bot @ D (kNm)	Bot @ B (kNm)
450 x 800	0	0	526.57	1986.13	2005.64	531.42	0	993.07	1013.44	277.05	531.42	0	277.05	0
500 x 800	90	0.69	622.63	2358.55	2382.72	628.58	0	1179.28	1266.8	345.01	0	628.58	0	345.01
300 x 900	180	0.48	464.11	1546.22	1588.48	475.96	0	773.11	886.76	273.66	475.96	0	273.66	0
400 x 600	270	0.46	562.24	3190.69	3546.97	613.22	0	1595.34	1626.2	310.84	0	613.22	0	310.84

Effective Moment for Beam

	Along D		Along B	
	Left	Right	Left	Right
Top (kNm)	475.96	531.42	613.22	628.58
Bottom (kNm)	273.66	277.05	310.84	345.01
Mnb (kNm)	MAX((Left Bottom + Right Top), (Left Top + Right		MAX((Left Top + Right Bottom), (Right Top + Left	
	805.07		958.23	

Check for Column Flexural Capacity

	Along D	Along B
Critical Load Combination Top	[11] : 0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	[11] : 0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)
Pu Top (kN)	587	587
Mnc Top (kNm)	1531.58	999.35
Critical Load Combination Bot	[11] : 0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	[11] : 0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)
Pu Bot (kN)	1103.74	1103.74
Mnc Bottom (kNm)	1166.72	767.91
Mnc (kNm)	2698.3	1767.26
	>= 1.2 x Mnb, Hence OK	>= 1.2 x Mnb, Hence OK

Where,

Mnb = Flexural Capacity of Beams in kN-m

Mnc Top = Flexural capacity of column above joint considered

Mnc Bottom = Flexural capacity of column below joint considered

Mnc = Mnc Top + Mnc Bottom, along D

Mnc = Mnc Top + Mnc Bottom, along B

Check for Column Flexural Capacity

Load Combination	Top Column	Bottom Column	Joint Flexure Check Along D				Joint Flexure Check Along B			
	Pu (kN)	Pu (kN)	Mnc Top (kNm)	Mnc Bottom (kNm)	Mnc Total (kNm)	Design Check Mnc Total/Mnb	Mnc Top (kNm)	Mnc Bottom (kNm)	Mnc Total (kNm)	Design Check Mnc Total/Mnb
4	893.72	1878.87	1609.89	1353.97	2963.86	3.68	1055.88	904.33	1960.22	2.05
5	901.66	1910.29	1611.92	1361.03	2972.95	3.69	1057.35	909.43	1966.78	2.05
6	903.14	1913.55	1612.3	1361.76	2974.06	3.69	1057.62	909.96	1967.58	2.05
7	892.24	1875.62	1609.51	1353.23	2962.75	3.68	1055.61	903.81	1959.41	2.04
8	588.49	1107	1531.96	1167.56	2699.53	3.35	999.62	768.51	1768.14	1.85
9	596.42	1138.42	1533.99	1175.72	2709.71	3.37	1001.08	774.34	1775.42	1.85
10	597.91	1141.68	1534.37	1176.57	2710.94	3.37	1001.36	774.94	1776.3	1.85
11	587	1103.74	1531.58	1166.72	**2698.3**	**3.35**	999.35	767.91	**1767.26**	**1.84**

C. <u>Calculation of Column Capacity:</u>

Column capacity shall be calculated along D and Along B of the column from PM curve. The load combinations which contains Earthquake load cases shall be considered for capacity calculation. The Axial force from all Earthquake load combinations which gives minimum column capacity from PM curve shall be considered as column capacity for joint check.

Column capacity of column above and below joint shall be considered. Summation of capacities of both the column shall be considered as total column capacity at that joint. At top floor, where top column doesn't exist, capacity of column below shall be considered in Joint check.

Column Above Joint at 12.058m level i.e. Bottom Node of Member 1831

Member force table from RCDC:

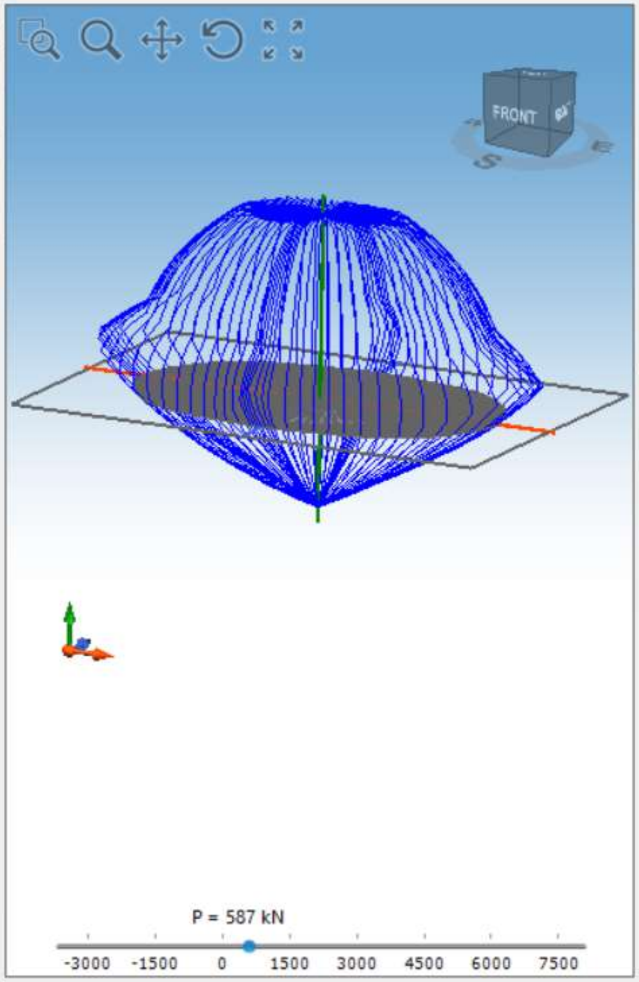
Columns	Level	Analysis No	Load Comb	Load Comb	Load Comb	Location	P	Mx	My	ShearX	ShearY
			Ref No	Analysis No	Description	(m)	(kN)	(kNm)	(kNm)	(kN)	(kN)
C22	16.258 m	1831	1		1.4 (LOAD 1: LOAD CASE 1)	0	921.59	3.05	7.71	-3.95	2.7
			1		1.4 (LOAD 1: LOAD CASE 1)	4.2	842.18	-8.3	-8.87	-3.95	2.7
			2		1.2 (LOAD 1: LOAD CASE 1) +1.6 (LOAD 2: LOAD CASE 2)	0	962.34	5.99	9.63	-4.64	4.06
			2		1.2 (LOAD 1: LOAD CASE 1) +1.6 (LOAD 2: LOAD CASE 2)	4.2	894.27	-11.05	-9.84	-4.64	4.06
			3		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2)	0	897.69	4.72	8.49	-4.17	3.4
			3		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2)	4.2	829.62	-9.57	-9	-4.17	3.4
			4		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	893.72	95.96	8.87	-4.38	60.01
			4		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	825.65	-156.04	-9.52	-4.38	60.01
			5		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	901.66	-86.51	8.11	-3.95	-53.21
			5		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	833.59	136.89	-8.48	-3.95	-53.21
			6		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	903.14	3.69	69.3	-40.82	2.83
			6		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	835.07	-8.21	-102.12	-40.82	2.83
			7		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	892.24	5.75	-52.32	32.49	3.97
			7		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	824.17	-10.93	84.11	32.49	3.97
			8		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	588.49	93.19	5.33	-2.75	58.35
			8		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	537.44	-151.8	-6.22	-2.75	58.35
			9		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	596.42	-89.27	4.57	-2.32	-54.87
			9		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	545.37	141.13	-5.18	-2.32	-54.87
			10		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	597.91	0.93	65.76	-39.19	1.17
			10		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	546.86	-3.98	-98.81	-39.19	1.17
			11		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	587	2.99	-55.86	34.12	2.31
			11		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	535.95	-6.69	87.41	34.12	2.31

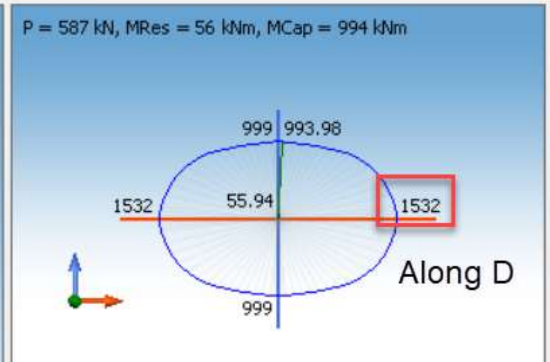
Along D

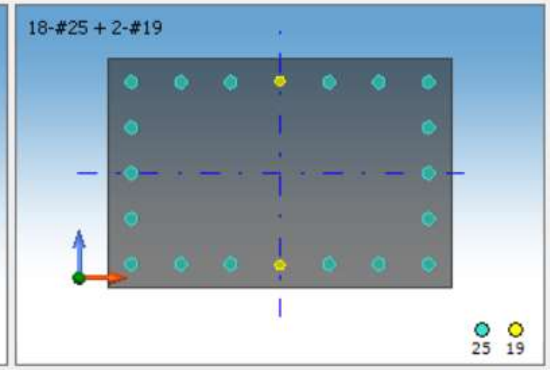
Pu which gives Minimum Moment capacity　　　　Pu　= 587 kN

Moment Capacity, (Mnc top)　　　　Mcap　= 1531.58 kNm (refer below PM curve)

Interaction Surface - C22







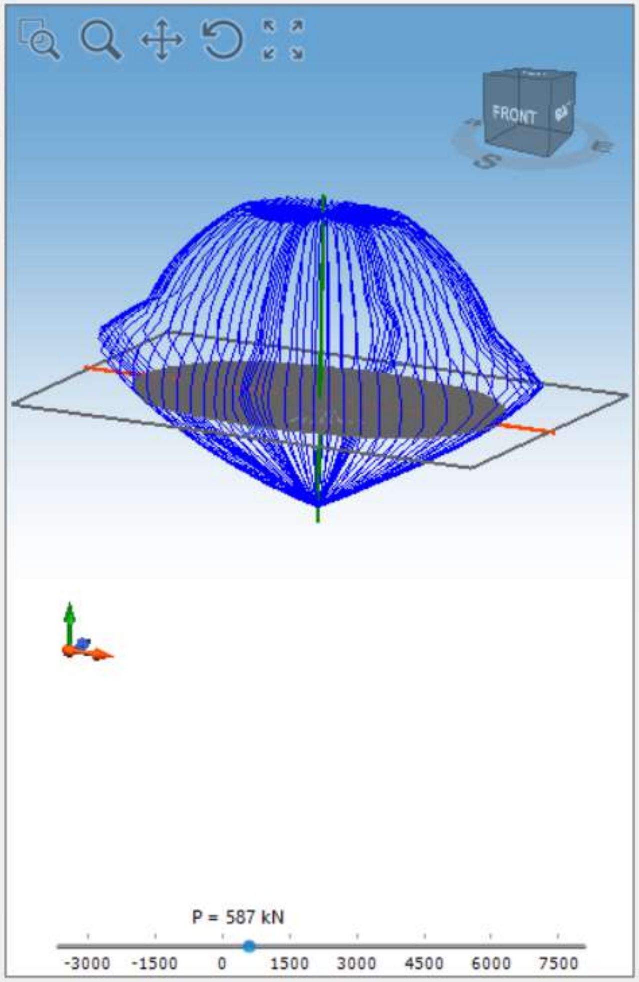
Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	1 (Bot)	921.59	3.05	7.71	68.4	8.29	1044.48	0.008
C22	1 (Top)	842.18	-8.3	-8.87	46.89	12.14	1195.59	0.01
C22	2 (Bot)	962.34	5.99	9.63	58.12	11.34	1089.64	0.01
C22	2 (Top)	894.27	-11.05	-9.84	41.71	14.8	1259.97	0.012
C22	3 (Bot)	897.69	4.72	8.49	60.92	9.72	1069.69	0.009
C22	3 (Top)	829.62	-9.57	-9	43.24	13.14	1239.68	0.011
C22	4 (Bot)	893.72	95.96	8.87	5.28	96.37	1589.36	0.061
C22	4 (Top)	825.65	-156.04	-9.52	3.49	156.33	1581.78	0.099
C22	5 (Bot)	901.66	-86.51	8.11	5.36	86.89	1590.88	0.055
C22	5 (Top)	833.59	136.89	-8.48	3.54	137.16	1583.48	0.087
C22	6 (Bot)	903.14	3.69	69.3	86.95	69.4	1049.12	0.066
C22	6 (Top)	835.07	-8.21	-102.12	85.4	102.45	1035.06	0.099
C22	7 (Bot)	892.24	5.75	-52.32	83.72	52.63	1044.11	0.05
C22	7 (Top)	824.17	-10.93	84.11	82.6	84.82	1031.3	0.082
C22	8 (Bot)	588.49	93.19	5.33	3.28	93.35	1520.55	0.061
C22	8 (Top)	537.44	-151.8	-6.22	2.35	151.93	1509.95	0.101
C22	9 (Bot)	596.42	-89.27	4.57	2.93	89.39	1523.83	0.059
C22	9 (Top)	545.37	141.13	-5.18	2.1	141.22	1512.93	0.093
C22	10 (Bot)	597.91	0.93	65.76	89.19	65.77	999.72	0.066
C22	10 (Top)	546.86	-3.98	-98.81	87.7	98.89	987.33	0.1
C22	11 (Bot)	587	2.99	-55.86	86.93	55.94	993.98	0.056
C22	11 (Top)	535.95	-6.69	87.41	85.62	87.67	983.82	0.089

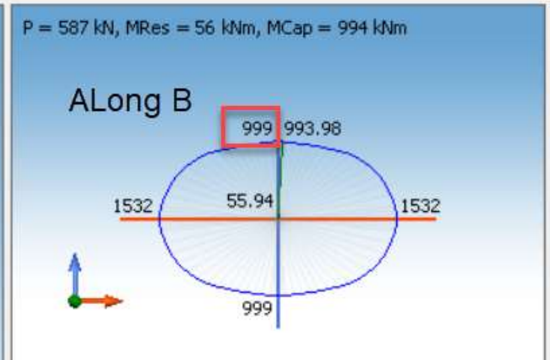
Along B

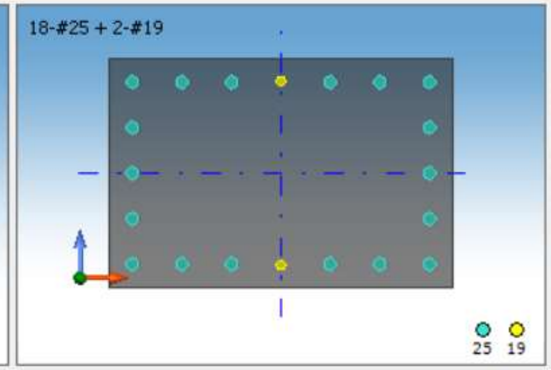
Pu which gives Minimum Moment capacity — Pu = 587 kN

Moment Capacity, (Mnc top) — Mcap = 999.35 kNm (refer below PM curve)

Interaction Surface - C22







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C22	6 (Bot)	903.14	3.69	69.3	86.95	69.4	1049.12	0.066
C22	6 (Top)	835.07	-8.21	-102.12	85.4	102.45	1035.06	0.099
C22	7 (Bot)	892.24	5.75	-52.32	83.72	52.63	1044.11	0.05
C22	7 (Top)	824.17	-10.93	84.11	82.6	84.82	1031.3	0.082
C22	8 (Bot)	588.49	93.19	5.33	3.28	93.35	1520.55	0.061
C22	8 (Top)	537.44	-151.8	-6.22	2.35	151.93	1509.95	0.101
C22	9 (Bot)	596.42	-89.27	4.57	2.93	89.39	1523.83	0.059
C22	9 (Top)	545.37	141.13	-5.18	2.1	141.22	1512.93	0.093
C22	10 (Bot)	597.91	0.93	65.76	89.19	65.77	999.72	0.066
C22	10 (Top)	546.86	-3.98	-98.81	87.7	98.89	987.33	0.1
C22	11 (Bot)	587	2.99	-55.86	86.93	55.94	993.98	0.056
C22	11 (Top)	535.95	-6.69	87.41	85.62	87.67	983.82	0.089

Column below Joint at 12.058m level i.e. top Node of Member 1821

Member force table from RCDC:

Columns	Level	Analysis No	Load Comb Ref No	Load Comb Analysis No	Load Comb Description	Location (m)	P (kN)	Mx (kNm)	My (kNm)	ShearX (kN)	ShearY (kN)
C22	12.058 m	1821	1		1.4 (LOAD 1: LOAD CASE 1)	0	1825.85	5.75	18.9	-10.92	-0.49
			1		1.4 (LOAD 1: LOAD CASE 1)	4.2	1746.44	7.8	-26.95	-10.92	-0.49
			2		1.2 (LOAD 1: LOAD CASE 1) +1.6 (LOAD 2: LOAD CASE 2)	0	2201.23	17.3	12.33	-7.8	4.71
			2		1.2 (LOAD 1: LOAD CASE 1) +1.6 (LOAD 2: LOAD CASE 2)	4.2	2133.17	-2.47	-20.42	-7.8	4.71
			3		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2)	0	1962.65	12.66	13.78	-8.38	2.79
			3		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2)	4.2	1894.58	0.96	-21.42	-8.38	2.79
			4		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	1946.94	170.52	14.14	-8.57	82.23
			4		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1878.87	-174.77	-21.84	-8.57	82.23
			5		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	1978.36	-145.2	13.41	-8.2	-76.66
			5		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1910.29	176.69	-21.01	-8.2	-76.66
			6		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1981.62	10.84	110.14	-57.02	2.04
			6		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1913.55	2.29	-129.28	-57.02	2.04
			7		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1943.68	14.48	-82.58	40.25	3.54
			7		1.2 (LOAD 1: LOAD CASE 1) +(LOAD 2: LOAD CASE 2) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1875.62	-0.37	86.43	40.25	3.54
			8		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	1158.05	161.56	12.51	-7.21	79.13
			8		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1107	-170.71	-17.74	-7.21	79.13
			9		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	0	1189.47	-154.17	11.78	-6.83	-79.76
			9		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1138.42	180.74	-16.91	-6.83	-79.76
			10		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1192.73	1.88	108.51	-55.65	-1.06
			10		0.9 (LOAD 1: LOAD CASE 1) +1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1141.68	6.34	-125.18	-55.65	-1.06
			11		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1154.8	5.52	-84.21	41.62	0.44
			11		0.9 (LOAD 1: LOAD CASE 1) -1.4 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1103.74	3.68	90.53	41.62	0.44

Note:

For column moment capacity calculation load combinations contains Earthquake load case should be considered.

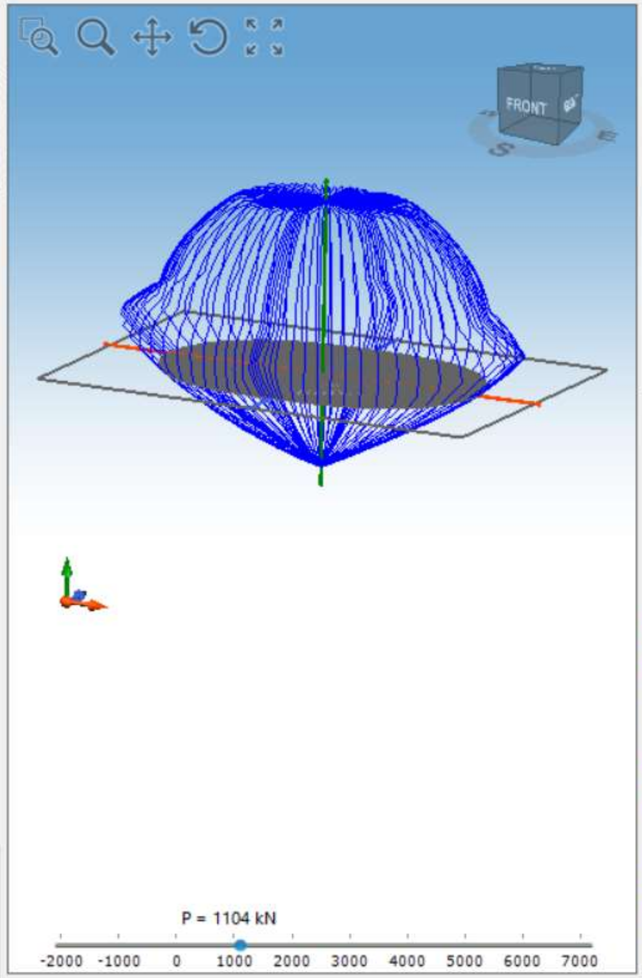
Pu from all Eq load combinations which gives minimum moment capacity should be considered.

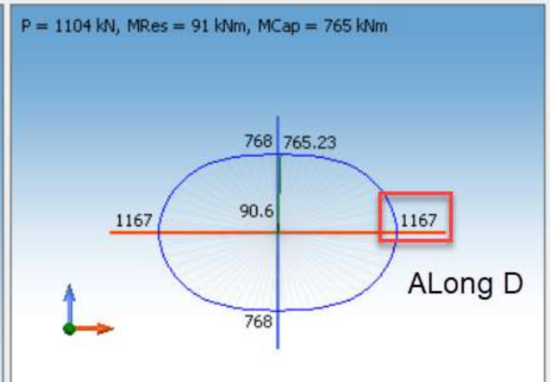
Along D

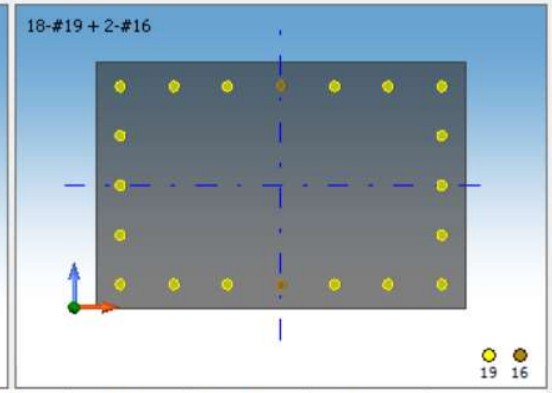
Pu which gives Minimum Moment capacity | Pu = 1103.74 kN

Moment Capacity, (Mnc top) | Mcap = 1166.72 kNm (refer below PM curve)

Interaction Surface - C22







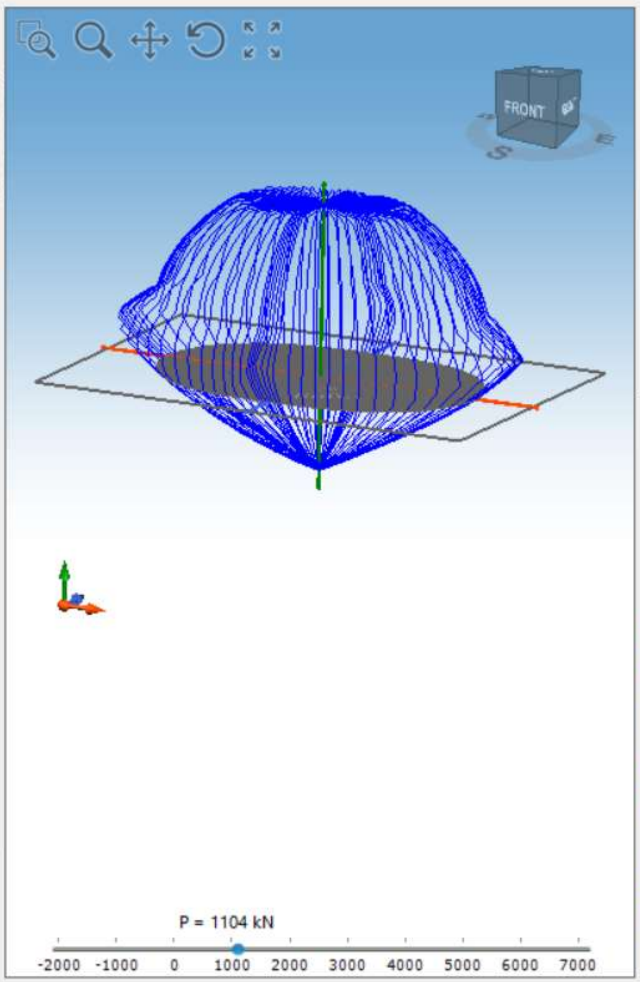
Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	1 (Bot)	1825.85	5.75	18.9	73.07	19.75	851.04	0.023
C22	1 (Top)	1746.44	7.8	-26.95	73.86	28.05	852	0.033
C22	2 (Bot)	2201.23	17.3	12.33	35.47	21.24	1096.17	0.019
C22	2 (Top)	2133.17	-2.47	-20.42	83.1	20.57	911.53	0.023
C22	3 (Bot)	1962.65	12.66	13.78	47.42	18.71	962.84	0.019
C22	3 (Top)	1894.58	0.96	-21.42	87.43	21.45	900.96	0.024
C22	4 (Bot)	1946.94	170.52	14.14	4.74	171.11	1361.57	0.126
C22	4 (Top)	1878.87	-174.77	-21.84	7.12	176.13	1338.03	0.132
C22	5 (Bot)	1978.36	-145.2	13.41	5.28	145.82	1365.58	0.107
C22	5 (Top)	1910.29	176.69	-21.01	6.78	177.93	1345.85	0.132
C22	6 (Bot)	1981.62	10.84	110.14	84.38	110.67	900.07	0.123
C22	6 (Top)	1913.55	2.29	-129.28	88.98	129.3	908.37	0.142
C22	7 (Bot)	1943.68	14.48	-82.58	80.06	83.84	877.6	0.096
C22	7 (Top)	1875.62	-0.37	86.43	89.76	86.43	903.39	0.096
C22	8 (Bot)	1158.05	161.56	12.51	4.43	162.05	1172.08	0.138
C22	8 (Top)	1107	-170.71	-17.74	5.93	171.63	1155	0.149
C22	9 (Bot)	1189.47	-154.17	11.78	4.37	154.62	1180.93	0.131
C22	9 (Top)	1138.42	180.74	-16.91	5.34	181.53	1164.96	0.156
C22	10 (Bot)	1192.73	1.88	108.51	89.01	108.53	783.34	0.139
C22	10 (Top)	1141.68	6.34	-125.18	87.1	125.34	772.49	0.162
C22	11 (Bot)	1154.8	5.52	-84.21	86.25	84.39	774.88	0.109
C22	11 (Top)	1103.74	3.68	90.53	87.67	90.6	765.23	0.118

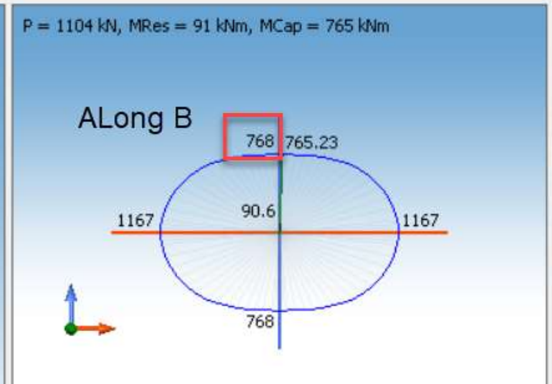
Along B

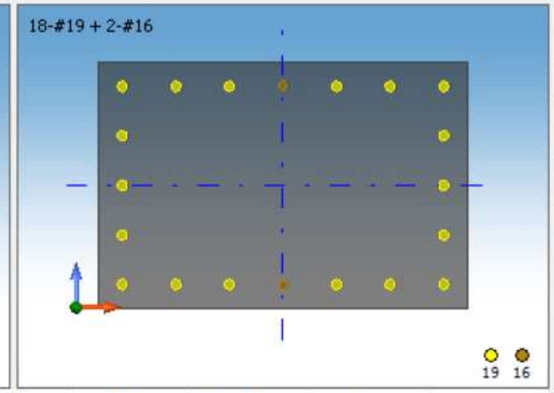
Pu which gives Minimum Moment capacity　　　　Pu　　= 1103.74 kN

Moment Capacity, (Mnc top)　　　　Mcap　= 767.91 kNm (refer below PM curve)

Interaction Surface - C22







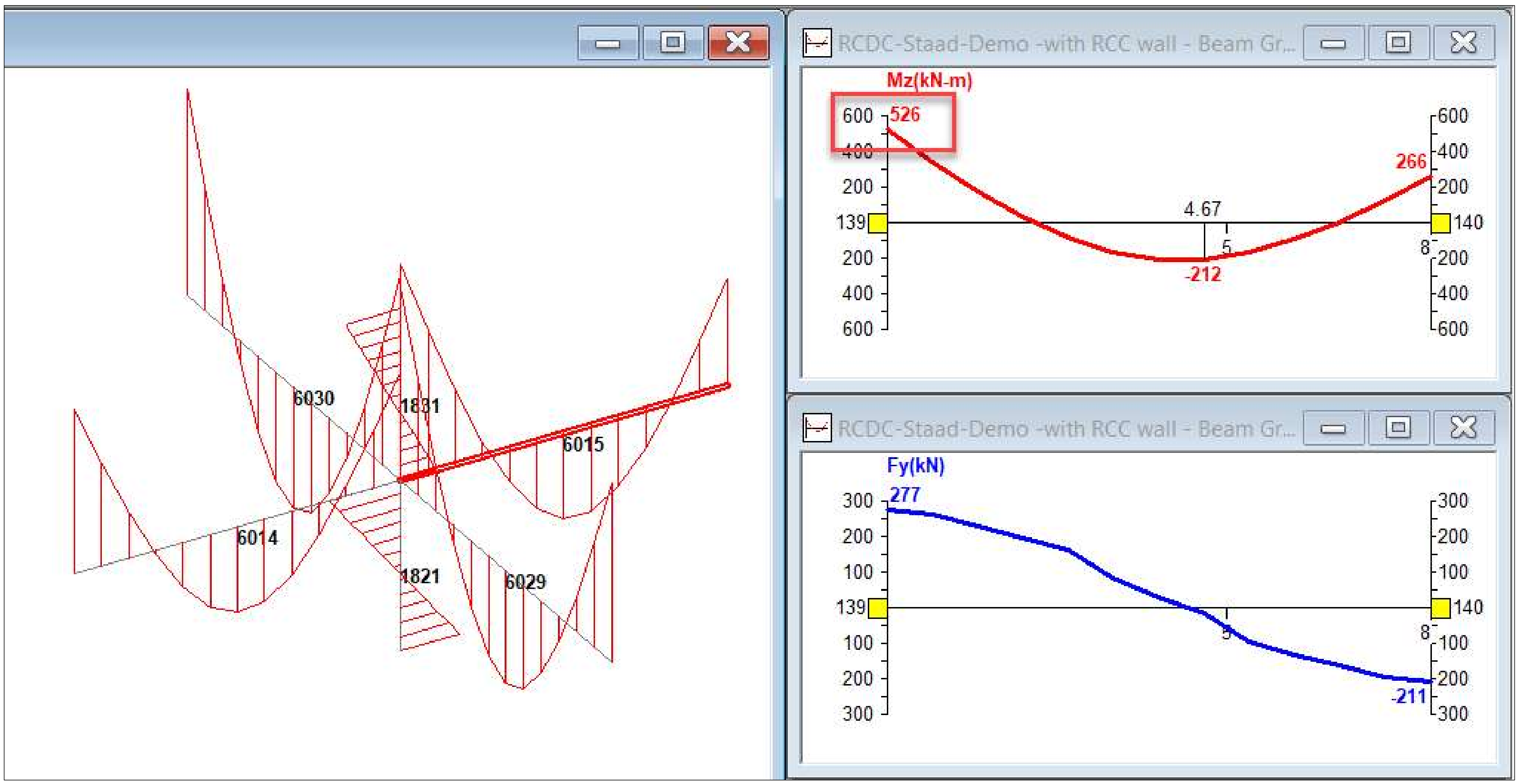
Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	1 (Bot)	1825.85	5.75	18.9	73.07	19.75	851.04	0.023
C22	1 (Top)	1746.44	7.8	-26.95	73.86	28.05	852	0.033
C22	2 (Bot)	2201.23	17.3	12.33	35.47	21.24	1096.17	0.019
C22	2 (Top)	2133.17	-2.47	-20.42	83.1	20.57	911.53	0.023
C22	3 (Bot)	1962.65	12.66	13.78	47.42	18.71	962.84	0.019
C22	3 (Top)	1894.58	0.96	-21.42	87.43	21.45	900.96	0.024
C22	4 (Bot)	1946.94	170.52	14.14	4.74	171.11	1361.57	0.126
C22	4 (Top)	1878.87	-174.77	-21.84	7.12	176.13	1338.03	0.132
C22	5 (Bot)	1978.36	-145.2	13.41	5.28	145.82	1365.58	0.107
C22	5 (Top)	1910.29	176.69	-21.01	6.78	177.93	1345.85	0.132
C22	6 (Bot)	1981.62	10.84	110.14	84.38	110.67	900.07	0.123
C22	6 (Top)	1913.55	2.29	-129.28	88.98	129.3	908.37	0.142
C22	7 (Bot)	1943.68	14.48	-82.58	80.06	83.84	877.6	0.096
C22	7 (Top)	1875.62	-0.37	86.43	89.76	86.43	903.39	0.096
C22	8 (Bot)	1158.05	161.56	12.51	4.43	162.05	1172.08	0.138
C22	8 (Top)	1107	-170.71	-17.74	5.93	171.63	1155	0.149
C22	9 (Bot)	1189.47	-154.17	11.78	4.37	154.62	1180.93	0.131
C22	9 (Top)	1138.42	180.74	-16.91	5.34	181.53	1164.96	0.156
C22	10 (Bot)	1192.73	1.88	108.51	89.01	108.53	783.34	0.139
C22	10 (Top)	1141.68	6.34	-125.18	87.1	125.34	772.49	0.162
C22	11 (Bot)	1154.8	5.52	-84.21	86.25	84.39	774.88	0.109
C22	11 (Top)	1103.74	3.68	90.53	87.67	90.6	765.23	0.118

D. <u>Calculation of Beam Capacity:</u>

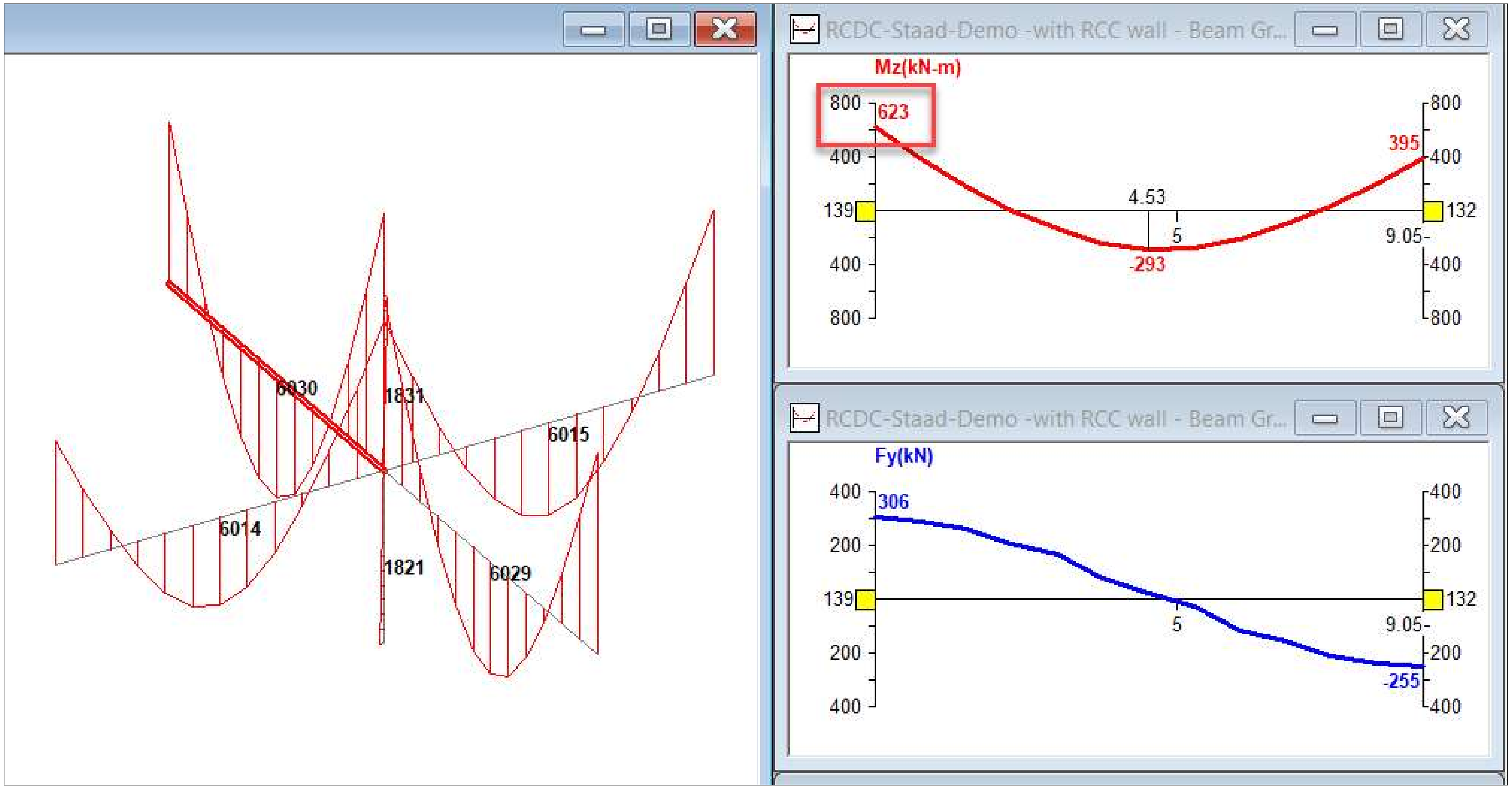
Steps to Calculate Mcap of Beam at Ends:

1. Identifying the angle of Beam in plan w.r.t. column Ly. (Ly= Major direction & Lx = minor direction)
2. Finding out the maximum moment at end of the beam which is supported on column. Calculating the area of reinforcement required in beam for Major direction moment and torsion if any.
3. Detailing the beam with actual rebar diameters and rebar arrangements.
4. Calculating the Mcap of the beam for provided reinforcement.
5. If the beam is not orthogonal to the column axis, resolving the Mcap of that beam along column direction.
6. Finding out the effective moments for column along Ly and Lx of the column.

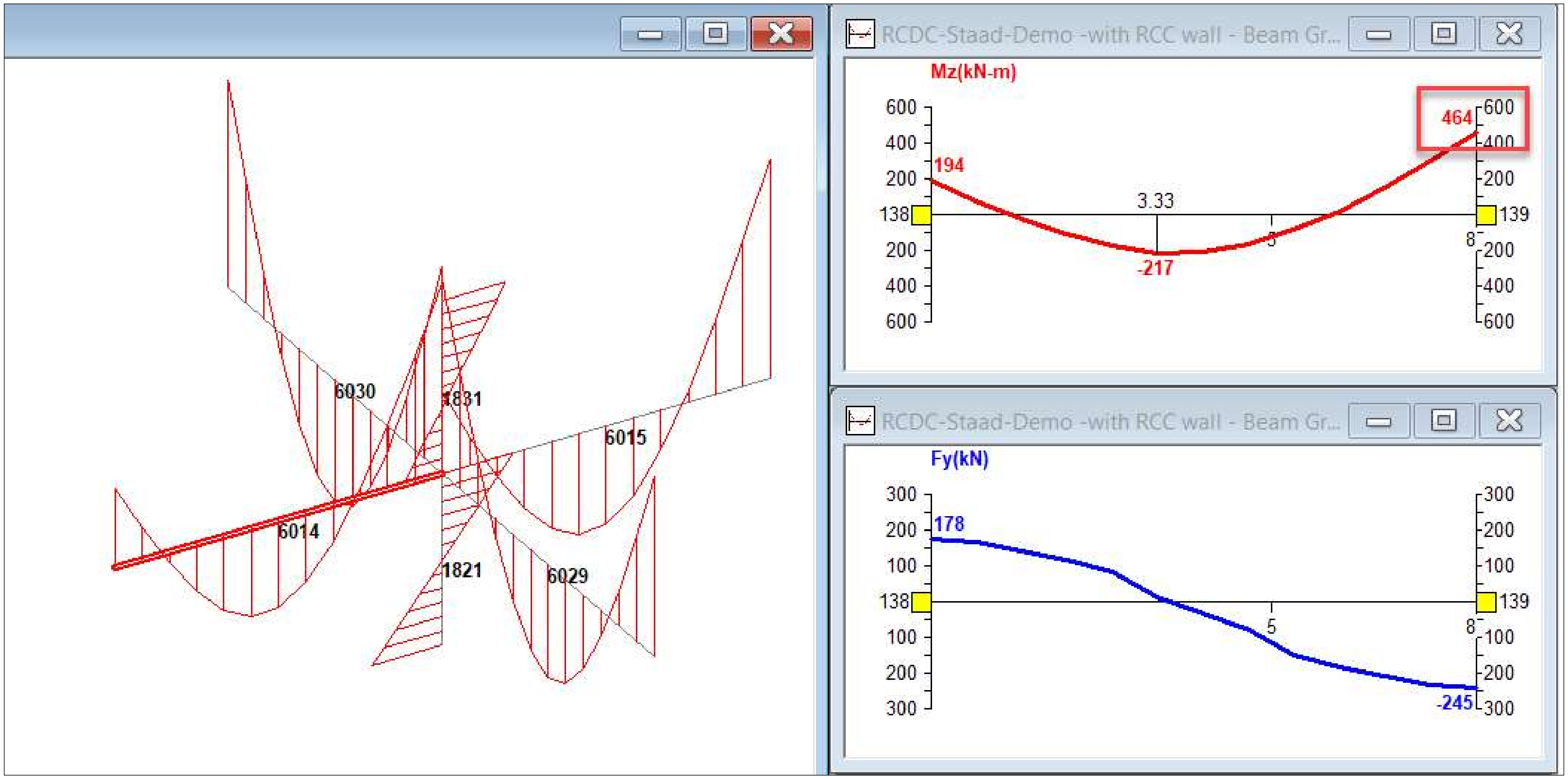
Beam @ 0 Location w.r.t. Colum Ly – Load Comb 15 – Maximum Bending Moment



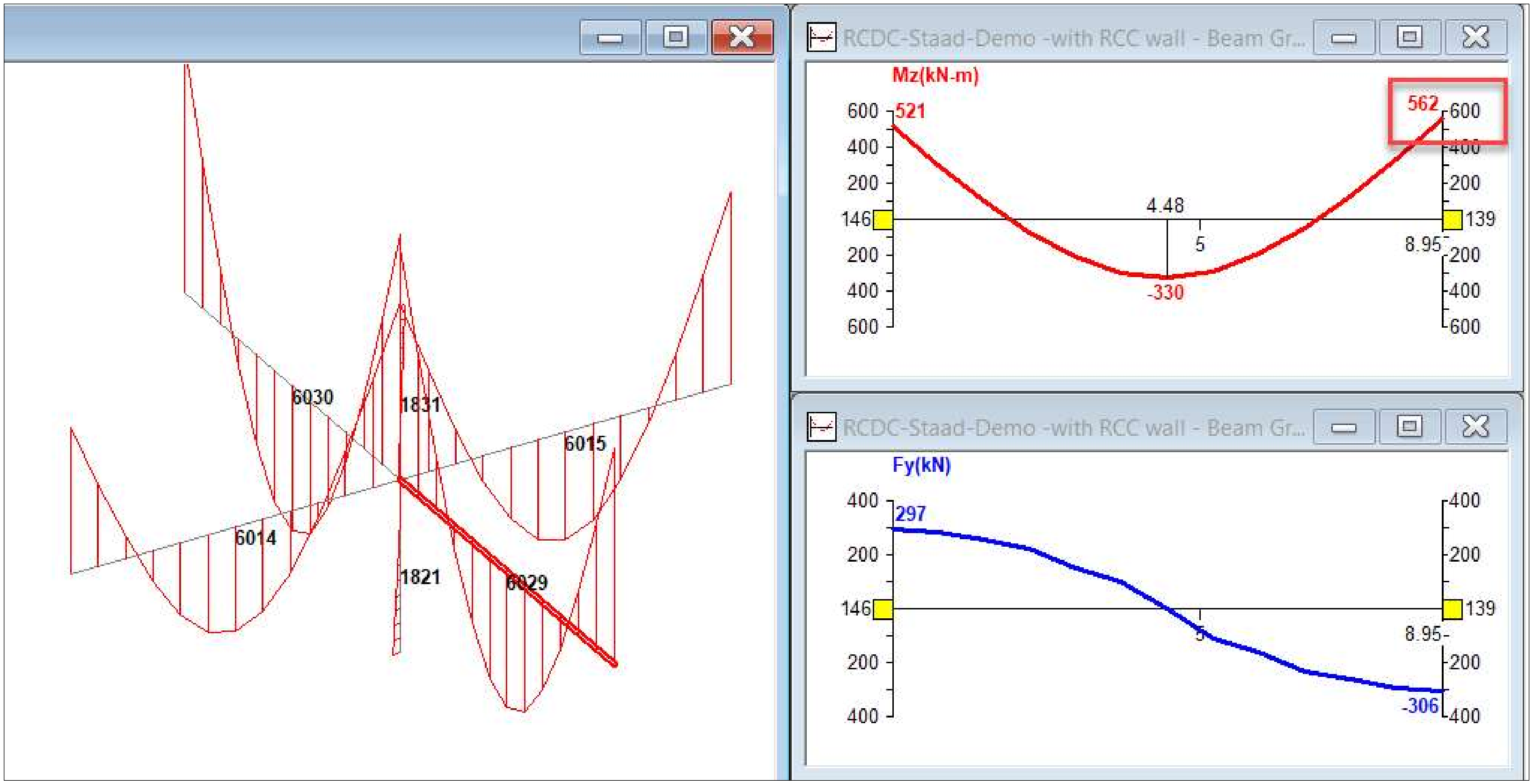
Beam @ 90 Location w.r.t. Colum Ly– Load Comb 16– Maximum Bending Moment



Beam @ 180 Location w.r.t. Colum Ly– Load Comb 14– Maximum Bending Moment



Beam @ 270 Location w.r.t. Colum Ly– Load Comb 13– Maximum Bending Moment



Sample for calculation of Beam capacity:

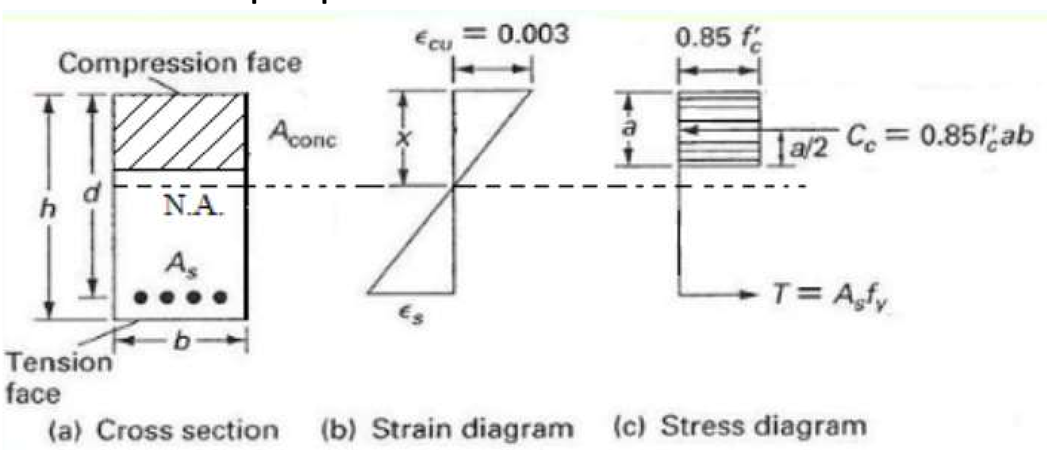
Beam @ 0 Location w.r.t. Colum Ly – Load Comb 15 – Maximum Bending Moment

Beam No	**:**	**B18**	
Analysis Reference (Member) 12.058 m	:	6015	
Beam Length	:	8000	mm
Breadth (B)	:	450	mm
Depth (D)	:	800	mm
Effective Depth (d)	:	745	mm
Design Code	:	ACI 318M - 2014	
Beam Type	:	Ductile Beam (Special Frame)	
Grade Of Concrete (f'c)	:	C25	N/sqmm
Grade Of Steel	:	Fy420	N/sqmm
Clear Cover (Cmin)	:	40	mm
Es	:	2x10^5	N/sqmm
Mubal	:	1518.23	kNm
As,min (flex) (B)	:	1095	sqmm
As,nominal (Bn)	:	427.05	sqmm
As,min(user input)(B')	:	427.05	sqmm

Calculation of Ast for Mu:

For Longitudinal Reinf						
	Beam Bottom			**Beam Top**		
	Left	**Mid**	**Right**	**Left**	**Mid**	**Right**
Critical L/C - RCDC	8	2	-	5	9	4
Mu (kNm)	80.73	264.03	-	526.57	59.05	538.79
As (flex) (sqmm) (C)	289.15	965.02	-	1986.13	210.99	2035.37
Asc (flex) (sqmm) (A)	-	-	-	-	-	-
Tu (kNm)	-	-	-	-	-	-
Tcr/4 (kNm)	-	-	-	-	-	-
Al, min(sqmm)(Tor.) (D)	-	-	-	-	-	-
Al (sqmm) (Tor.) (E)	-	-	-	-	-	-
Al (Dist) (sqmm) (D)	-	-	-	-	-	-
Ast (sqmm)	435.82	1117.5	1146.08	1986.13	435.82	2035.37
AstPrv (sqmm)	633.4	1140.12	1266.8	2005.64	506.72	2292.16
Reinforcement Provided	5-#13	5-#13 4-#13	5-#13 5-#13	4-#19 3-#19	4-#13	4-#19 4-#19

Calculation of Mcap for provided reinforcement:



Ast provided	=	2005.64 sqmm
Xu-max/Deff	=	0.003 / 0.007
	=	0.428571
Xu-max		= 319.2857 mm
Fc Max	=	Xu-max x 0.85 x f’c x B / 1000
	=	2595.194 kN
Mu-lim	=	Fc Max x (Deff – (0.85 x Xu-max)/2)
	=	1581.261 kN-m
Check		Mu-lim > Mu , Beam to be designed as Singly reinforced section
a	=	Ast provided x fy / (0.85 x f’c x B)
	=	88.09 mm
j	=	(Deff – (0.5 x a)) / Deff
	=	0.940879
c	=	a /0.85
	=	103.6363
Tensile force	=	Ast provided x fy
	=	842.3688 kN
Xu-act	=	a / 0.85
	=	103.6363 mm
Mn	=	Tensile force x j x Deff
	=	590.462 kN-m
Mcap	=	Mn x 0.9
	=	531.42 kNm

7. Design of Beam Column Joint for Shear

Nominal shear strength of the column is calculated based on the effective shear area and permissible concrete shear strength. Forces in the longitudinal beam reinforcement at the joint face shall be calculated assuming that the stress in the flexural tensile reinforcement is 1.25 fy. Shear force in beam at each face i.e. top and bottom is calculated as per the reinforcement provided at that face. Maximum shear force is calculated which gives maximum shear from following conditions,

a. Maximum (Left bottom + Right Top, Left top + Right Bottom) &

b. Maximum (Left top + Right bottom, Left bottom + Right Top)

Effective shear area is calculated as per the beam width, depth and column width and depth. It also depends on the direction on which beam is resting on column.

Beams Along D

Angle w.r.t Column Ly	Reference Location	Width	Depth	Ast Pro Top	Ast Pro Bot
(deg)		(mm)	(mm)	(sqmm)	(sqmm)
0	Right	450	800	2005.64	1013.44
180	Left	300	900	1588.48	886.76

Shear Checks

Conditions	AST-Total	V-Reinf	Vuy	Vj (Shear Demand)	B'	D'	Aj	Vn'	Vj < Vn'
	(sqmm)	(kN)	(kN)	(kN)	(mm)	(mm)	(sqmm)	(kN)	
Right Top + Left Bottom	2892.4	1518.51	805.07	713.44	600	900	540000	4590	OK
Left Top + Right Bottom	2601.92	1366.01	805.07	560.94	600	900	540000	4590	OK

Beams Along B

Angle w.r.t Column Ly	Reference Location	Width	Depth	Ast Pro Top	Ast Pro Bot
(deg)		(mm)	(mm)	(sqmm)	(sqmm)
90	Right	500	800	2382.72	1266.8
270	Left	400	600	3546.97	1626.2

Shear Checks

Conditions	AST-Total	V-Reinf	Vux	Vj (Shear Demand)	B'	D'	Aj	Vn'	Vj < Vn'
	(sqmm)	(kN)	(kN)	(kN)	(mm)	(mm)	(sqmm)	(kN)	
Right Top + Left Bottom	4008.92	2104.68	958.23	1146.46	900	600	540000	4590	OK
Left Top + Right Bottom	4813.77	2527.23	958.23	1569	900	600	540000	4590	OK

Example for calculation of effective width:

For Shear Along D of the Column

Beam Resting on the 0-degree w.r.t. Column Ly

Column Size	= 600 x 900
Beam Size	= 450 x 800
x	= (600 – 450)/2
	= 75 mm
Effective Width(B’1)	= b + 2x
	= 450+2x75
	= 600 mm
Effective Width(B’2)	= B+hc
	= 450+800
	= 1250 mm
Effective Width(B’)	= Min (600,1250)
	= 600 mm
Effective Depth	= D’ (Column Depth)
	= 900 mm
Effective area	= 600 x 900
	= 540000 sqmm
V-Reinf. calculation:	
Right top + left Bottom	= 2005.64 + 886.76
	= 2892.4 Sqmm
V-reinf	= 2892.4 x 420 x 1.25 x /1000
	= 1518.51 kN

Note:

Calculation of reinforcement provided in Beam is like as explained in Flexural joint check.

Check At Beam-Column Joints:

1. **Flexure Strength Of Joint:**

Moment Capacity Calculations for Beam

Concrete Grade,fck	=	C25	N/sqmm
Steel Grade,fy	=	Fy420	N/sqmm

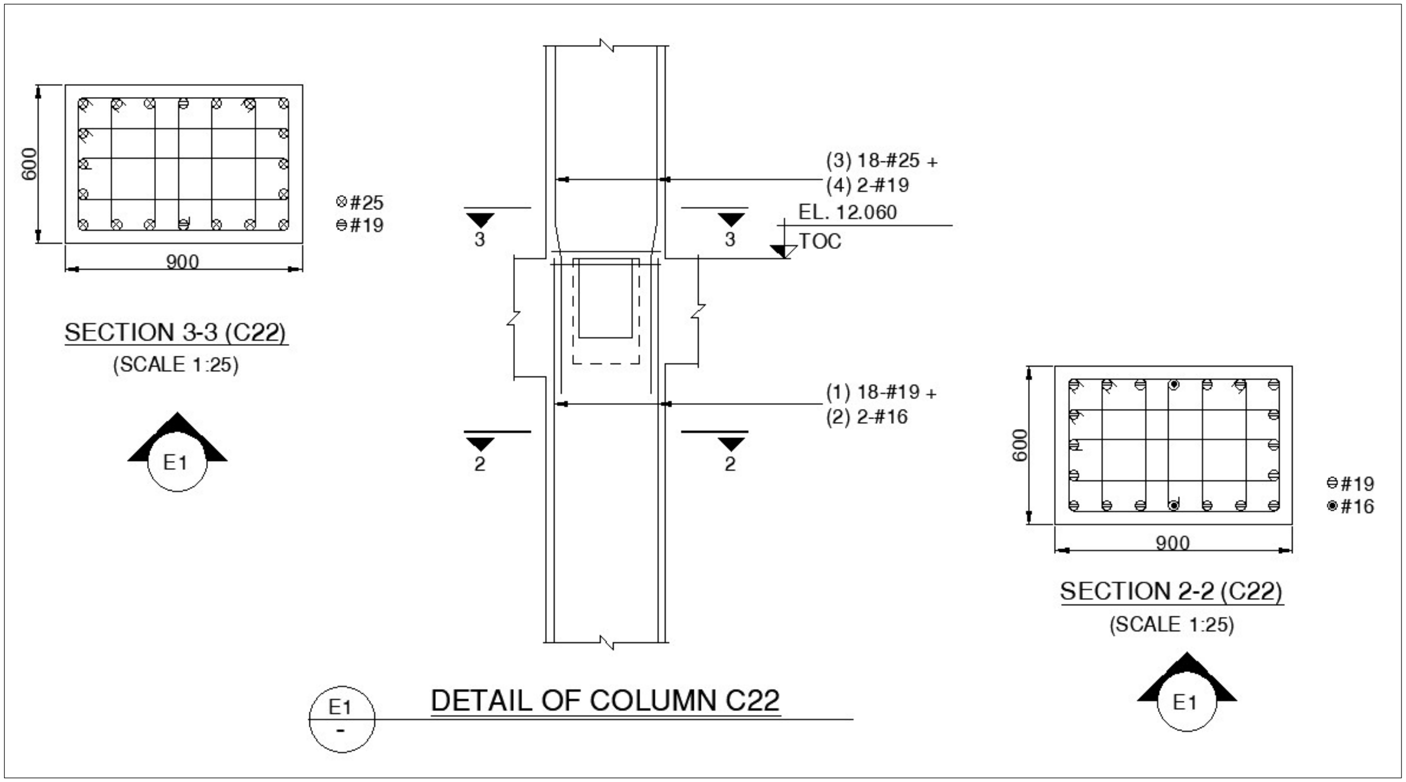
Beam Size	Beam angle w.r.t. column Ly	Torsion moment	Moment Capacity for Top Reinforcement				Moment Capacity for Bottom Reinforcement				Resultant Moment			
(mm)	(deg)	(kNm)	Mu (kNm)	Ast Req (sqmm)	Ast Pro (sqmm)	Mu Cap (kNm)	Mu (kNm)	Ast Req (sqmm)	Ast Pro (sqmm)	Mu Cap (kNm)	Top @ D (kNm)	Top @ B (kNm)	Bot @ D (kNm)	Bot @ B (kNm)
450 x 800	0	0	526.57	1986.13	2005.64	531.42	0	993.07	1013.44	277.05	531.42	0	277.05	0
500 x 800	90	0.69	622.63	2358.55	2382.72	628.58	0	1179.28	1266.8	345.01	0	628.58	0	345.01
300 x 900	180	0.48	464.11	1546.22	1588.48	475.96	0	773.11	886.76	273.66	475.96	0	273.66	0
400 x 600	270	0.46	562.24	3190.69	3546.97	613.22	0	1595.34	1626.2	310.84	0	613.22	0	310.84

Effective Moment for Beam

	Along D		Along B	
	Left	Right	Left	Right
Top (kNm)	475.96	531.42	613.22	628.58
Bottom (kNm)	273.66	277.05	310.84	345.01
Mnb (kNm)	MAX((Left Bottom + Right Top), (Left Top + Right Bottom))		MAX((Left Top + Right Bottom), (Right Top + Left Bottom))	
	805.07		958.23	

Vj (Shear Demand)	=1518.51 – 805.07	
	= 713.44 kN	
Vn'	= 1.7 x λ x Sqrt (f’c) x Aj	
	= 1.7 x 1 x Sqrt (25) x 540000	
	= 4590 kN	
Check	Vj < Vn'	Ok

RCDC DRAWING OUTPUT



8. Sample STAAD files used for validation

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ENGINEER DATE 17-Apr-19
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 8 0 0; 3 16 0 0; 4 24 0 0; 5 31.96 0 0; 6 0 0 5.71; 7 8 0 5.71;
8 16 0 5.71; 9 24 0 5.71; 10 31.96 0 5.71; 11 0 0 14.61; 12 8 0 14.61;
13 16 0 14.61; 14 24 0 14.61; 16 36.77 0 14.61; 17 46.08 0 10.87; 18 0 0 23.66;
19 8 0 23.66; 20 16 0 23.66; 21 24 0 23.66; 22 31.96 0 23.66; 23 39.75 0 23.66;
24 49.06 0 19.36; 25 0 0 32.61; 26 8 0 32.61; 27 16 0 32.61; 28 24 0 32.61;
29 31.96 0 32.61; 30 37.83 0 32.61; 31 42.7 0 32.61; 41 0 4.2 0; 42 8 4.2 0;
43 16 4.2 0; 44 24 4.2 0; 45 31.96 4.2 0; 46 0 4.2 5.71; 47 8 4.2 5.71;
48 16 4.2 5.71; 49 24 4.2 5.71; 50 31.96 4.2 5.71; 51 0 4.2 14.61;
52 8 4.2 14.61; 53 16 4.2 14.61; 54 24 4.2 14.61; 55 31.96 4.2 14.61;
56 36.77 4.2 14.61; 57 46.08 4.2 10.87; 58 0 4.2 23.66; 59 8 4.2 23.66;
60 16 4.2 23.66; 61 24 4.2 23.66; 62 31.96 4.2 23.66; 63 39.75 4.2 23.66;
64 49.06 4.2 19.36; 65 0 4.2 32.61; 66 8 4.2 32.61; 67 16 4.2 32.61;
68 24 4.2 32.61; 69 31.96 4.2 32.61; 70 37.83 4.2 32.61; 71 42.7 4.2 32.61;
72 33.8399 4.2 5.71; 73 31.96 4.2 17.86; 74 37.8402 4.2 17.86;
75 34.36 4.2 17.86; 76 34.36 4.2 14.61; 77 31.96 4.2 26.15;
78 40.5707 4.2 26.15; 79 37.83 4.2 23.66; 80 37.83 4.2 26.15; 81 0 7.8576 0;
82 8 7.8576 0; 83 16 7.8576 0; 84 24 7.8576 0; 85 31.96 7.8576 0;
86 0 7.8576 5.71; 87 8 7.8576 5.71; 88 16 7.8576 5.71; 89 24 7.8576 5.71;
90 31.96 7.8576 5.71; 91 0 7.8576 14.61; 92 8 7.8576 14.61; 93 16 7.8576 14.61;
94 24 7.8576 14.61; 95 31.96 7.8576 14.61; 96 36.77 7.8576 14.61;
97 46.08 7.8576 10.87; 98 0 7.8576 23.66; 99 8 7.8576 23.66;
100 16 7.8576 23.66; 101 24 7.8576 23.66; 102 31.96 7.8576 23.66;
103 39.75 7.8576 23.66; 104 49.06 7.8576 19.36; 105 0 7.8576 32.61;
106 8 7.8576 32.61; 107 16 7.8576 32.61; 108 24 7.8576 32.61;
109 31.96 7.8576 32.61; 110 37.83 7.8576 32.61; 111 42.7 7.8576 32.61;
112 33.8399 7.8576 5.71; 113 31.96 7.8576 17.86; 114 37.8402 7.8576 17.86;
115 34.36 7.8576 17.86; 116 34.36 7.8576 14.61; 117 31.96 7.8576 26.15;
118 40.5707 7.8576 26.15; 119 37.83 7.8576 23.66; 120 37.83 7.8576 26.15;
121 0 12.0576 0; 122 8 12.0576 0; 123 16 12.0576 0; 124 24 12.0576 0;
125 31.96 12.0576 0; 126 0 12.0576 5.71; 127 8 12.0576 5.71;
128 16 12.0576 5.71; 129 24 12.0576 5.71; 130 31.96 12.0576 5.71;
131 0 12.0576 14.61; 132 8 12.0576 14.61; 133 16 12.0576 14.61;
134 24 12.0576 14.61; 135 31.96 12.0576 14.61; 136 36.77 12.0576 14.61;
138 0 12.0576 23.66; 139 8 12.0576 23.66; 140 16 12.0576 23.66;
141 24 12.0576 23.66; 142 31.96 12.0576 23.66; 143 39.75 12.0576 23.66;
145 0 12.0576 32.61; 146 8 12.0576 32.61; 147 16 12.0576 32.61;
148 24 12.0576 32.61; 149 31.96 12.0576 32.61; 150 37.83 12.0576 32.61;
151 42.7 12.0576 32.61; 152 33.8399 12.0576 5.71; 153 31.96 12.0576 17.86;
154 37.8402 12.0576 17.86; 155 34.36 12.0576 17.86; 156 34.36 12.0576 14.61;
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157 31.96 12.0576 26.15; 158 40.5707 12.0576 26.15; 159 37.83 12.0576 23.66;
160 37.83 12.0576 26.15; 161 0 16.2576 0; 162 8 16.2576 0; 163 16 16.2576 0;
164 24 16.2576 0; 165 31.96 16.2576 0; 166 0 16.2576 5.71; 167 8 16.2576 5.71;
168 16 16.2576 5.71; 169 24 16.2576 5.71; 170 31.96 16.2576 5.71;
171 0 16.2576 14.61; 172 8 16.2576 14.61; 173 16 16.2576 14.61;
174 24 16.2576 14.61; 175 31.96 16.2576 14.61; 176 36.77 16.2576 14.61;
178 0 16.2576 23.66; 179 8 16.2576 23.66; 180 16 16.2576 23.66;
181 24 16.2576 23.66; 182 31.96 16.2576 23.66; 183 39.75 16.2576 23.66;
185 0 16.2576 32.61; 186 8 16.2576 32.61; 187 16 16.2576 32.61;
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191 42.7 16.2576 32.61; 192 33.8399 16.2576 5.71; 193 31.96 16.2576 17.86;
194 37.8402 16.2576 17.86; 195 34.36 16.2576 17.86; 196 34.36 16.2576 14.61;
197 31.96 16.2576 26.15; 198 40.5707 16.2576 26.15; 199 37.83 16.2576 23.66;
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203 31.96 7.8576 16.085; 204 34.36 7.8576 16.085; 205 31.96 12.0576 16.085;
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213 31.96 0 16.085; 214 34.36 0 16.085; 215 31.96 4.2 14.31;
216 33.16 4.2 14.31; 217 31.96 7.8576 14.31; 218 33.16 7.8576 14.31;
219 31.96 12.0576 14.31; 220 33.16 12.0576 14.31; 221 31.96 16.2576 14.31;
222 33.16 16.2576 14.31; 223 34.36 4.2 14.31; 224 34.36 7.8576 14.31;
225 34.36 12.0576 14.31; 226 34.36 16.2576 14.31; 227 33.16 0 14.31;
MEMBER INCIDENCES
1 1 41; 11 41 81; 21 81 121; 31 121 161; 101 2 42; 111 42 82; 121 82 122;
131 122 162; 201 3 43; 211 43 83; 221 83 123; 231 123 163; 301 4 44; 311 44 84;
321 84 124; 331 124 164; 401 5 45; 411 45 85; 421 85 125; 431 125 165;
501 6 46; 511 46 86; 521 86 126; 531 126 166; 601 7 47; 611 47 87; 621 87 127;
631 127 167; 701 8 48; 711 48 88; 721 88 128; 731 128 168; 801 9 49; 811 49 89;
821 89 129; 831 129 169; 901 10 50; 911 50 90; 921 90 130; 931 130 170;
1001 11 51; 1011 51 91; 1021 91 131; 1031 131 171; 1101 12 52; 1111 52 92;
1121 92 132; 1131 132 172; 1201 13 53; 1211 53 93; 1221 93 133; 1231 133 173;
1301 14 54; 1311 54 94; 1321 94 134; 1331 134 174; 1501 16 56; 1511 56 96;
1521 96 136; 1531 136 176; 1601 17 57; 1611 57 97; 1701 18 58; 1711 58 98;
1721 98 138; 1731 138 178; 1801 19 59; 1811 59 99; 1821 99 139; 1831 139 179;
1901 20 60; 1911 60 100; 1921 100 140; 1931 140 180; 2001 21 61; 2011 61 101;
2021 101 141; 2031 141 181; 2101 22 62; 2111 62 102; 2121 102 142;
2131 142 182; 2201 23 63; 2211 63 103; 2221 103 143; 2231 143 183; 2301 24 64;
2311 64 104; 2401 25 65; 2411 65 105; 2421 105 145; 2431 145 185; 2501 26 66;
2511 66 106; 2521 106 146; 2531 146 186; 2601 27 67; 2611 67 107; 2621 107 147;
2631 147 187; 2701 28 68; 2711 68 108; 2721 108 148; 2731 148 188; 2801 29 69;
2811 69 109; 2821 109 149; 2831 149 189; 2901 30 70; 2911 70 110; 2921 110 150;
2931 150 190; 3001 31 71; 3011 71 111; 3021 111 151; 3031 151 191; 4001 41 42;
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6003 123 124; 6004 124 125; 6005 126 127; 6006 127 128; 6007 128 129;
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7003 163 164; 7004 164 165; 7005 166 167; 7006 167 168; 7007 168 169;
7008 169 170; 7009 171 172; 7010 172 173; 7011 173 174; 7012 174 175;
7014 178 179; 7015 179 180; 7016 180 181; 7017 181 182; 7018 182 199;
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7024 190 191; 7025 185 178; 7026 178 171; 7027 171 166; 7028 166 161;
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7044 170 165; 7045 191 198; 7046 183 194; 7047 176 192; 7051 170 192;
7052 192 165; 7053 193 207; 7054 193 195; 7055 194 176; 7056 195 194;
7057 196 176; 7058 195 208; 7059 197 182; 7060 197 200; 7061 198 183;
7062 199 183; 7063 190 200; 7064 200 199; 7065 201 55; 7066 202 76;
7067 203 95; 7068 204 116; 7069 205 135; 7070 206 156; 7071 207 175;
7072 208 196; 7077 213 201; 7079 214 202; 7080 201 203; 7081 203 205;
7082 202 204; 7083 204 206; 7086 205 207; 7087 206 208; 7088 215 50;
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7094 221 170; 7095 221 222; 7096 216 223; 7097 218 224; 7098 220 225;
7099 222 226; 7100 227 216; 7101 216 218; 7102 218 220; 7103 220 222;
7104 76 223; 7105 116 224; 7106 156 225; 7107 196 226;

```
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.5e+07
POISSON 0.17
DENSITY 25
ALPHA 1e-05
DAMP 0.05
ISOTROPIC CONCDUMMY
E 2.5e+07
POISSON 0.17
DENSITY 0
ALPHA 1e-05
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
1 11 21 31 101 111 121 131 201 211 221 231 301 311 321 331 401 411 421 431 -
501 511 521 531 601 611 621 631 701 711 721 731 801 811 821 831 901 911 921 -
931 1001 1011 1021 1031 1101 1111 1121 1131 1201 1211 1221 1231 1301 1311 -
1321 1331 1701 1711 1721 1731 2001 2011 2021 2031 2101 2111 2121 2131 2701 -
2711 2721 2731 2801 2811 2821 2831 2901 2911 2921 2931 3001 3011 3021 -
3031 PRIS IX 1e-09 YD 0.7 ZD 0.7
1501 1511 1521 1531 2201 2211 2221 -
2231 PRIS AX 0.315 IX 1e-09 IY 0.00531562 IZ 0.0128625 YD 0.9 ZD 0.6
1601 1611 2301 -
2311 PRIS AX 0.2025 IX 1e-09 IY 0.00341719 IZ 0.00341719 YD 0.5 ZD 0.5
MEMBER PROPERTY INDIAN
4001 TO 4004 4019 TO 4028 4041 4042 4044 4048 TO 4050 4054 4056 4059 4063 -
4064 5001 TO 5004 5019 TO 5028 5041 5042 5044 5048 TO 5050 5054 5056 5059 -
5063 5064 6001 TO 6004 6019 TO 6028 6041 6042 6044 6054 6056 6059 6063 6064 -
7001 TO 7004 7019 TO 7028 7041 7042 7044 7054 7056 7059 7063 7064 7088 7090 -
7092 7094 PRIS AX 0.315 IX 1e-09 IY 0.00321562 IZ 0.0212625 YD 0.8 ZD 0.4
4005 TO 4012 4015 TO 4018 4031 TO 4040 4045 TO 4047 4051 4052 4055 4057 4061 -
4062 5005 TO 5012 5015 TO 5018 5031 TO 5040 5045 TO 5047 5051 5052 5055 5057 -
5061 5062 6005 TO 6012 6015 TO 6018 6031 TO 6040 6045 TO 6047 6051 6052 6055 -
6057 6061 6062 7005 TO 7012 7015 TO 7018 7031 TO 7040 7045 TO 7047 7051 7052 -
7055 7057 7061 -
7062 PRIS AX 0.54 IX 1e-09 IY 0.0162 IZ 0.03645 YD 0.8 ZD 0.45
4060 5060 6060 -
7060 PRIS AX 0.1725 IX 1e-09 IY 0.000760437 IZ 0.00808594 YD 0.75 ZD 0.23
MEMBER PROPERTY INDIAN
7077 7079 TO 7083 7086 7087 PRIS YD 3.55 ZD 0.35
7100 TO 7103 PRIS YD 2.4 ZD 0.3
MEMBER PROPERTY INDIAN
4043 4053 4058 5043 5053 5058 6043 6053 6058 7043 7053 7058 7065 TO 7072 7089 -
7091 7093 7095 TO 7099 7104 TO 7107 PRIS YD 4.2 ZD 0.35
MEMBER PROPERTY INDIAN
1801 1811 1821 1831 1901 1911 1921 1931 2401 2411 2421 2431 2501 2511 2521 -
```

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2531 2601 2611 2621 2631 PRIS YD 0.9 ZD 0.6
MEMBER PROPERTY
4029 5029 6029 7029 PRIS YD 0.6 ZD 0.4
4030 5030 6030 7030 PRIS YD 0.8 ZD 0.5
4014 5014 6014 7014 PRIS YD 0.9 ZD 0.3
SUPPORTS
1 TO 4 6 TO 9 11 TO 14 16 TO 21 23 TO 28 30 31 FIXED
5 10 22 29 213 214 227 FIXED
CONSTANTS
BETA 90 MEMB 1901 1911 1921 1931 2601 2611 2621 2631 7077 7079 TO 7083 7086 -
7087
MATERIAL CONCRETE MEMB 1 11 21 31 101 111 121 131 201 211 221 231 301 311 -
321 331 401 411 421 431 501 511 521 531 601 611 621 631 701 711 721 731 801 -
811 821 831 901 911 921 931 1001 1011 1021 1031 1101 1111 1121 1131 1201 -
1211 1221 1231 1301 1311 1321 1331 1501 1511 1521 1531 1601 1611 1701 1711 -
1721 1731 1801 1811 1821 1831 1901 1911 1921 1931 2001 2011 2021 2031 2101 -
2111 2121 2131 2201 2211 2221 2231 2301 2311 2401 2411 2421 2431 2501 2511 -
2521 2531 2601 2611 2621 2631 2701 2711 2721 2731 2801 2811 2821 2831 2901 -
2911 2921 2931 3001 3011 3021 3031 4001 TO 4012 4014 TO 4042 4044 TO 4052 -
4054 TO 4057 4059 TO 4064 5001 TO 5012 5014 TO 5042 5044 TO 5052 -
5054 TO 5057 5059 TO 5064 6001 TO 6012 6014 TO 6042 6044 TO 6047 6051 6052 -
6054 TO 6057 6059 TO 6064 7001 TO 7012 7014 TO 7042 7044 TO 7047 7051 7052 -
7054 TO 7057 7059 TO 7064 7077 7079 TO 7083 7086 TO 7088 7090 7092 7094 7100 -
7101 TO 7103
MATERIAL CONCDUMMY MEMB 4043 4053 4058 5043 5053 5058 6043 6053 6058 7043 -
7053 7058 7065 TO 7072 7089 7091 7093 7095 TO 7099 7104 TO 7107
LOAD 1 LOADTYPE Dead  TITLE LOAD CASE 1
SELFWEIGHT Y -1
MEMBER LOAD
4001 TO 4004 4019 TO 4028 4041 4042 4053 4059 4060 4063 4064 5001 TO 5004 -
5019 TO 5028 5041 5042 5053 5059 5060 5063 5064 6001 TO 6004 6019 TO 6028 -
6041 6042 6053 6059 6060 6063 6064 7065 7067 7069 UNI GY -14.285
7001 TO 7004 7019 TO 7028 7041 7042 7053 7059 7060 7063 7064 7071 UNI GY -5
FLOOR LOAD
YRANGE 7 16 FLOAD -6 XRANGE 0 33  ZRANGE 0 33  GY
YRANGE 7 16 FLOAD -6 XRANGE 31.96 36.77  ZRANGE 0 14.61  GY
YRANGE 7 16 FLOAD -6 XRANGE 31.96 42.7  ZRANGE 23.66 32.61  GY
YRANGE 7 16 FLOAD -6 XRANGE 31.96 39.75  ZRANGE 17.86 23.66  GY
YRANGE 7 16 FLOAD -6 XRANGE 34.36 37.84  ZRANGE 14.61 17.86  GY
YRANGE 7 10 FLOAD -6 XRANGE 36.77 49.06  ZRANGE 10.87 23.66  GY
YRANGE 15 17 FLOAD -6 XRANGE 0 33  ZRANGE 0 33  GY
YRANGE 15 17 FLOAD -6 XRANGE 31.96 36.77  ZRANGE 0 14.61  GY
YRANGE 15 17 FLOAD -6 XRANGE 31.96 42.7  ZRANGE 23.66 32.61  GY
YRANGE 15 17 FLOAD -6 XRANGE 31.96 39.75  ZRANGE 17.86 23.66  GY
YRANGE 15 17 FLOAD -6 XRANGE 34.36 37.84  ZRANGE 14.61 17.86  GY
LOAD 2 LOADTYPE Live  TITLE LOAD CASE 2
FLOOR LOAD
```

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YRANGE 7 16 FLOAD -4 XRANGE 0 33  ZRANGE 0 33  GY
YRANGE 7 16 FLOAD -4 XRANGE 31.96 36.77  ZRANGE 0 14.61  GY
YRANGE 7 16 FLOAD -4 XRANGE 31.96 42.7  ZRANGE 23.66 32.61  GY
YRANGE 7 16 FLOAD -4 XRANGE 31.96 39.75  ZRANGE 17.86 23.66  GY
YRANGE 7 16 FLOAD -4 XRANGE 34.36 37.84  ZRANGE 14.61 17.86  GY
YRANGE 7 10 FLOAD -2 XRANGE 36.77 49.06  ZRANGE 10.87 23.66  GY
YRANGE 15 17 FLOAD -1.5 XRANGE 0 33  ZRANGE 0 33  GY
YRANGE 15 17 FLOAD -1.5 XRANGE 31.96 36.77  ZRANGE 0 14.61  GY
YRANGE 15 17 FLOAD -1.5 XRANGE 31.96 42.7  ZRANGE 23.66 32.61  GY
YRANGE 15 17 FLOAD -1.5 XRANGE 31.96 39.75  ZRANGE 17.86 23.66  GY
YRANGE 15 17 FLOAD -1.5 XRANGE 34.36 37.84  ZRANGE 14.61 17.86  GY
LOAD 3 LOADTYPE None  TITLE LOAD CASE 3 EQ-X
JOINT LOAD
161 TO 176 178 TO 183 185 TO 191 221 FX 35
121 TO 136 138 TO 143 145 TO 151 219 FX 15
81 TO 111 217 FX 7.5
41 TO 71 215 FX 2
LOAD 4 LOADTYPE None  TITLE LOAD CASE 4 EQ-Y
JOINT LOAD
161 TO 176 178 TO 183 185 TO 191 221 FZ 35
121 TO 136 138 TO 143 145 TO 151 219 FZ 15
81 TO 111 217 FZ 7.5
41 TO 71 215 FZ 2
LOAD COMBINATION 11
1 1.4
LOAD COMBINATION 12
1 1.2 2 1.0
LOAD COMBINATION 13
1 1.2 2 1.6
LOAD COMBINATION 14
1 1.2 2 1.0 3 1.4
LOAD COMBINATION 15
1 1.2 2 1.0 3 -1.4
LOAD COMBINATION 16
1 1.2 2 1.0 4 1.4
LOAD COMBINATION 17
1 1.2 2 1.0 4 -1.4
LOAD COMBINATION 18
1 0.9 3 1.4
LOAD COMBINATION 19
1 0.9 3 -1.4
LOAD COMBINATION 20
1 0.9 4 1.4
LOAD COMBINATION 21
1 0.9 4 -1.4
PERFORM ANALYSIS
FINISH
```