

COMPUTER AIDED ANALYSIS AND DESIGN OF MULTI-STOREYED BUILDING USING STAAD Pro

Pushkar Rathod¹, Shruti Rathod², Rahul Chandrashekar³

¹Undergraduate, Dept. of Civil Engineering, Datta Meghe College of Engineering, Navi Mumbai, India. ²Technogem Consultants Pvt. Ltd., Consulting Engineers, Thane 400604, India. ³Larsen & Toubro Limited, Buildings & Factories, Residential Buildings, EDRC, Mumbai 400093, India. ______***______

Abstract: The main objective is to analyze and design a multi-storeyed building [G + 21 (3 dimensional frame)]using STAAD Pro. The design of G+21 building involves manual load calculations and the whole structure is analyzed by STAAD Pro. Limit State Design method is used in STAAD-Pro analysis conforming to IS Code of Practice. STAAD Pro is the professional's choice; from model generation, analysis and design to visualization and result verification, STAAD Pro gives accurate results and the software is user friendly too. To check the accuracy of our results with the software generated results, we analyzed a simple 2D frame manually. The results proved to be very accurate. A G+7 storey building was initially analyzed for all possible load and load combinations as per IS Code of Practice.

Key Words: STAAD Pro, Analysis, Multi-storeyed, Design, IS Code of Practice, Seismic.

1.INTRODUCTION

The paper involves analysis and design of multi-storeved [G + 21] using a very popular designing software STAAD Pro. We have chosen STAAD Pro because of its following advantages:

-Easy to use interface, -Conformation with the Indian Standard Codes, -Versatile nature of solving any type of problem, -Accuracy of the solution.

STAAD Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD Pro is preferred for steel, concrete, timber, aluminum and coldformed steel design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles and much more.

To start with we have solved some sample problems using STAAD Pro and checked the accuracy of the results with manual calculations. The results were to satisfaction and were accurate.

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. Structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it.

2.ANALYSIS AND DESIGN OF G + 21 RCC FRAMED **BUILDING USING STAAD Pro:**

G+21 storey building. All columns = 0.50 X 0.50 m (until ground floor) Columns at the ground floor: 0.80 X 0.80 m All beams = 0.30 X 0.50 m All slabs = 0.20 m thick Terracing = 0.20 m thick avg. Parapet = 0.10 m thick RCC

2.1 Physical parameters of building:

Length = 4 bays @ 5.0m = 20.0m Width = 3 bays @ 5 m =15.0m Height = 4m + 21 storeys @ 3.3m = 73.3m (1.0m parapet being non- structural for seismic purposes, is not considered of building frame height) Grade of concrete and steel used: M30 concrete and Fe 415 steel. Base support: Fixed.

2.2 Self Weight:

Self weight was auto generated by STAA Pro software with the self weight command in the load case column.

2.3 Dead Load:

Terrace - 14.482 KN/m² Typical Floor - 13.5 KN/m² First Floor - 14.37 KN/m²

2.4 Live Load:

Live load on the floors is $2.5 kN/m^2$ Live load on the roof is $0.75 kN/m^2$

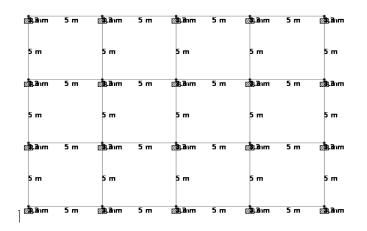
2.5 Wind load:

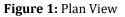
Height [h]	Design wind speed [Vz]	Design wind pressure [Pz]
Up to 10 m	36.379 m/s	0.793 KN/sq m
15 m	38.85 m/s	0.905 KN/sq m
20 m	40.51 m/s	0.984 KN/sq m
30 m	42.58 m/s	1.087 KN/sq m

Table 1: Wind Speed and Pressure

2.6 Seismic load:

The seismic load values were calculated as per IS 1893-2002. STAAD Pro has a seismic load generator in accordance with the IS code mentioned.





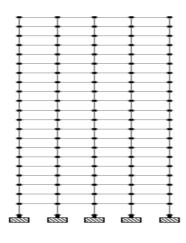
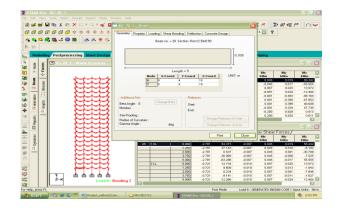
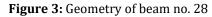


Figure 2: Elevation View

3. RESULT

Some of sample analysis and design results have been shown below for a beam.





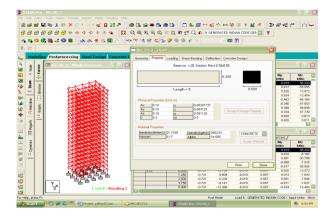


Figure 4: Property of beam no. 28

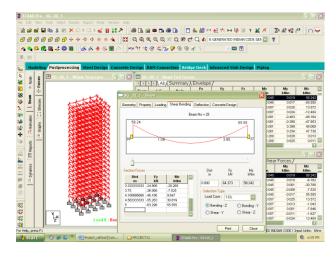


Figure 5: Shear bending of beam no. 28

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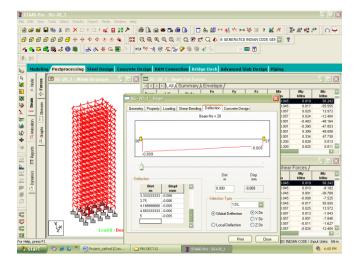


Figure 6: Shear bending of beam no. 28

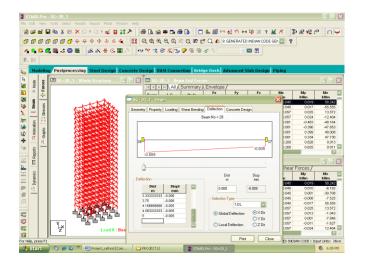


Figure 7: Deflection of beam no. 28

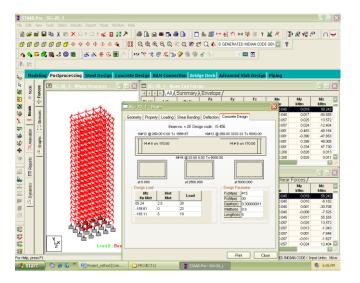


Figure 8: Concrete design of beam no. 28

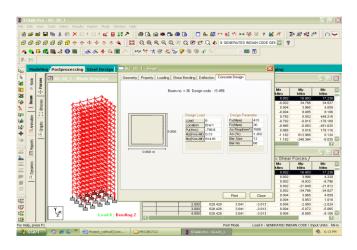


Figure 9: Concrete design of beam no. 28

BEAM NO. 28 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.)

Length = 5000mm, Size = 500mm X 300mm, Cover = 25mm

Table 2: Summary of Reinforcement Area (Sq.mm)

Section	0 mm	2500 mm	5000 mm
Тор	2109.40	277.00	2047.78
Reinforcement	Sq. mm	Sq. mm	Sq. mm
Bottom	529.05	986.77	523.98
Reinforcement	Sq. mm	Sq. mm	Sq. mm

Table 3: Summary of Provided Reinforcement Area

Section	0 mm	2500 mm	5000 mm
Тор	19-12i	4-12i	19-12i
R/f	2 layers	1 layer	2 layers
Bottom	4-16i	5-16i	4-16i
R/f	1 layer	1 layer	1 layer
Shear	2 legged 8i	2 legged 8i	2 legged 8i
R/f	@ 170mm	@ 170mm	@ 170mm
	c/c	c/c	c/c

SHEAR DESIGN RESULTS AT DISTANCE D(EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

Shear Design result at 665.0 mm AWAY from start support

VY = 104.84 MX = 0.07 LD = 23 Provide 2 legged 8i @ 170mm c/c

Shear Design result at 665.0 mm AWAY from end support

VY = -103.05 MX = 0.06 LD = 19 Provide 2 legged 8i @ 170mm c/c

BEAM NO. 48 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.) Length = 5000mm, Size = 500mm X 300mm, Cover = 25mm

Section	0 mm	2500 mm	5000 mm		
Тор	2617.73	275.48	2684.60		
Reinforcement	Sq. mm	Sq. mm	Sq. mm		
Bottom	814.18	928.82	883.74		
Reinforcement	Sq. mm	Sq. mm	Sq. mm		

Table 4: Summary of Reinforcement Area (Sq.mm)

Section	0 mm	2500 mm	5000 mm
Тор	14-16i	4-16i	14-16i
R/f	2 layers	1 layer	2 layers
Bottom	4-20i	4-20i	4-20i
R/f	1 layer	1 layer	1 layer
Shear	2 legged 8i	2 legged 8i	2 legged 8i
R/f	@ 170mm	@ 170mm	@ 170mm
	c/c	c/c	c/c

Table 5: Summary of Provided Reinforcement Area

SHEAR DESIGN RESULTS AT DISTANCE D(EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

Shear Design result at 665.0 mm away from start support

VY = 128.96 MX = 0.00 LD = 12 Provide 2 legged 8i @ 170mm c/c

Shear Design result at 665.0 mm away from end support

VY = -130.93 MX = 0.00 LD = 16 Provide 2 legged 8i @ 170mm c/c

COLUMN NO. 34 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.) Length = 4000mm, Size = 800mm X 800mm, Cover = 40mm Guiding Load Case: 26 END JOINT: 33 SHORT COLUMN

Required steel area = 10682.54 sq. mm Required concrete area = 629317.44 sq. mm Main r/f = Provide 56 - 16 dia. (1.76% - 11259.47 sq. mm) (equally distributed) Tie r/f = Provide 8mm dia. Rectangular ties @ 225mm c/c Section capacity based on r/f required (KNS-MET) Puz = 11820.73 Muz1 = 1037.19 Muy1 = 1037.19 Interaction ratio = 0.99 (as per Cl. 39.6 IS 456:2000) Section capacity based on r/f provided (KNS-MET) Worst load case = 26 End joint = 33 Puz = 11992.51 Muz = 1090.84 Muy = 1090.84 IR = 0.91

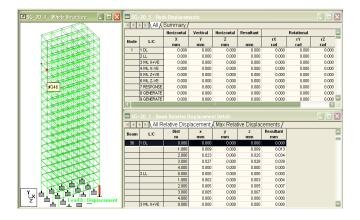
COLUMN NO. 332 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.) Length = 3300mm, Size = 600mm X 600mm, Cover = 40mm

Guiding Load Case: 7 END JOINT: 156 SHORT COLUMN

Required steel area = 2880.00 sq. mm Required concrete area = 357120.00 sq. mm Main r/f = Provide 28 - 12 dia. (0.88% - 3166.73 sq. mm) (equally distributed) Tie r/f = Provide 8mm dia. Rectangular ties @ 190mm c/c Section capacity based on r/f required (KNS-MET) Puz = 5717.52 Muz1 = 180.32 Muy1 = 180.32 Interaction ratio = 0.48 (as per Cl. 39.6 IS 456:2000) Section capacity based on r/f provided (KNS-MET) Worst load case = 8 End joint = 136 Puz = 5162.51 Muz = 0.00 Muy = 0.00 IR = 0.88

POST PROCESSING MODE





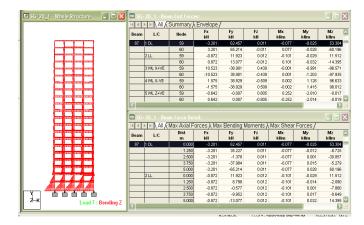


Figure 11: Bending in Z

The stress at any point of any member can be found out in this mode. The figure below depicts a particular case.



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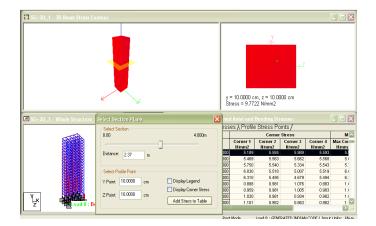


Figure 12: Shear stress at any section

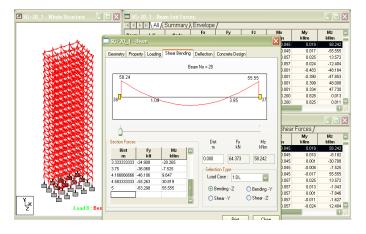


Figure 13: Graph for shear force and bending moment for a beam

The above figure shows that the bending moment and the shear force can be studied from the graphs generated by STAAD Pro. The whole structure is shown in the screen and we may select any member and at the right side we will get the BMD and SFD for that member. The above figure shows the diagrams for member beam 1402.

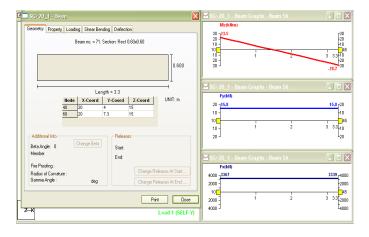


Figure 14: Graph for shear force and bending moment for a column

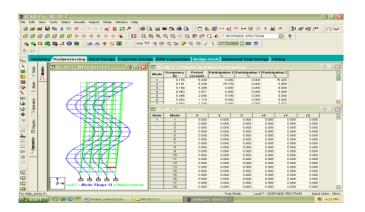


Figure 15: Deflection mode post processing

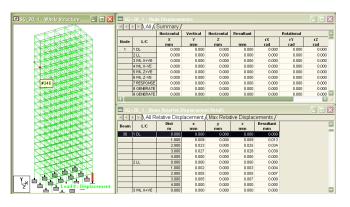


Figure 16: Nodes displacement summary

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1	8	_	20 GENERAT	-205.429	-32.567	-40.200	213,506	0.000	-0.005	-0.001	
	m l	<u> </u>	29 OENERAT	206.116	-11.927	40.609	212.106	0.000	0.005	0.001	
-	<u></u>	<u> </u>	30 GENERAT	-205.601	-21.444	-48.302	212,284	0.000	-0.005	-0.001	
-1	22	422	1 DL	0.235	-22.139	0.194	22.141	0.000	-0.000	-0.000	
= I	Rectors		211	0.028	-5.040	0.045	5.040	0.000	-0.000	-0.000	
٤I	3	<u> </u>	3 VAL X+VE	60.414	0.456	-0.000	60.416	0.000	0.000	-0.000	
Internal Vice	÷		4 WL X-VE	-68.406	-0.456	0.000	68.408	-0.000	-0.000	0.000	
۲I	<u> </u>		5 VAL Z+VE	0.003	2.524	101.505	101.536	0.000	-0.000	-0.000	
-1			6 WL Z-VE	-0.003	-2.525	-101.482	101.514	-0.000	0.000	0.000	
αI			7 RESPONSE	137.229	0.753	16.111	138.173	0.000	0.003	0.000	
nuda.			8 GENERATE	0.395	-40.768	0.358	40.772	0.001	-0.000	-0.000	
2			9 OENERATE	02.413	-32.067	0.286	00.432	0.001	0.000	-0.001	
			10 GENERAT	-81.772	-33.162	0.287	88.241	0.001	-0.000	-0.000	
-1			11 GENERAT	0.319	-29.586	122.092	125.626	0.001	-0.000	-0.000	
children (12 GENERAT	0.313	-35.645	-121.493	126.614	0.000	0.000	-0.000	
51			13 OENERAT	-01.701	-33.162	0.267	00.249	0.001	-0.000	-0.000	
51			14 GENERAT	82.404	-32.068	0.286	88.424	0.001	0.000	-0.001	
			15 GENERAT	0.313	-35.644	-121.519	126.639	0.000	0.000	-0.000	
-1			16 GENERAT	0.319	-29.585	122.065	125.600	0.001	-0.000	-0.000	
			17 GENERAT	164.991	-31.711	19.619	169.152	0.001	0.004	0.000	
			18 GENERAT	-164.359	-33.618	-19.046	168.819	0.001	-0.004	-0.001	
		<u> </u>	19 OENERAT	102.974	-32.524	0.290	107.989	0.001	0.000	-0.001	
			20 GENERAT	-102.257	-33.892	0.291	107.728	0.001	-0.000	0.000	
			21 GENERAT	0.357	-29.422	152.548	155.360	0.001	-0.000	-0.000	
		_	22 GENERAT	0.349	-36.996	-151.933	156.373	-0.000	0.000	-0.000	
1		-	23 OENERAT 24 OENERAT	-102.268 102.963	-33.093	0.292	107.739	0.001	-0.000	0.000	
			24 GENERAT	102.963	-32.525	0.290	107.978	0.001	0.000		

Figure 16: Node displacement table 01

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8	51		X+VE	60.410	-1.660	0.002	68,430	0.000	-0.000	-0.000				
-			X-VE	.68 425	1.679	-0.002	68 645	-0.000	0.000	0.000				
	22		Z+VE	0.004	-2.528	100.998	101.030	0.000	0.000	-0.000				
S	Reaction		Z-VE	0.004	2.528	101.009	101.041	-0.000	-0.000	0.000				
Arimation	18		SPONSE	98.050	3,400	32.305	103.294	0.000	0.003	0.001				
3	1 -	8.06	NERATE	0.003	-33.643	0.045	33,643	-0.001	-0.000	0.001				
et	1 <u>-</u>	9.04	NERATE	82.094	-28.930	0.038	87.042	-0.000	-0.000	0.000				
		10 0	ENERAT	-82.108	-24.899	0.034	85.800	-0.000	0.000	0.001				
32		11 0	ENERAT	0.007	-29.948	121,234	124.070	0.000	0.000	0.000				
Piports			ENERAT	-0.003	-23.881	-121.175	123,506	-0.001	-0.000	0.000				
æ			ENERAT	-82.089	-24.898	0.034	05.782	-0.000	0.000	0.001				
			ENERAT	82.112	-28.929	0.035	87.059	-0.000	-0.000	0.000				
			ENERAT	-0.003	-23.000	-121.162	123,493	-0.001	-0.000	0.000				
.22			ENERAT	0.007	-29.947	121.247	124,991	0.000	0.000	0.000				
5			ENERAT	117.662	-22.728	38.803	125.963	-0.000	0.004	0.001				
Dynamics			ENERAT	-117.658	-31.100	-38.731	127.713	-0.000	-0.004	-0.000				
1.5			ENERAT	102.682	-30.591	0.009	107.142	-0.000	-0.000	0.000				
-			ENERAT	-102.569	-26.663	0.004	105.704	-0.000	0.000	0.001				
			ENERAT	0.074	-31.864	151.584	164.897	0.000	0.000	0.000				
			ENERAT	0.062	-24.280	-151.427	153.352	-0.001	-0.000	0.000				
			ENERAT	-102.547	-25.551	0.004	105.682	-0.000	0.000	0.001				
			ENERAT	102.705	-30.590	0.009	107.164	-0.000	-0.000	0.000				
			ENERAT	0.062	-24.279	-151.411	153.345	-0.001	-0.000	0.000				
			ENERAT	147.143	-31.863	40.545	156.610	-0.000	0.000	0.000				
			ENERAT	-147.007	-22.039	40.545	156.610	-0.000	-0.005	-0.000				
			CARDAT	-147.007	-33.303	-40.372	100.304	-0.000	-0.006	-0.000				
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Figure 17: Node displacement table 02

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-	8	Max X	421	27 GENERAT	mm 206.288	-23.050	mm 48.711	mm 213.210	rad 0.001	rad 0.005	rad 0.000	
IIIOO	8	Min X	425	30 GENERAT	-205,842	-21.457	-48,239	212.505	0.000	-0.005	-0.001	
8	m	Max Y	440	7 RESPONSE	98.050	3,488	32.306	103.294	0.000	0.003	0.001	
• •	_	Min Y	433	8 GENERATE	0.260	-51.655	0.049	51.656	-0.000	-0.000	-0.000	
1		Max Z	423	21 GENERAT	0.228	-30.718	152,893	155.949	0.001	-0.000	-0.000	
81	3	Min Z	438	22 GENERAT	0.267	-30.741	-152.591	155.857	-0.001	-0.000	-0.000	
Internet of the second s		Max rX	63	26 GENERAT	0.007	-6.945	25.975	26.889	0.003	0.000	-0.000	
ē	÷	MinrX	78	25 GENERAT	0.001	-6.953	-25.968	26.882	-0.003	0.000	-0.000	
t l'	-	MaxrY	411	27 GENERAT	163.494	-27.768	48.323	172.732	-0.000	0.005	0.001	
		Min rY Mix rZ	415 65	28 GENERAT	-163.036	-38.033	-47.987	174.155 39.203	-0.000	-0.005	-0.001	
ŧ		Max rz Min rZ	61	27 GENERAT 28 GENERAT	37.482	-5.072	10.306	39.003	0.001	-0.001	0.005	
۶I		Max Ref	425	28 GENERAT	-37,460	-32.590	-10.313	213.874	0.001	-0.001	-0.000	
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Figure 18: Node displacement table 03

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Bram	Displacement		Hode	LC	Fx kli	ry kii	Fz kH	Mx kilm	My klim	Mz	
8	m		1	1 DL	13.019	3554.551	12.921	16,895	0.004	-17,198	1
				211	3.041	628.427	3.013	3,965	0.004	-4.059	
	Reactions			374 X+VE	-68.377	-551.041	-0.012	-0.053	-0.985	461.625	
8	tt			4 WL X-VE	67.778	551.019	0.009	0.052	0.792	-449.218	
12	8			SWL Z+VE	-0.025	-790.598	-91.613	-614.813	1.337	0.135	
Arinotion	- ÷			6 WL Z-VE 7 RESPONSE	0.022 84.503	790.583 503.797	91.161 23.168	612.960 150.054	-1.102 19.176	-0.124 636.260	
8	-			8 GENERATE	24.091	6274.467	23.168	31,291	19.176	-31.886	
				9 GENERATE	62,780	4358.325	19.106	24.958	-1.172	516.441	
15				10 OENERAT	100.606	5680.797	19.132	25.095	0.961	-564.570	
Reports			-							E IF	5
			LC		Fx kli	Fy kli	Fz	Mx klim	My klim	Mz kNm	Ê
-B			1	Loads	0.000	-22375.636	0.000	6.6091986	0.000	-0.01373E6	1
 Dynamics 				Reactions	-0.000	22375.636	-0.000	-6.6091986	0.000	8.8137366	
12				Difference	-0.000	-0.000	-0.000	0.000	0.000	-0.000	
-			2	Londs	0.000	-5530.300	0.000	1.63296E6	0.000	-2.17728E6	
		sta sta sta sta		Reactions Difference	-0.000	5530.300	-0.000	-1.6329686	-0.000	2.1772686	
			3	Loads	333.842	-0.000	-0.000	0.000		-486.30515E	
				Reactions	-333.842	0.000	-0.000	-0.000	-90575.372	400.30515E	
		Y - KA CKA STRA STRA STRA STRA ST		Difference	-0.000	0.000	-0.000	-0.000	-0.000	0.000	
		Z-x X = K0.650 Alter alter atta and 0 ad 3	4	Loads	-333.842	0.000	0.000	0.000	-90575.372	406.30515E	
		T = 191.00 Constant Constant Constant		Reactions	333.842	0.000	0.000	0.000	98575.372	-486.30515E -0.000	
								0.000			

Figure 19: Node reactions

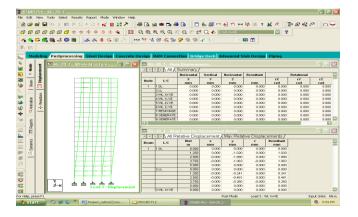


Figure 20: Node displacement

4.CONCLUSION

The program contains a number of parameters which are designed as per IS: 456(2000). Members are designed for flexure, shear and torsion.

Design for Flexure:

Maximum sagging (creating tensile stress at the bottom face of the beam) and hogging (creating tensile stress at

the top face) moments are calculated for all active load cases at each of the above mentioned sections. Where ever the rectangular section is inadequate as singly reinforced section, doubly reinforced section is tried.

Design for Shear:

Shear reinforcement is calculated to resist both shear forces and torsional moments. Two-legged stirrups are provided to take care of the balance shear forces acting on these sections.

Beam Design Output:

The default design output of the beam contains flexural and shear reinforcement provided along the length of the beam.

Column Design:

Columns are designed for axial forces and biaxial moments at the ends. All active load cases are tested to calculate reinforcement. The loading which yield maximum reinforcement is called the critical load. Column design is done for square section. Square columns are designed with reinforcement distributed on each side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under uni-axial moment. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456 have been taken care of in the column design of STAAD.

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