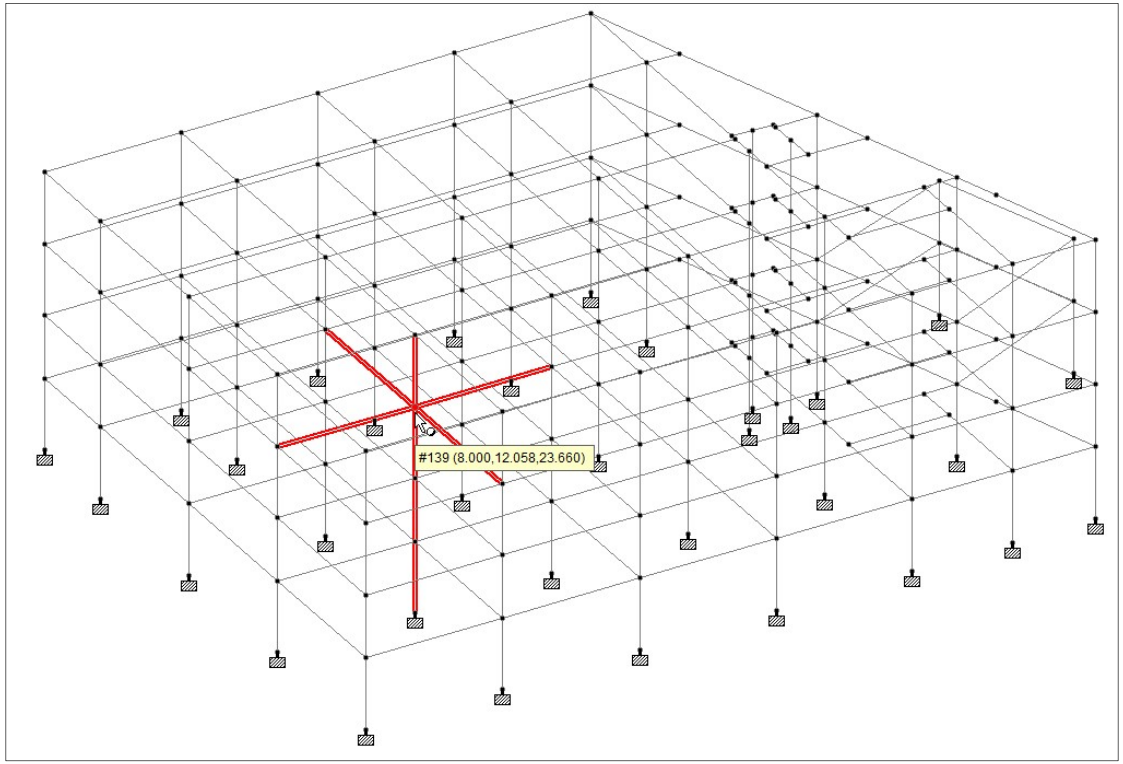
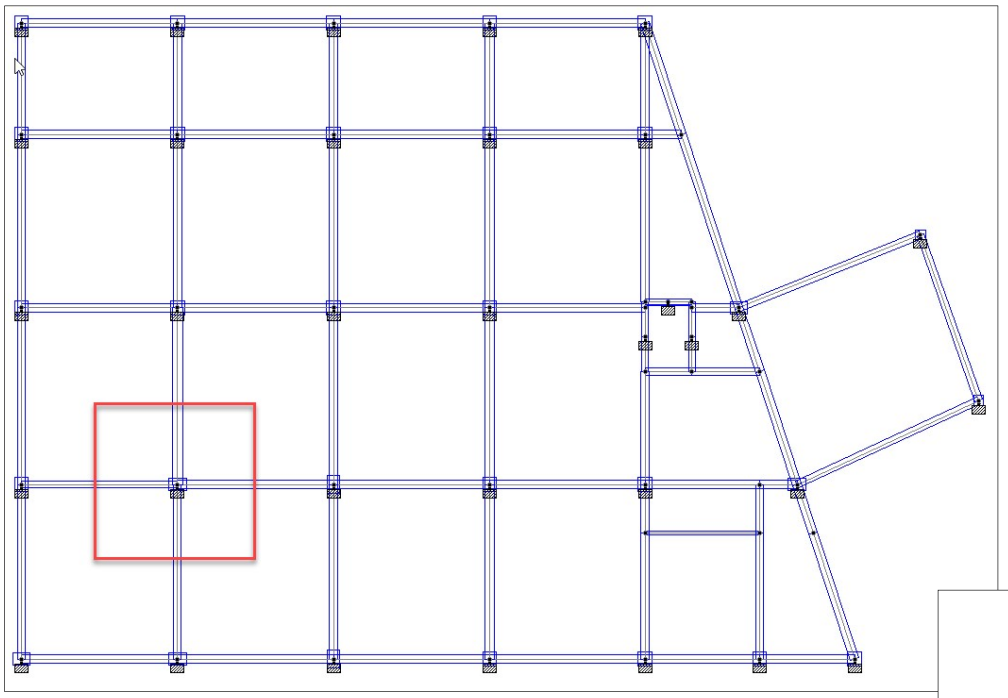
Validation Problem for Joint Checks as per IS 13920-2016

Input Data:

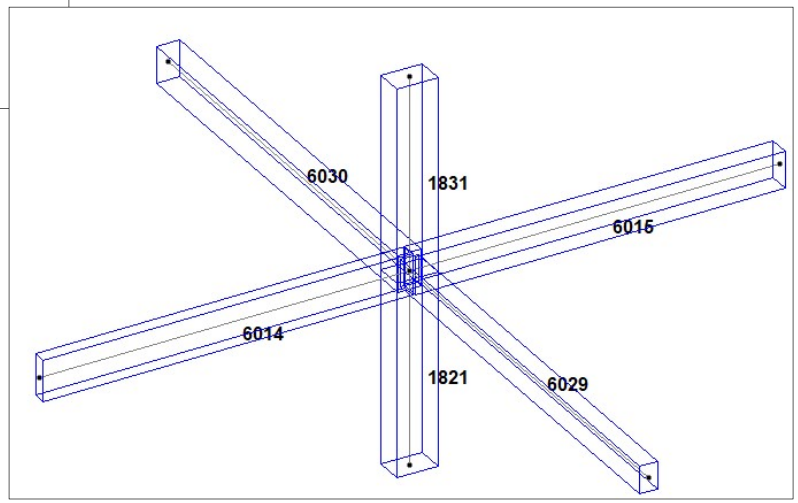
STAAD file	= RCDC-Staad-Demo -with RCC wall
Joint level	= 12.058 m
Column No. (RCDC)	= C22
Column Member no. (below joint)	= 1821
Column Member no.(above joint)	= 1831
Column Size	= 600 x 900
Height of column below Joint	= 4200 mm
Height of column Above Joint	= 4200 mm



3D View



Top View



Element Numbers at Joint at 12.058m level

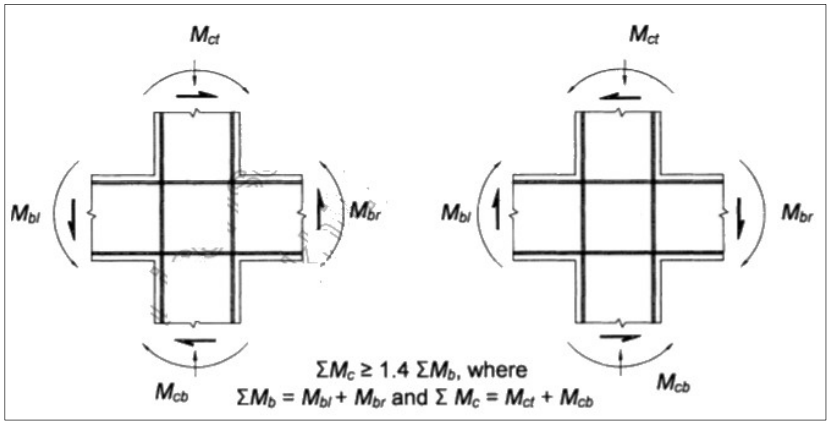
Note: STAAD command file is available at end of this document

Relative Strength of Beams and Column at a Joint (Clause 7.2)

7.2 Relative Strengths of Beams and Columns at a Joint

7.2.1 At each beam-column joint of a moment-resisting frame, the sum of nominal design strength of columns meeting at that joint (with nominal strength calculated for the factored axial load in the direction of the lateral force under consideration so as to give least column nominal design strength) along each principal plane shall be at least 1.4 times the sum of nominal design strength of beams meeting at that joint in the same plane (*see* Fig. 8).

In the event of a beam-column joint not conforming to above, the columns at the joint shall be considered to be gravity columns only and shall not be considered as part of the lateral load resisting system.



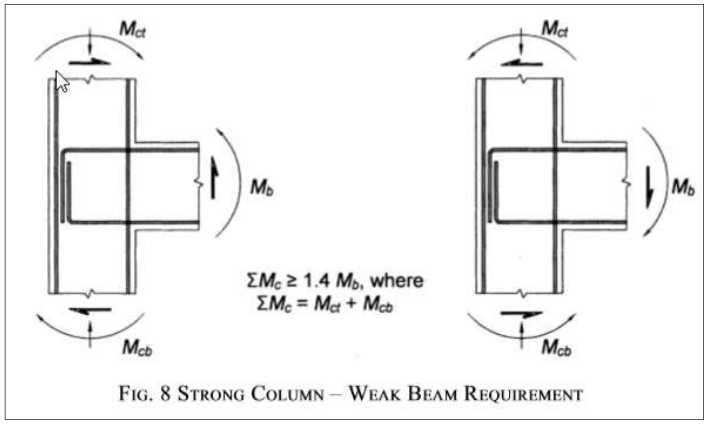


FIG. 8 STRONG COLUMN – WEAK BEAM REQUIREMENT

Amendment No. 1 to IS 13920 : 2016

7.2.1.1

'The design moment of resistance of a column shall be estimated for factored axial forces arising in all load combination using the design *P-M* interaction diagram.'

RCDC Report for Flexural strength of Joint

General Data:

Column No.	:	C22	
Joint at Level	:	12.058m	
Design Code	=	IS 456 + IS 13920 - 2016	
Concrete Grade	=	M25	N/sqmm
Steel Grade	=	Fe415	N/sqmm
Column Width	=	600	mm
Column Depth	=	900	mm

Check At Beam-Column Joints:

1. Flexure Strength Of Joint:

Moment Capacity Calculations for Beam

Beam Size	gle w.r.t. co	rsion mome	Moment Capacity Beam at Top				Moment Capacity Beam at Bottom				Resultant Moment			
(mm)	(deg)	(kNm)	Mu	Ast Req	Ast Pro	Mu Cap	Mu	Ast Req	Ast Pro	Mu Cap	Top @ D	Top @ B	Bot @ D	Bot @ B
			(kNm)	(sqmm)	(sqmm)	(kNm)	(kNm)	(sqmm)	(sqmm)	(kNm)	(kNm)	(kNm)	(kNm)	(kNm)
450 x 800	0	0	523.32	2182.62	2199.12	526.77	0	969.4	1005.3	256.88	526.77	0	256.88	0
500 x 800	90	1.29	672.37	2877.03	3141.6	726.1	0	1077.11	1206.36	306.95	0	726.1	0	306.95
300 x 900	180	0.68	482.52	1800.11	1884.96	503.72	0	733.01	804.24	232.37	503.72	0	232.37	0
400 x 600	270	-0.45	582.49	3572.5	3926.96	672.69	0	630.36	804.24	148.51	0	672.69	0	148.51

Effective Moment for Column

	Mu Major (Along D) (kNm)		Mu Minor (Along B) (kNm)	
	Left	Right	Left	Right
Top	503.72	526.77	672.69	726.1
Bottom	232.37	256.88	148.51	306.95

Moment Along D:

Mnb	=	MAX((Left Bottom + Right Top), (Left Top + Right Bottom))
	=	760.59 kNm
Mnc Top	=	1490.97 kNm
Mnc Bottom	=	1004.41 kNm
Mncd	=	2495.39 kNm
Mncd	>=	1.4 x Mnb, Hence OK

Moment Along B:

Mnb	=	MAX((Left Top + Right Bottom), (Right Top + Left Bottom))	
	=	979.64	kNm
Mnc Top	=	1055.77	kNm
Mnc Bottom	=	704.11	kNm
Mncb	=	1759.88	kNm
Mncb	>=	1.4 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
Mncd	= Mnc Top + Mnc Bottom, along D
Mncb	= Mnc Top + Mnc Bottom, along B

Calculation of Column Capacity:

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

Member force table from RCDC:

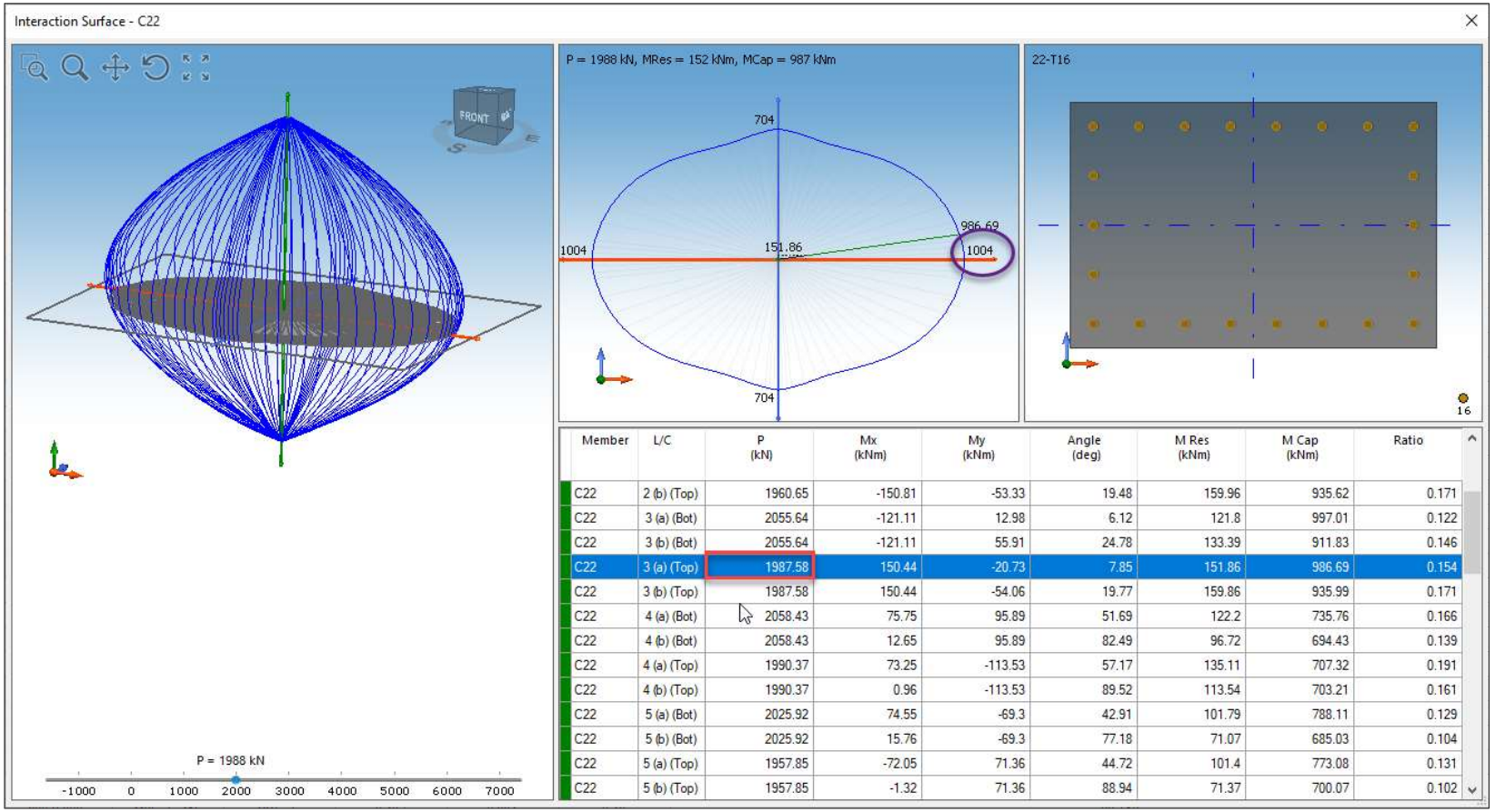
Columns	Level	Analysis No	Load Comb	Load Comb	Load Comb	Location	P	Mx	My	ShearX	ShearY
			Ref No	Analysis No	Description	(m)	(kN)	(kNm)	(kNm)	(kN)	(kN)
C22	12.058m	1821	1		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)	0	2552.72	17.76	16.62	-10.24	4.28
			1		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)	4.2	2467.64	-0.23	-26.36	-10.24	4.28
			2		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 3: LOAD CASE 3 EQ-X)	0	2028.71	149.52	13.61	-8.35	71.52
			2		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1960.65	-150.81	-21.45	-8.35	71.52
			3		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 3: LOAD CASE 3 EQ-X)	0	2055.64	-121.11	12.98	-8.03	-64.67
			3		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1987.58	150.44	-20.73	**-8.03**	-64.67
			4		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	0	2058.43	12.65	95.89	-49.88	2.78
			4		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1990.37	0.96	-113.53	-49.88	2.78
			5		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	0	2025.92	15.76	-69.3	33.5	4.07
			5		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1957.85	-1.32	71.36	33.5	4.07
			6		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	1939.44	175.3	20.64	-11.9	84.6
			6		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1854.35	-179.92	-29.32	-11.9	84.6
			7		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	1973.1	-162.98	19.86	-11.5	-85.64
			7		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1888.02	196.64	-28.42	-11.5	-85.64
			8		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1976.59	4.22	123.49	-63.81	-1.33
			8		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1891.51	9.78	-144.43	-63.81	-1.33
			9		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1935.95	8.11	-82.99	40.41	0.28
			9		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1850.86	6.93	86.68	40.41	0.28
			10		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	1156.93	172.84	12.54	-7.22	84.81
			10		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1105.88	-183.26	-17.77	-7.22	84.81
			11		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	1190.59	-165.44	11.76	-6.82	-85.44
			11		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	1139.54	193.29	-16.88	-6.82	-85.44
			12		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1194.08	1.75	115.39	-59.13	-1.12
			12		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1143.03	6.44	-132.88	-59.13	-1.12
			13		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	1153.44	5.65	-91.09	45.09	0.49
			13		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	1102.39	3.59	98.23	45.09	0.49
C22	16.258m	1831	1		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)	0	1149.05	6.43	11.09	-5.4	4.53

Maximum Pu from Eq Combination Along X	1987.58	kN
Maximum Pu from Eq Combination Along Y	1990.37	kN

Along D

Maximum Pu from All Earthquake load combination — P = 1987.58 kN

Corresponding Column Capacity (Mnc Bottom) — Mx = 1004.41 kNm (refer below PM curve)

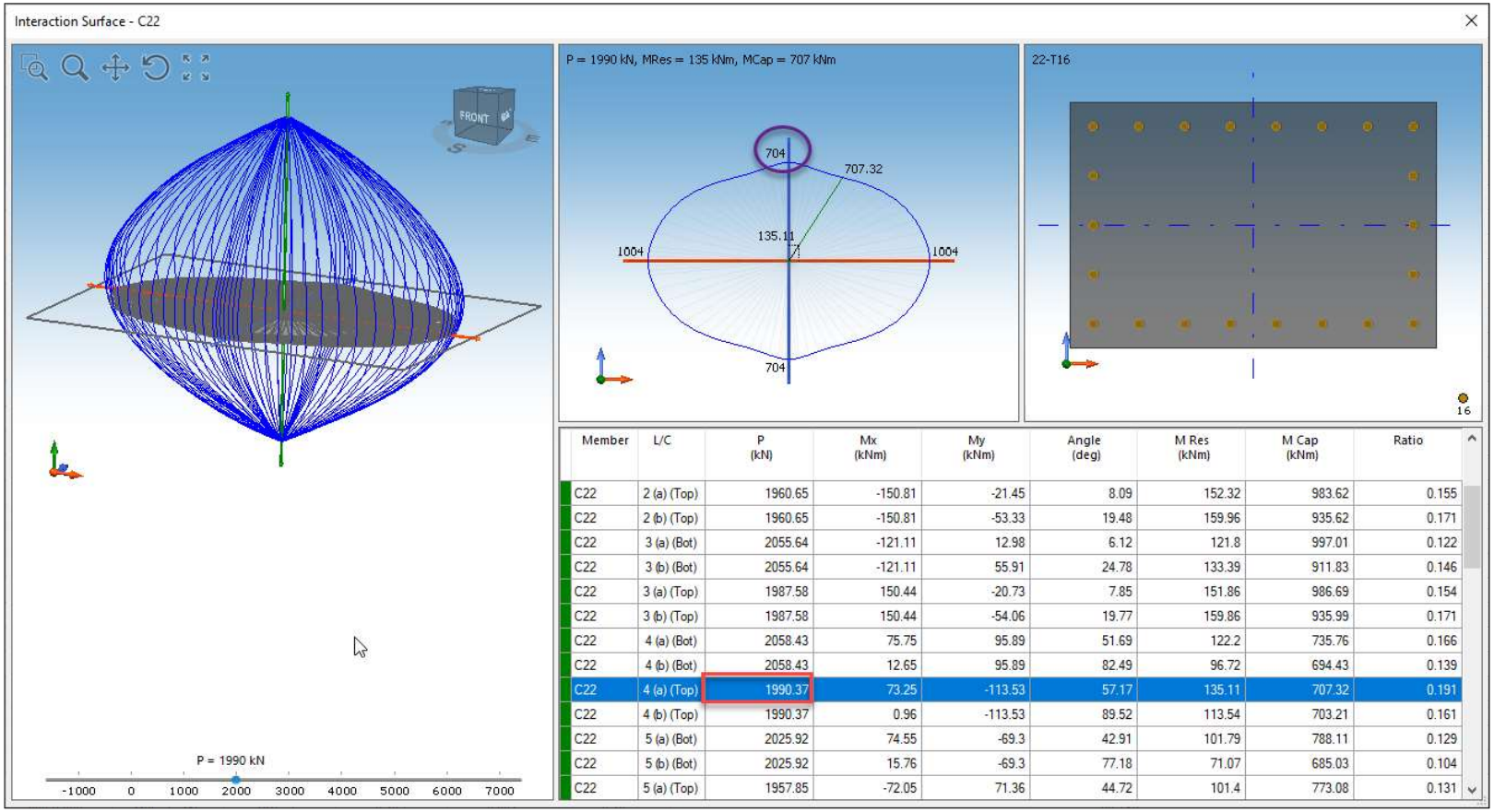


Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	2 (b) (Top)	1960.65	-150.81	-53.33	19.48	159.96	935.62	0.171
C22	3 (a) (Bot)	2055.64	-121.11	12.98	6.12	121.8	997.01	0.122
C22	3 (b) (Bot)	2055.64	-121.11	55.91	24.78	133.39	911.83	0.146
C22	3 (a) (Top)	1987.58	150.44	-20.73	7.85	151.86	986.69	0.154
C22	3 (b) (Top)	1987.58	150.44	-54.06	19.77	159.86	935.99	0.171
C22	4 (a) (Bot)	2058.43	75.75	95.89	51.69	122.2	735.76	0.166
C22	4 (b) (Bot)	2058.43	12.65	95.89	82.49	96.72	694.43	0.139
C22	4 (a) (Top)	1990.37	73.25	-113.53	57.17	135.11	707.32	0.191
C22	4 (b) (Top)	1990.37	0.96	-113.53	89.52	113.54	703.21	0.161
C22	5 (a) (Bot)	2025.92	74.55	-69.3	42.91	101.79	788.11	0.129
C22	5 (b) (Bot)	2025.92	15.76	-69.3	77.18	71.07	685.03	0.104
C22	5 (a) (Top)	1957.85	-72.05	71.36	44.72	101.4	773.08	0.131
C22	5 (b) (Top)	1957.85	-1.32	71.36	88.94	71.37	700.07	0.102

Along B

Maximum Pu from All Earthquake load combination — P = 1990.37 kN

Corresponding Column Capacity (Mnc Bottom) — Mx = 704.11 kNm (refer below PM curve)



Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	2 (a) (Top)	1960.65	-150.81	-21.45	8.09	152.32	983.62	0.155
C22	2 (b) (Top)	1960.65	-150.81	-53.33	19.48	159.96	935.62	0.171
C22	3 (a) (Bot)	2055.64	-121.11	12.98	6.12	121.8	997.01	0.122
C22	3 (b) (Bot)	2055.64	-121.11	55.91	24.78	133.39	911.83	0.146
C22	3 (a) (Top)	1987.58	150.44	-20.73	7.85	151.86	986.69	0.154
C22	3 (b) (Top)	1987.58	150.44	-54.06	19.77	159.86	935.99	0.171
C22	4 (a) (Bot)	2058.43	75.75	95.89	51.69	122.2	735.76	0.166
C22	4 (b) (Bot)	2058.43	12.65	95.89	82.49	96.72	694.43	0.139
C22	4 (a) (Top)	1990.37	73.25	-113.53	57.17	135.11	707.32	0.191
C22	4 (b) (Top)	1990.37	0.96	-113.53	89.52	113.54	703.21	0.161
C22	5 (a) (Bot)	2025.92	74.55	-69.3	42.91	101.79	788.11	0.129
C22	5 (b) (Bot)	2025.92	15.76	-69.3	77.18	71.07	685.03	0.104
C22	5 (a) (Top)	1957.85	-72.05	71.36	44.72	101.4	773.08	0.131

Column Above Joint at 16.258m level i.e. Bottom Node of Member 1831

Member force table from RCDC:

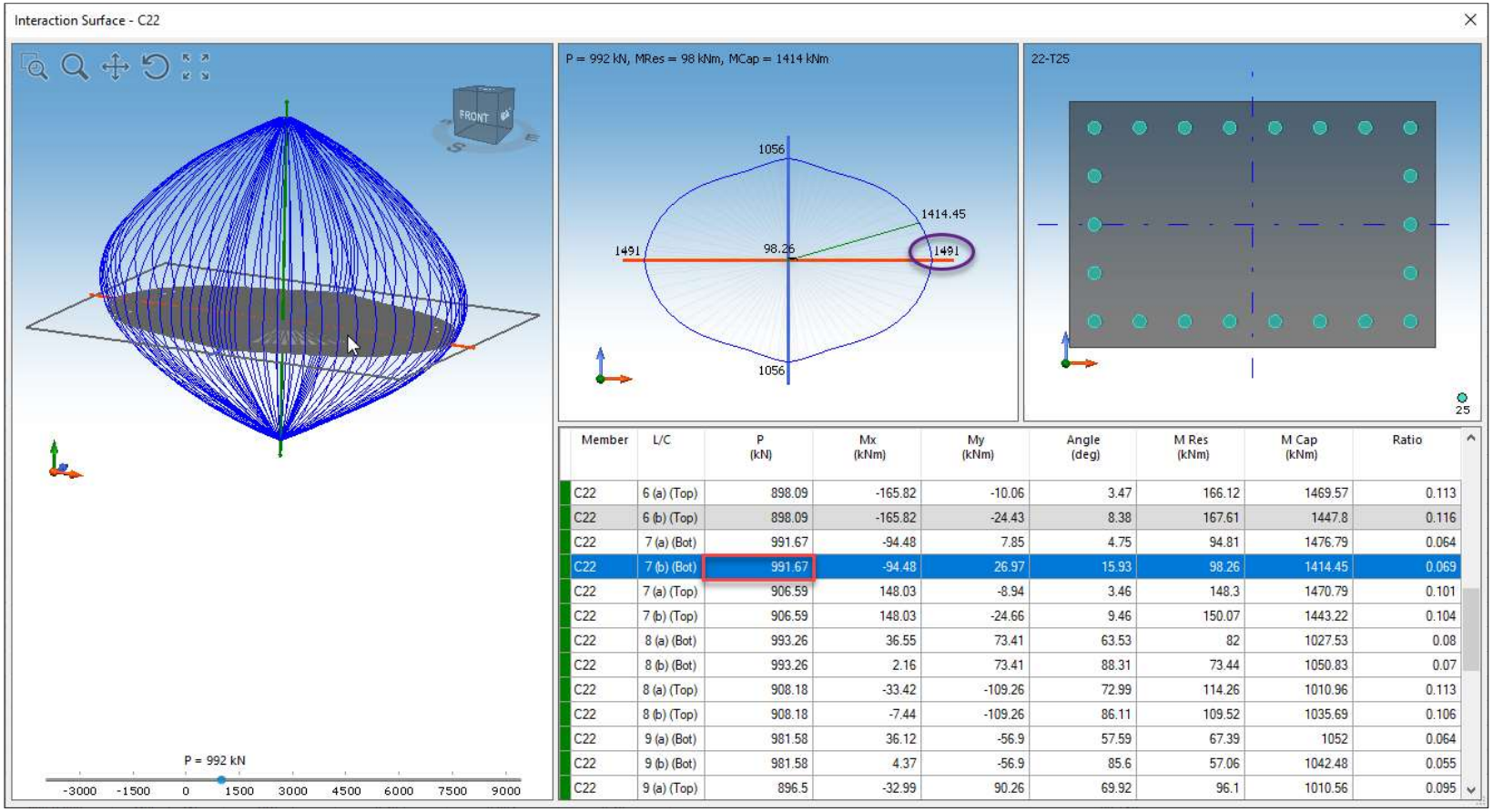
Columns	Level	Analysis No	Load Comb	Load Comb	Load Comb	Location	P	Mx	My	ShearX	ShearY
			Ref No	Analysis No	Description	(m)	(kN)	(kNm)	(kNm)	(kN)	(kN)
C22	16.258m	1831	1		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)	0	1149.05	6.43	11.09	-5.4	4.53
			1		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)	4.2	1063.96	-12.58	-11.6	-5.4	4.53
			2		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 3: LOAD CASE 3 EQ-X)	0	915.84	83.35	9.2	-4.51	52.14
			2		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	847.77	-135.6	-9.73	-4.51	52.14
			3		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 3: LOAD CASE 3 EQ-X)	0	922.64	-73.06	8.54	-4.14	-44.9
			3		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	854.57	115.48	-8.84	-4.14	-44.9
			4		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	0	923.91	4.26	60.99	-35.74	3.13
			4		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	855.84	-8.9	-89.09	-35.74	3.13
			5		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	0	914.56	6.03	-43.25	27.1	4.11
			5		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) -1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	846.5	-11.23	70.53	27.1	4.11
			6		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	983.17	101.02	8.66	-4.46	63.55
			6		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	898.09	-165.82	-10.06	-4.46	63.55
			7		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	991.67	-94.48	7.85	-4	-57.76
			7		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	906.59	148.03	-8.94	-4	-57.76
			8		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	993.26	2.16	73.41	-43.5	2.29
			8		1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	908.18	-7.44	-109.26	-43.5	2.29
			9		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	981.58	4.37	-56.9	35.05	3.51
			9		1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	896.5	-10.35	90.26	35.05	3.51
			10		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	588.2	99.71	5.36	-2.77	62.39
			10		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	537.15	-162.26	-6.26	-2.77	62.39
			11		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	0	596.7	-95.79	4.55	-2.31	-58.92
			11		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)	4.2	545.65	151.59	-5.14	-2.31	-58.92
			12		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	598.3	0.86	70.11	-41.81	1.13
			12		0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	547.24	-3.88	-105.46	-41.81	1.13
			13		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	0	586.61	3.07	-60.2	36.74	2.35
			13		0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)	4.2	535.56	-6.79	94.06	36.74	2.35

Maximum Pu from Eq Combination Along X	991.67	kN
Maximum Pu from Eq Combination Along Y	993.26	kN

Along D

Maximum Pu from All Earthquake load combination — P = 991.67 kN

Corresponding Column Capacity (Mnc Top) — Mx = 1490.97 kNm (refer below PM curve)

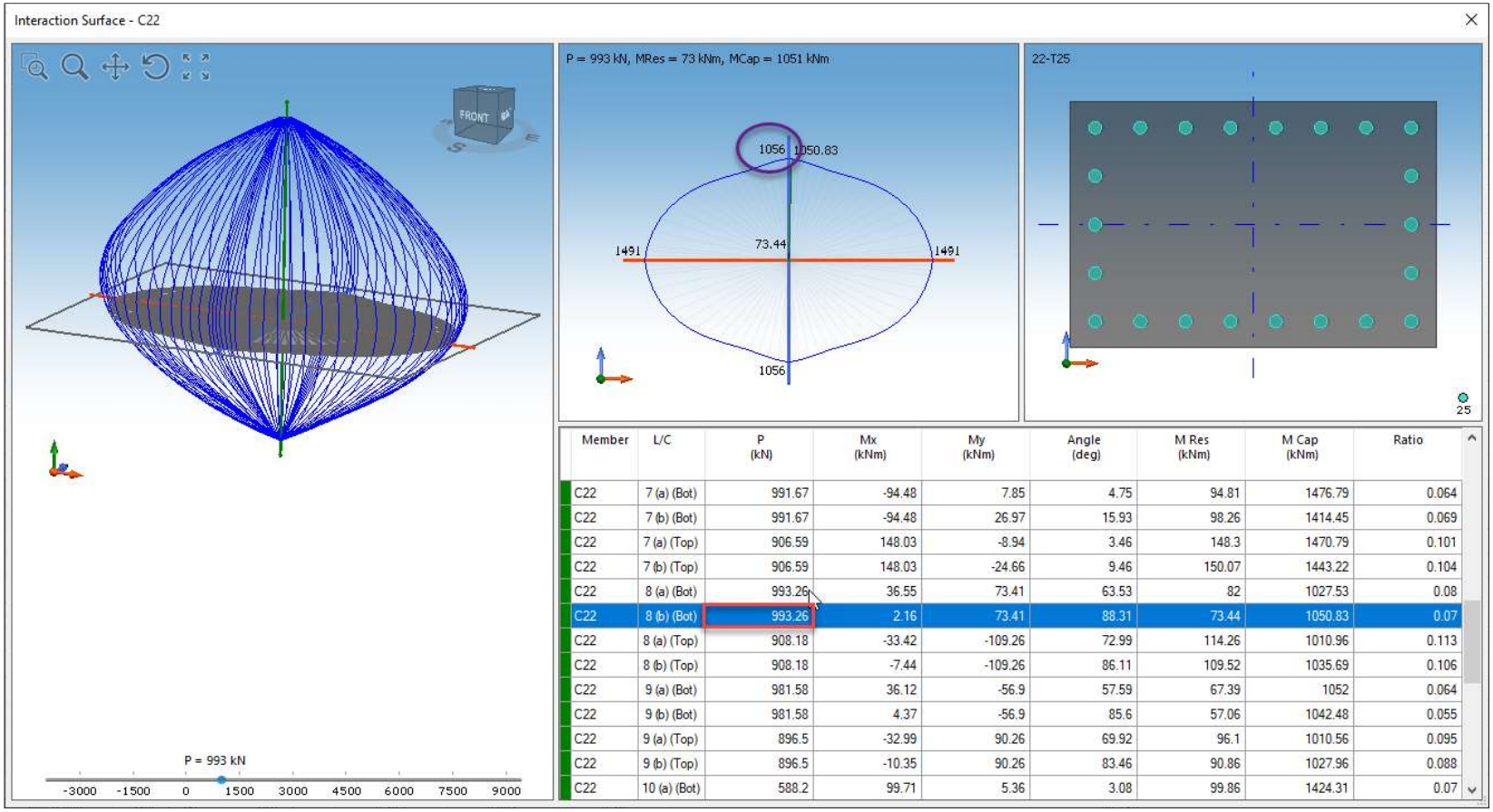


Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	6 (a) (Top)	898.09	-165.82	-10.06	3.47	166.12	1469.57	0.113
C22	6 (b) (Top)	898.09	-165.82	-24.43	8.38	167.61	1447.8	0.116
C22	7 (a) (Bot)	991.67	-94.48	7.85	4.75	94.81	1476.79	0.064
C22	7 (b) (Bot)	991.67	-94.48	26.97	15.93	98.26	1414.45	0.069
C22	7 (a) (Top)	906.59	148.03	-8.94	3.46	148.3	1470.79	0.101
C22	7 (b) (Top)	906.59	148.03	-24.66	9.46	150.07	1443.22	0.104
C22	8 (a) (Bot)	993.26	36.55	73.41	63.53	82	1027.53	0.08
C22	8 (b) (Bot)	993.26	2.16	73.41	88.31	73.44	1050.83	0.07
C22	8 (a) (Top)	908.18	-33.42	-109.26	72.99	114.26	1010.96	0.113
C22	8 (b) (Top)	908.18	-7.44	-109.26	86.11	109.52	1035.69	0.106
C22	9 (a) (Bot)	981.58	36.12	-56.9	57.59	67.39	1052	0.064
C22	9 (b) (Bot)	981.58	4.37	-56.9	85.6	57.06	1042.48	0.055
C22	9 (a) (Top)	896.5	-32.99	90.26	69.92	96.1	1010.56	0.095

Along B

Maximum Pu from All Earthquake load combination — P = 993.26 kN

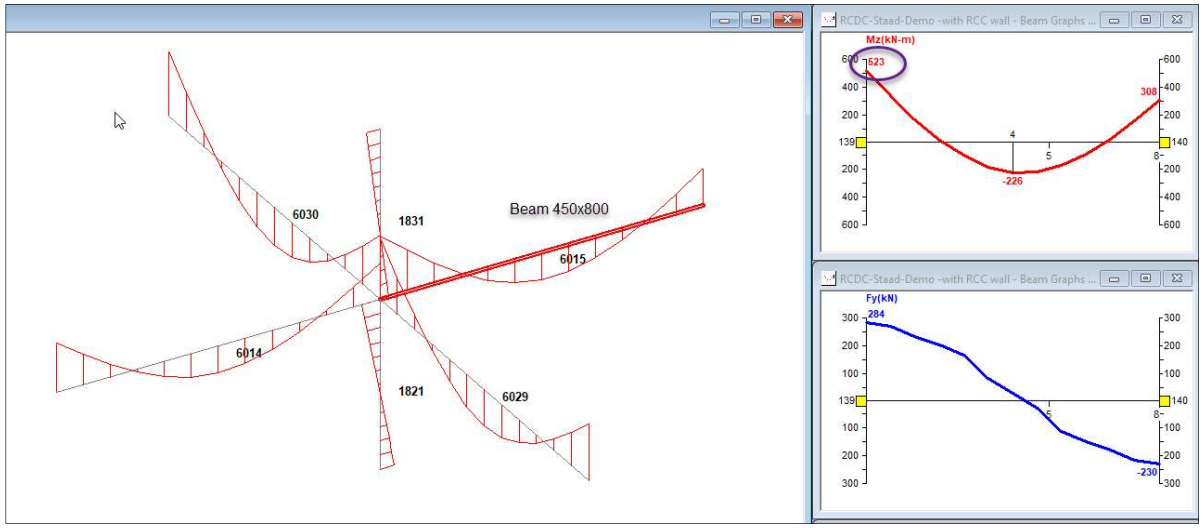
Corresponding Column Capacity (Mnc Top) — Mx = 1055.77 kNm (refer below PM curve)



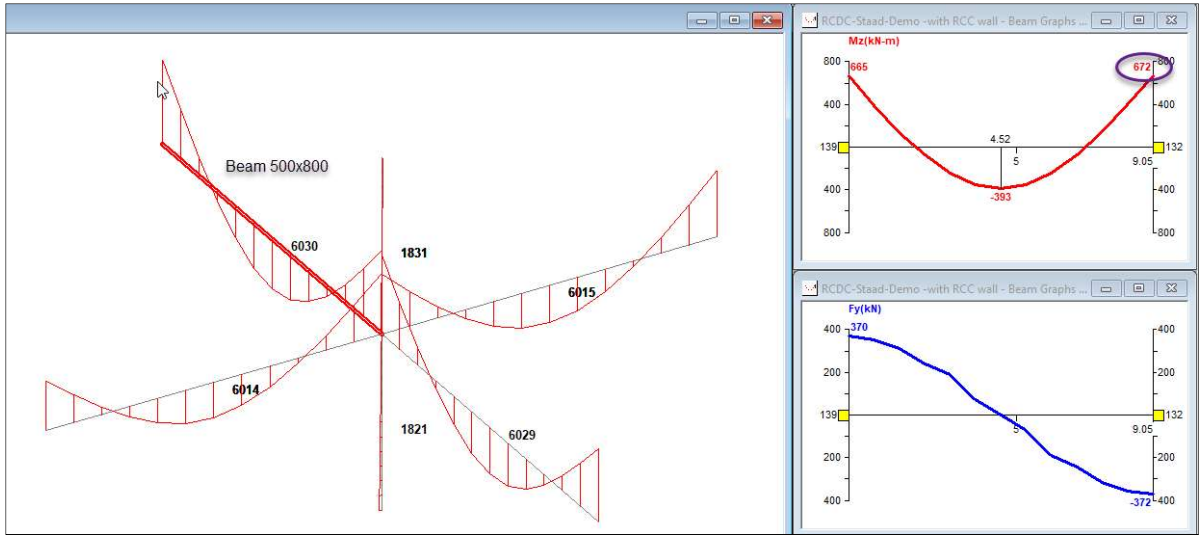
Member	L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C22	7 (a) (Bot)	991.67	-94.48	7.85	4.75	94.81	1476.79	0.064
C22	7 (b) (Bot)	991.67	-94.48	26.97	15.93	98.26	1414.45	0.069
C22	7 (a) (Top)	906.59	148.03	-8.94	3.46	148.3	1470.79	0.101
C22	7 (b) (Top)	906.59	148.03	-24.66	9.46	150.07	1443.22	0.104
C22	8 (a) (Bot)	993.26	36.55	73.41	63.53	82	1027.53	0.08
C22	8 (b) (Bot)	993.26	2.16	73.41	88.31	73.44	1050.83	0.07
C22	8 (a) (Top)	908.18	-33.42	-109.26	72.99	114.26	1010.96	0.113
C22	8 (b) (Top)	908.18	-7.44	-109.26	86.11	109.52	1035.69	0.106
C22	9 (a) (Bot)	981.58	36.12	-56.9	57.59	67.39	1052	0.064
C22	9 (b) (Bot)	981.58	4.37	-56.9	85.6	57.06	1042.48	0.055
C22	9 (a) (Top)	896.5	-32.99	90.26	69.92	96.1	1010.56	0.095
C22	9 (b) (Top)	896.5	-10.35	90.26	83.46	90.86	1027.96	0.088
C22	10 (a) (Bot)	588.2	99.71	5.36	3.08	99.86	1424.31	0.07

Calculation of Beam Capacity:

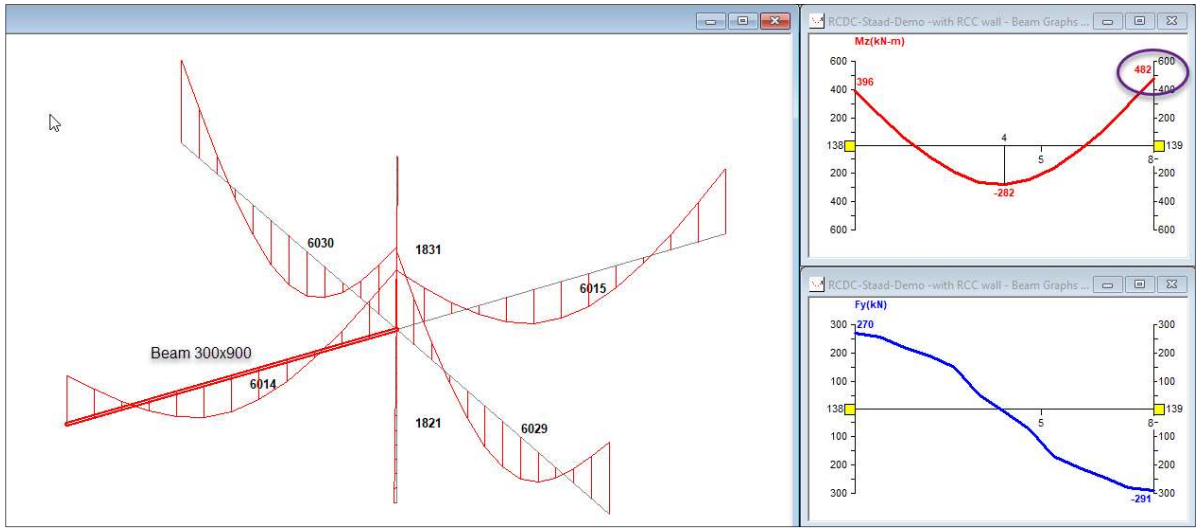
Beam @ 0 Location w.r.t. Colum Ly – Load Comb 13 – Maximum Bending Moment



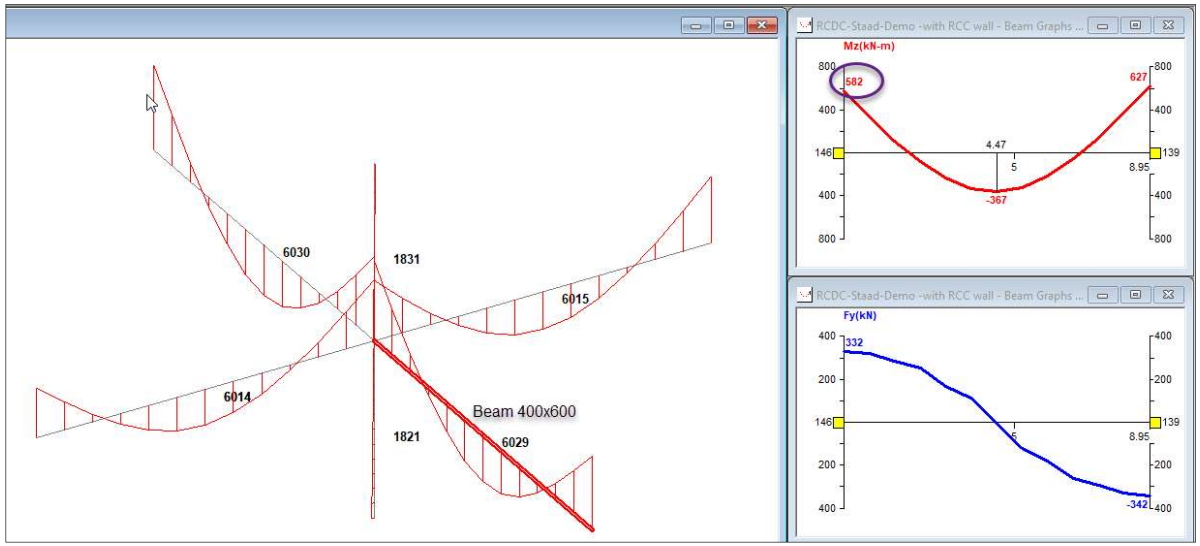
Beam @ 90 Location w.r.t. Colum Ly– Load Comb 11– Maximum Bending Moment



Beam @ 180 Location w.r.t. Colum Ly– Load Comb 11– Maximum Bending Moment



Beam @ 270 Location w.r.t. Colum Ly– Load Comb 11– Maximum Bending Moment



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.

Sample for calculation of Beam capacity:

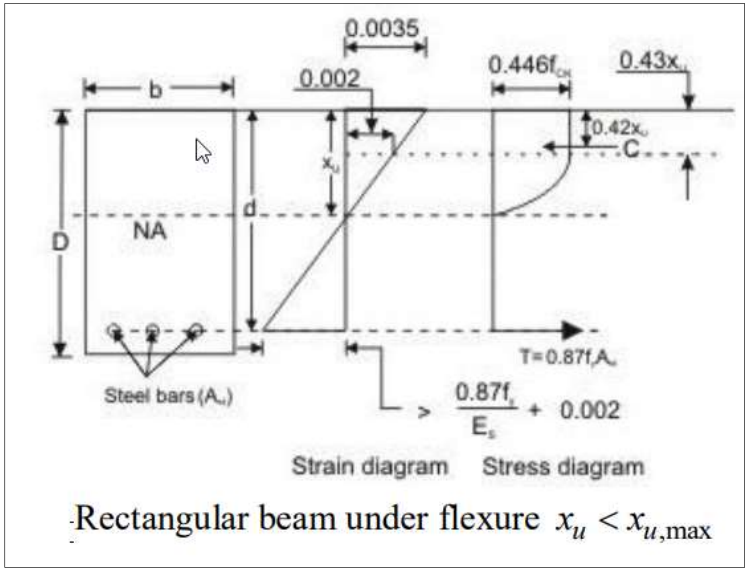
Beam @ 0 Location w.r.t. Colum Ly – Load Comb 13 – Maximum Bending Moment

Beam Width,B	=	450 mm
Beam Depth,D	=	800 mm
Mu	=	523.32 kN-m
Tu	=	0 kN-m
Deff	=	745 mm
Grade of Concrete,fc	=	M25
Grade of Steel,fy	=	Fe415
Es	=	2 x 10^5 N/sqmm

Calculation of Ast for Mu:

Flexure Design						
	Beam Bottom			Beam Top		
	Left	Mid	Right	Left	Mid	Right
Critical L/C - RCDC	-	1	7	3	11	2
Mu (kNm)	-	297.96	97.3	523.32	65.44	541.6
Tu (kNm)	0	0	0	0	0	0
M_{Tu} (kNm)	0	0	0	0	0	0
Mud (kNm)	0	297.96	97.3	523.32	65.44	541.61
MuLim (kNm)	862	862	862	862	862	862
R	0	1.193	0.39	2.095	0.262	2.168
Ptmin (%)	0.289	0.289	0.289	0.289	0.289	0.289
Ptclc (%)	0.328	0.351	0.375	0.651	0.289	0.677
Pcclc (%)	0	0	0	0	0	0
PtPrv (%)	0.375	0.375	0.375	0.656	0.439	0.679
AstCalc (sqmm)	1099.56	1176.62	1256.64	2182.62	969.4	2269.95
AstPrv (sqmm)	1256.64	1256.64	1256.64	2199.1	1472.61	2277.64
Reinforcement	4-T20	4-T20	4-T20	4-T25 3-T10	3-T25	4-T25 4-T10

Calculation of Mcap for provided reinforcement:



Ast provided	=	2199.1 sqmm
Xu-max/Deff	=	0.0035 / (0.0055 + 0.87 x (fy/Es)
	=	0.4791
Xu-max	=	356.93 mm
Fc Max	=	Xu-max x 0.36 x fc x B / 1000
	=	1445.57 kN
Mu-lim	=	Fc Max x (Deff – 0.416 x Xu-max)
	=	862 kN-m
Check		Mu-lim > Mu , Beam to be designed as Singly reinforced section
Tensile force	=	Ast provided x 0.87 x fy
	=	793.98 kN
Xu-act	=	Tensile force / (0.36 x fc x B)
	=	196.04 mm
Mcap	=	Tensile force x (Deff – 0.416 x Xu-act)
	=	526.77 kN-m

Design of Beam Column Joint for Distortional Shear (Clause 9.1)

9.1.1 *Shear Strength of Concrete in a Joint*

The nominal shear strength τ_{jc} of concrete in a beam-column joint shall be taken as

$$\tau_{jc} = \begin{cases} 1.5\ A_{cj}\sqrt{f_{ck}} & \text{for joints confined by beams on all four faces} \\ 1.2\ A_{cj}\sqrt{f_{ck}} & \text{for joints confined by beams on three faces} \\ 1.0\ A_{cj}\sqrt{f_{ck}} & \text{for other joints} \end{cases}$$

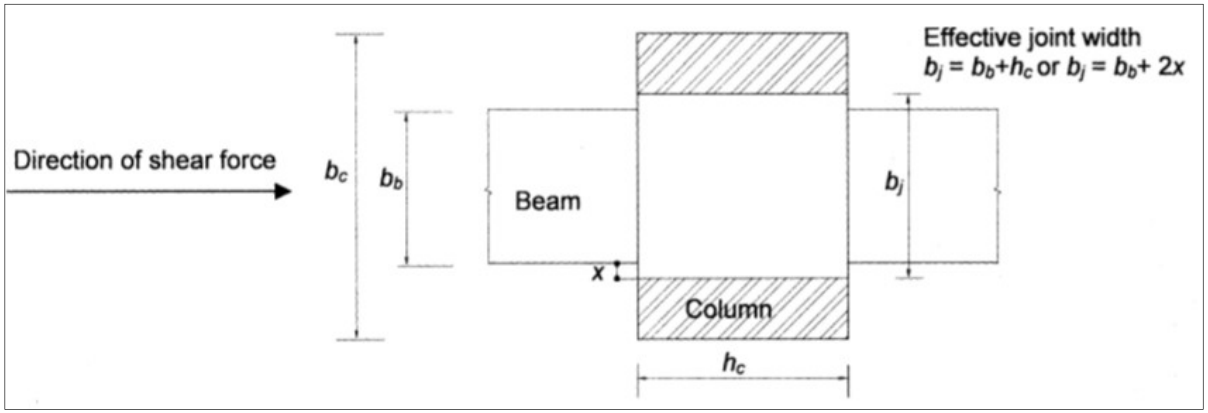
9.1.2 *Design Shear Stress Demand on a Joint*

a) Design shear stress demand acting horizontally along each of the two principal plan directions of the joint shall be estimated from earthquake shaking considered along each of these directions, using

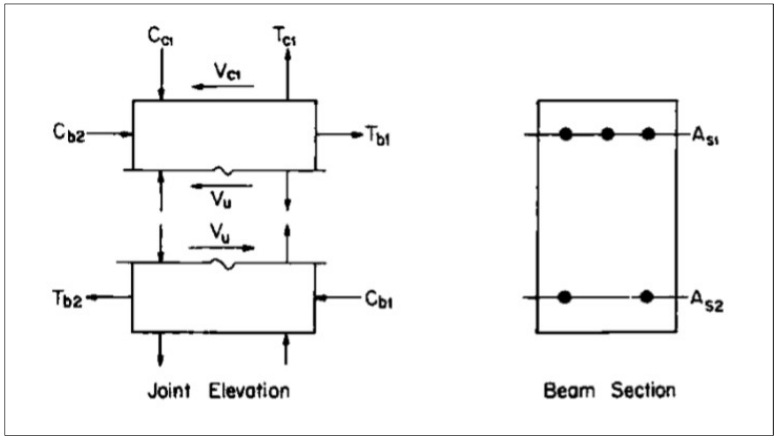
$$\tau_{jdX} = \frac{V_{djX}}{b_j w_j}$$ for shaking along plan direction X of earthquake shaking,

$$\tau_{jdY} = \frac{V_{djY}}{b_j w_j}$$ for shaking along plan direction Y of earthquake shaking

It shall be ensured that the joint shear capacity of joint concrete estimated using **9.1.1** exceeds both τ_{jdX} and τ_{jdY}.



Total shear to be considered is not clearly mentioned in code. Below is the snap showing shear to be considered for Joint check.



Joint shear, $V_u = T_{b1} + C_{b2} - V_{c1}$

where,

$C_{b1} = T_{b1} = 1.25 f_y A_{s1}$

$T_{b2} = C_{b2} = 1.25 f_y A_{s2}$

V_{C1} is column shear as per clause 7.3.4

Evaluation of horizontal joint shear. T = tension force; C = compression force; V = shear force; subscript b for beam; subscript c for column; and subscript s for steel (adapted from ACI 352-1989).

Ref: Technical paper Published by Mr. Sudhir K Jain and Dr. C.V.R. Murthy,IITK-GSDMA-EQ11-V4.0

The logic for calculating shear demand is based on the technical paper published by IITK. Below is the link to download paper, http://www.iitk.ac.in/nicee/IITK-GSDMA/EQ11.pdf

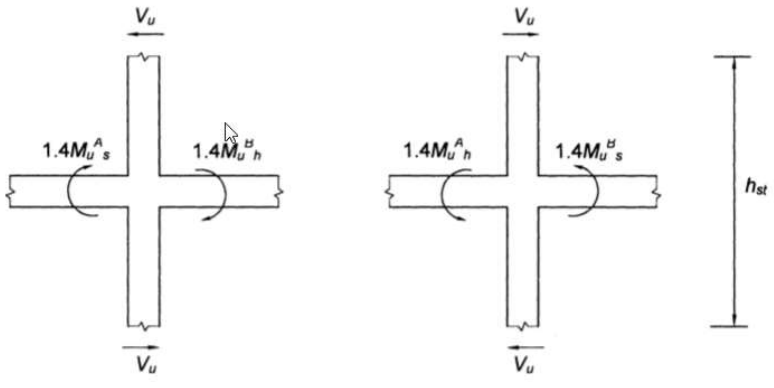


FIG. 11 EQUILIBRIUM DESIGN SHEAR FORCE DEMAND ON COLUMN WHEN PLASTIC HINGES ARE FORMED AT BEAM ENDS

Calculation of Column Shear (V Shear Demand)

Output from RCDC

2. Shear Strength of Joint:

Beams Along D

Angle w.r.t Column Ly (deg)	Reference Lo	Width (mm)	Depth (mm)	Ast Pro Top (sqmm)	Ast Pro Bot (sqmm)
0	Right	450	800	2199.12	1005.3
180	Left	300	900	1884.96	804.24

Shear Checks

Conditions	AST-Total (sqmm)	V-Reinf (kN)	Max (Vuy1, Vuy2) (kN)	V (Shear Demand) (kN)	B' (mm)	D' (mm)	Aje (sqmm)	τjd (sqmm)	τjc (sqmm)	τjd < τjc
Right Top + Left Bottom	3003.36	1557.99	247.63	1310.36	600	900	540000	2.43	7.5	OK
Left Top + Right Bottom	2890.26	1499.32	247.63	1251.69	600	900	540000	2.32	7.5	OK

Beams Along B

Angle w.r.t Column Ly (deg)	Reference Lo	Width (mm)	Depth (mm)	Ast Pro Top (sqmm)	Ast Pro Bot (sqmm)
90	Right	500	800	3141.6	1206.36
270	Left	400	600	3926.96	804.24

Shear Checks

Conditions	AST-Total (sqmm)	V-Reinf (kN)	Max (Vux1, Vux2) (kN)	V (Shear Demand) (kN)	B' (mm)	D' (mm)	Aje (sqmm)	τjd (sqmm)	τjc (sqmm)	τjd < τjc
Right Top + Left Bottom	3945.84	2046.9	311.7	1735.2	900	600	540000	3.21	7.5	OK
Left Top + Right Bottom	5133.32	2662.91	311.7	2351.21	900	600	540000	4.35	7.5	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	= 2199.12 + 804.24
	= 3003.36 Sqmm
V-reinf	= 3003.36 x 415 x 1.25 x /1000
	= 1557.99 kN
Vuy1 , Vuy2	= from beam Capacity

Note:

Beam capacity is calculated like explained in Flexural joint check.

Design Of Shear

Shear Calculation from Beam Capacity

Along D:

Height of column above level considered (hst1)	=	1700 mm
Height of column below level considered (hst2)	=	1700 mm
Height (hst)	=	4300 mm

Along B:

Height of column above level considered (hst1)	=	1800 mm
Height of column below level considered (hst2)	=	1800 mm
Height (hst)	=	4400 mm

Beam Size	Beam angle w.r.t. column Ly	Torsion moment	Moment Capacity Beam @ Top				Moment Capacity Beam @ Bottom				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 Ly (kNm)	Top Lx (kNm)	Bot Ly (kNm)	Bot Lx (kNm)
450x800	0	0	523.32	2182.62	2199.12	526.77	0	969.4	1005.3	256.88	526.77	0	256.88	0
500x800	90	1.29	672.37	2877.03	3141.6	726.1	0	1077.11	1206.36	306.95	0	726.1	0	306.95
300x900	180	0.68	482.52	1800.11	1884.96	503.72	0	733.01	804.24	232.37	503.72	0	232.37	0
400x600	270	-0.45	582.49	3572.5	3926.96	672.69	0	630.36	804.24	148.51	0	672.69	0	148.51

Effective moment for Column

	Mu Major (Along D) (kNm)		Mu Minor (Along B) (kNm)	
	Left	Right	Left	Right
Top	503.72	526.77	672.69	726.1
Bottom	232.37	256.88	148.51	306.95

Shear along D:

Sway Right

Vuy1 = 1.4 x (Left,Bottom + Right,Top)/hst

= 247.16 kN

Sway Left

Vuy2 = 1.4 x (Left,Top + Right,Bottom)/hst

= 247.63 kN

Shear along B:

Sway Left

Vux1 = 1.4 x (Left,Bottom + Right,Top)/hst

= 278.28 kN

Sway Right

Vux2 = 1.4 x (Left,Top + Right,Bottom)/hst

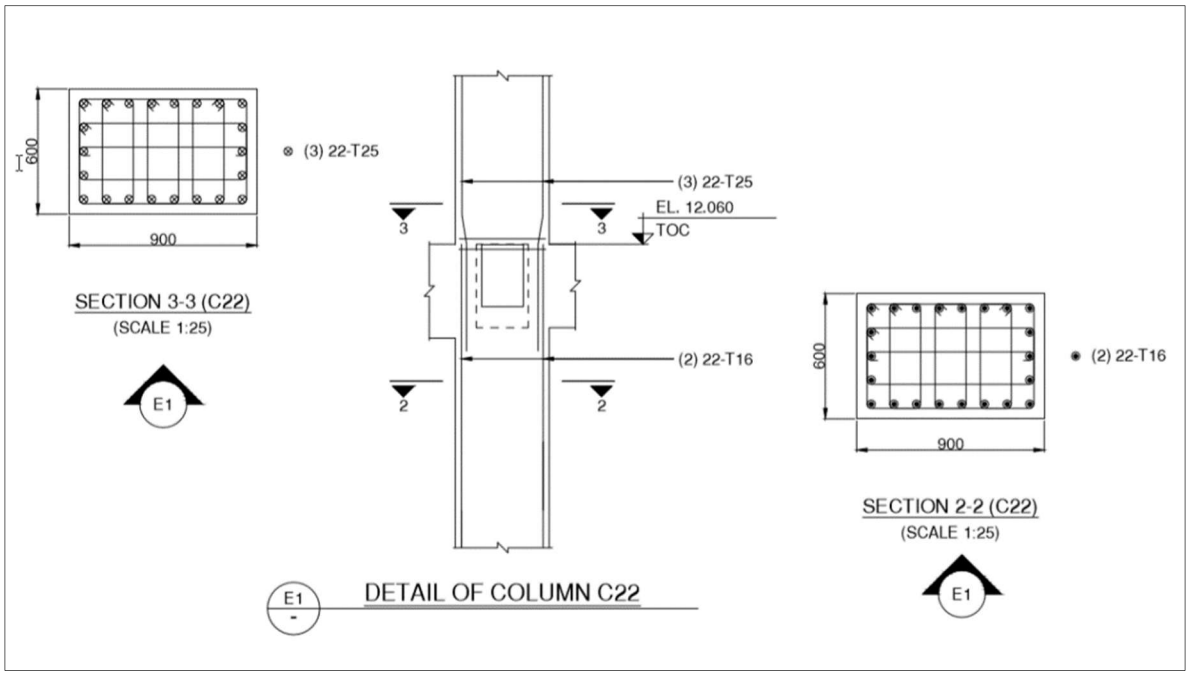
= 311.7 kN

V (Shear Demand) =1557.99 – 247.63

= 1310.36 kN

Tjd	= 1310.36 / 540000	
	= 2.43 N/sqmm	
Tjc	= 1.5 x Sqrt (25)	
	= 7.5 N/sqmm	
Check	Tjd < Tjc	Ok

RCDC DRAWING OUTPUT



STAAD SPACE
START JOB INFORMATION
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
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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;
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75 34.36 4.2 17.86; 76 34.36 4.2 14.61; 77 31.96 4.2 26.15;
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MEMBER INCIDENCES
1 1 41; 11 41 81; 21 81 121; 31 121 161; 101 2 42; 111 42 82; 121 82 122;

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4002 42 43; 4003 43 44; 4004 44 45; 4005 46 47; 4006 47 48; 4007 48 49;
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4015 59 60; 4016 60 61; 4017 61 62; 4018 62 79; 4019 65 66; 4020 66 67;
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6003 123 124; 6004 124 125; 6005 126 127; 6006 127 128; 6007 128 129;
6008 129 130; 6009 131 132; 6010 132 133; 6011 133 134; 6012 134 135;
6014 138 139; 6015 139 140; 6016 140 141; 6017 141 142; 6018 142 159;
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6044 130 125; 6045 151 158; 6046 143 154; 6047 136 152; 6051 130 152;
6052 152 125; 6053 153 205; 6054 153 155; 6055 154 136; 6056 155 154;
6057 156 136; 6058 155 206; 6059 157 142; 6060 157 160; 6061 158 143;
6062 159 143; 6063 150 160; 6064 160 159; 7001 161 162; 7002 162 163;
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;
7019 185 186; 7020 186 187; 7021 187 188; 7022 188 189; 7023 189 190;
7024 190 191; 7025 185 178; 7026 178 171; 7027 171 166; 7028 166 161;
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7039 174 169; 7040 169 164; 7041 189 197; 7042 182 193; 7043 175 221;
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;
7089 215 216; 7090 217 90; 7091 217 218; 7092 219 130; 7093 219 220;

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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
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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 -
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
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

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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 1.5 2 1.5
LOAD COMBINATION 12
1 1.2 2 1.2 3 1.2
LOAD COMBINATION 13
1 1.2 2 1.2 3 -1.2
LOAD COMBINATION 14
1 1.2 2 1.2 4 1.2
LOAD COMBINATION 15
1 1.2 2 1.2 4 -1.2
LOAD COMBINATION 16
1 1.5 3 1.5
LOAD COMBINATION 17
1 1.5 3 -1.5
LOAD COMBINATION 18
1 1.5 4 1.5
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LOAD COMBINATION 19
1 1.5 4 -1.5
LOAD COMBINATION 20
1 0.9 3 1.5
LOAD COMBINATION 21
1 0.9 3 -1.5
LOAD COMBINATION 22
1 0.9 4 1.5
LOAD COMBINATION 23
1 0.9 4 -1.5
PERFORM ANALYSIS
FINISH
```