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Study on Performance of Cantilever Space Frame Structure for Lateral Load

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ABSTRACT

In the present0 day, it is observed that there is a growing0 interest0 in space0 frame0 systems. A space frame is a 3D structural system in which well0 organized0 linear0 axial0 elements0 are put together0 for the uniform distribution of forces. This paper presents to understand the performance of cantilever space frame and regular plane frame steel structure. This space frame structure uses a double layer grid element. Thus the entire steel frame structure is designed as a hollow pipe section. The analysis is carried out for static load is done using SAP2000 software. The result were extracted for shear force and bending moment and compared with the cantilever space frame and regular plane frame structure.

KEYWORDS: *Space Frame, Cantilever, Double Layer Grid, Equivalent static method*

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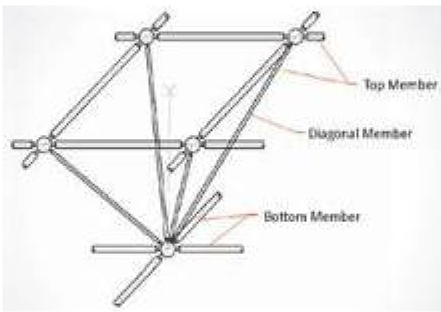
1. INTRODUCTION

A growing interest in space frame structures has been witnessed worldwide over the previous half century. The look for innovative structural forms to accommodate large unobstructed areas has always been the main objective of architects and engineers. With the coming on of new building techniques & construction materials, space frames frequently provide the right answer and satisfy the requirements for lightness, economy, and speedy construction. Significant growth has been made in the process of the development of the space frame.

The space frames are extremely statically0 indeterminate and their analysis leads to extremely tedious computation if by hand. The difficulty of the complex analysis of such systems contributed to their limited use. By using computer programs has been0 radically changing0 the whole0 approach to the analysis of space frames. By using computer programs, it is possible to analyze very complex0 space structures with great accuracy and less time involved. Based on studying various kinds of literature, the parameters are set for the project considered i.e. to study the behavior & performance of cantilever space frame structure subjected to lateral load and then to understand the performance of steel structure for double layer grid and also observe the behavior of structure Static Performance.

A. Space Frame Components

In general, 0members are axial elements with circular or rectangular sections; all0 members can only resist tension or compression. The space grid is an assembly of relatively long tension0 members and short compression members.



Typical detail of one unit of double layer grid Space Frame element

Different types of space frame connection consist of welded, bolted and threaded. Chief issue within the structural0 joint design is that the thought of a truly rigid connection that may support a load.

2. DESIGN OF STRUCTURAL MEMBERS

Here the height of 5m, Width of 10m at each column interval is 2m & length of 13m with including extra projection structural models are considered for the hollow pipe section space framed structure considered for the analysis. Below Fig 1 shows the dimension of the cantilever space frame structure modelled in AutoCAD. Double layered Grid design is considered for the analysis. The structural models are modelled using SAP2000 software. The proposed models are cantilever space frame structures. Table 1 shows the material properties used in this project.

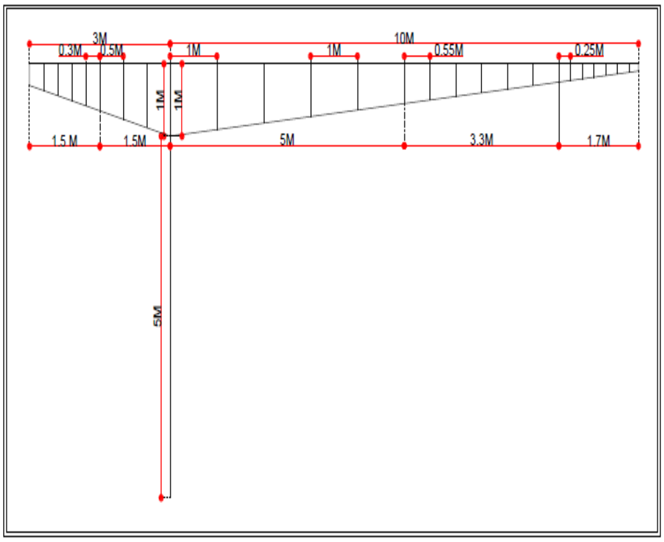


Fig 1 Plan View

Table-1: Material properties considered for Structure

Sl. No.	Description	Data
1.	Structure Height	5m
2.	Structure Width	10m
3.	Overall span Length	13m
4.	Column Size used	ISNB 300H
5.	Beam Size used	ISNB 20H (TOP CHORD) ISNB 65H (BOTTOM CHORD)
6.	Brace Size used	ISNB 15H, ISNB 40H, ISNB 65H, ISNB 20H, ISNB 175H
7.	Thickness of Roof	20mm
8.	Grade of Steel (f_y)	Fe 345

3. ANALYSIS AND DISCUSSION

The models are first loaded with dead loads and then lateral loads are applied to check the behaviour of the models. Models are then analyzed with a combination of loads automatically calculated from the program. The selecting the span of cantilever space frame structure is (1, 3, and 6). The results are taken from the bottom members of starting three members at fixed end support and the last three members at free end support. The results obtained from analysis based on shear force and bending moment are discussed in terms of model analysis and Equivalent Static Analysis. Fig 2 & 3 shows 3D modeled of cantilever space frame and plane frame structure.

A. Equivalent Static Analysis (ESA)

Equivalent static analysis of both cantilever space frame structure and regular cantilever plane frame structure is analysed based on the seismic load. The results of the ESA are tabulated as shown below.

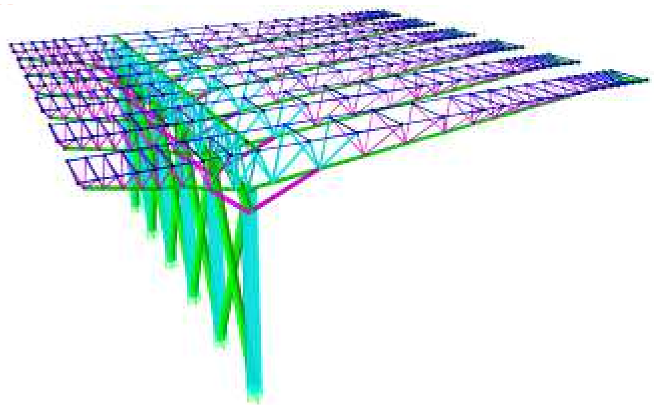


Fig 2: 3D Rendered View of Space Frame Structure

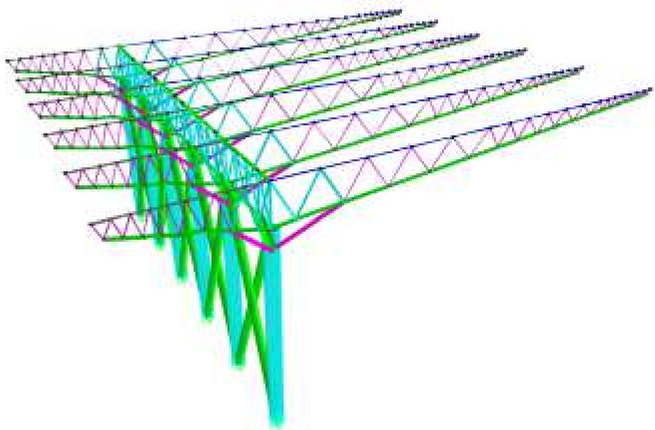


Fig 3: Rendered View of Plane Frame Structure

Table-2: Model analysis of Shear Force both Space Frame and Plane Frame Structure

Shear Force (kN)				
Frame no's	End Type	Member no's	Model	
			Space Frame	Plane Frame
Cantilever Frame -1	Fixed End	199	-2.826	-2.039
		200	0.871	0.756
		201	0.069	-0.010
	Free End	214	-0.326	-0.208
		215	-0.489	-0.25
		216	-0.378	0.883
Cantilever Frame -3	Fixed End	619	-3.236	-3.086
		620	1.379	1.099
		621	0.049	-0.045
	Free End	634	-0.421	-0.401
		635	-0.635	-0.482
		636	-0.483	1.706
Cantilever Frame -6	Fixed End	1249	-2.826	-2.039
		1250	0.871	0.755
		1251	0.069	-0.010
	Free End	1264	-0.326	-0.208
		1265	-0.489	-0.250
		1266	-0.378	0.883

Here,

- From table 2 it can be seen that the model analysis of shear force at fixed end support, the span of each cantilever space frame value shows more when compared to the cantilever plane frame structure.
- In the model analysis of shear force at the free end, the span of each cantilever space frame value shows more when compared to the cantilever plane frame structure. But at end of each span of cantilever space frame structure, the members are (216, 636, 1266) the values are lesser (-0.378, -0.483, -0.378), when compared to cantilever plane frame structure the values is (0.883, 1.706, 0.883).
- In the model analysis of shear force, to compared the span of each cantilever frame (1, 3, and 6) at fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are lesser when compared to the span of middle cantilever frame - 3.

Table-3: Model analysis of Bending moment both Space Frame and Plane Frame Structure

Bending Moment (kN-m)				
Frame no's	End Type	Member no's	Model	
			Space Frame	Plane Frame
Cantilever Frame -1	Fixed End	199	0.503	0.386
		200	0.384	0.346
		201	-0.072	-0.045
	Free End	214	0.020	0.170
		215	0.206	0.270
		216	0.353	0.264
Cantilever Frame -3	Fixed End	619	0.541	0.588
		620	0.435	0.527
		621	-0.093	-0.067
	Free End	634	0.017	0.335
		635	0.258	0.526
		636	0.443	0.514
Cantilever Frame -6	Fixed End	1249	0.503	0.386
		1250	0.384	0.346
		1251	-0.072	-0.045

	Free End	1264	0.020	0.170
		1265	0.206	0.270
		1266	0.353	0.264

Here,

- From table 3 it can be seen that the model analysis of bending moment at the fixed end support, the span of each cantilever space frame-1 and cantilever space frame-6 value shows more (0.503, 0.384, -0.072) when compared to cantilever plane frame structure the values are (0.386, 0.346. -0.045). But in the middle span of the cantilever space frame - 3 value shows lesser (0.541, 0.435), when compared to the cantilever plane frame structure the values are (0.588, 0.527). After these (619 and 620) of two members at fixed end support are starting with the member of (621), the span of middle cantilever space frame-3 values are more (-0.093) when compared to cantilever plane frame structure the value is (-0.067).
- The Model analysis of bending moment at free end, the span of each cantilever space frame shows lesser values are (0.020, 0.206, 0.017, 0.258, 0.443) when compared to cantilever plane frame structure the values are (0.170, 0.270, 0.335, 0.526, 0.514). But at the end of span cantilever frame-1 and cantilever frame-6 at free end,
- the member (216, 1266) value shows more (0.353) when compared to cantilever plane frame structure the value is (0.264).
- In the model analysis of bending moment, to compared the span of each cantilever frame (1, 3, and 6), the span of cantilever frame-1 and cantilever frame-6 at fixed end support and a free end, the values are lesser when compared to the span of middle cantilever frame-3.

Table-4: Earthquake in X-direction of Shear Force both Space Frame and Plane Frame Structure

Shear Force (kN)				
Frame no's	End Type	Member no's	EQ-X	
			Space Frame	Plane Frame
Cantilever Frame -1	Fixed End	199	0.373	0.286
		200	0.060	0.054
		201	0.010	0.005
	Free End	214	0.000	0.000
		215	0.000	0.000
		216	0.006	0.005
Cantilever Frame -3	Fixed End	619	0.395	0.326
		620	0.062	0.059
		621	0.010	0.005
	Free End	634	0.005	0.000
		635	0.007	0.000
		636	0.011	0.003
Cantilever Frame -6	Fixed End	1249	0.373	0.286
		1250	0.060	0.054
		1251	0.010	0.005
	Free End	1264	0.000	0.000
		1265	0.000	0.000
		1266	0.006	0.005

Here,

- From table 4 it can be seen that the Earthquake analysis in X-direction of shear force both at fixed end support and a free end, the span of each cantilever space frame value shows more when compared to cantilever plane frame structure.
- The compared the span of cantilever frame (1, 3, and 6) of Earthquake analysis in X-direction of shear force both at fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are lesser when compared to the span of middle cantilever frame - 3.

Table-5: Earthquake in X-direction of Bending Moment both Space Frame and Plane Frame Structure

Bending Moment (kN-m)				
Frame no's	End Type	Member no's	EQ-X	
			Space Frame	Plane Frame
Cantilever Frame -1	Fixed End	199	0.144	0.109
		200	0.032	0.029
		201	0.006	0.004
	Free End	214	0.004	0.001
		215	0.004	0.001
		216	0.006	0.001
Cantilever Frame -3	Fixed End	619	0.154	0.124
		620	0.034	0.033
		621	0.007	0.004
	Free End	634	0.005	0.001
		635	0.007	0.001
		636	0.010	0.001
Cantilever Frame -6	Fixed End	1249	0.144	0.109
		1250	0.032	0.029
		1251	0.006	0.004
	Free End	1264	0.004	0.001
		1265	0.004	0.001
		1266	0.006	0.001

Here,

- From table 5 it can be seen that the Earthquake analysis in X-direction of bending moment both at fixed end support and a free end of each cantilever space frame value shows more when compared to cantilever plane frame structure.
- The compared the span of cantilever frame (1, 3, and 6) of Earthquake analysis in X-direction of bending moment both at fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are lesser when compared to the span of middle cantilever frame - 3.

Table-6: Earthquake in Y-direction of Shear Force both Space Frame and Plane Frame Structure

Shear Force (kN)				
Frame no's	End Type	Member no's	EQ-Y	
			Space Frame	Plane Frame
Cantilever Frame -1	Fixed End	199	0.158	0.394
		200	0.027	0.077
		201	0.004	0.007
	Free End	214	0.005	0.006
		215	0.009	0.006
		216	0.017	0.033
Cantilever Frame -3	Fixed End	619	0.067	0.069
		620	0.011	0.013
		621	0.001	0.001
	Free End	634	0.003	0.000
		635	0.002	0.000
		636	0.009	0.001
Cantilever Frame -6	Fixed End	1249	0.158	0.394
		1250	0.027	0.077
		1251	0.004	0.007
	Free End	1264	0.005	0.006
		1265	0.006	0.006
		1266	0.017	0.033

Here,

- From table 6 it can be seen that the Earthquake analysis in Y-direction of shear force at both fixed end support
- and a free end of cantilever space frame value shows lesser when compared to cantilever plane frame structure. But in the middle of cantilever space frame - 3 at the free end the members are (634, 635, 636), the value shows more (0.003, 0.002, 0.009) when compared to cantilever plane frame structure the values are (0.000, 0.000, 0.001).
- The compared the span of cantilever frame (1, 3, and 6) of Earthquake analysis in X-direction of shear force both at fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are more when compared to the span of middle cantilever frame - 3.

Table-7: Earthquake in Y-direction of Bending Moment both Space Frame and Plane Frame Structure

Bending Moment (kN-m)				
Frame no's	End Type	Member no's	EQ-Y	
			Space Frame	Plane Frame
Cantilever Frame -1	**Fixed End**	199	0.063	0.153
		200	0.016	0.043
		201	0.004	0.005
	Free End	214	0.001	0.007
		215	0.003	0.009
		216	0.007	0.009
Cantilever Frame -3	**Fixed End**	619	0.024	0.026
		620	0.006	0.007
		621	0.001	0.000
	Free End	634	0.001	0.000
		635	0.002	0.000
		636	0.002	0.000
Cantilever Frame -6	**Fixed End**	1249	0.063	0.153
		1250	0.016	0.043
		1251	0.004	0.005
	Free End	1264	0.001	0.007
		1265	0.003	0.009
		1266	0.007	0.009

Here,

- From table 7 it can be seen that the Earthquake analysis in Y-direction of bending moment at both fixed end support and a free end of cantilever space frame value shows lesser when compared to cantilever plane frame structure. But in the middle of cantilever space frame – 3 at the free end the members are (634, 635, 636), the value shows more (0.001, 0.002, 0.002) when compared to cantilever plane frame structure the values are (0.000, 0.000 0.000).
- The compared the span of cantilever frame (1, 3, and 6) of Earthquake analysis in Y-direction of bending moment both at fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are more when compared to the span of middle cantilever frame - 3.

4. CONCLUSION

Based on analysis and discussion, the results are extracted and tabulated. The analysis results are compared and conclusions are drawn in this chapter.

- From the overall analysis, it is observed that the performance of space frame structure is better when compared to plane frame0 structure since space frame is strong0 due to the inherent0 rigidity0 of0 the0 triangle0 and flexing the loads which can be transferred as tension0 and0 compression0 loads0 along0 the length0 of0 each0 strut.
- The model analysis0 of shear force value shows more in cantilever space frame structure when compared to the regular plane frame structure.
- The model analysis of bending moment value shows more at fixed end support in cantilever space frame structure when compared to the plane

frame structure. But in the free end of cantilever space frame structure value shows lesser when compared to the plane frame structure.

- The model analysis of shear force and bending moment, to compared the span of each cantilever frame (1, 3, and 6), the span of cantilever frame-1 and cantilever frame-6 the value shows are lesser when compared to the span of middle cantilever frame-3.
- The static analysis of EQ-X in both shear force and bending moment value shows more when compared to the EQ-Y value.
- The compared span of cantilever frame (1, 3, and 6) of Earthquake analysis in X-direction of shear force and bending moment at both fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are lesser when compared to the span of middle cantilever frame - 3.
- The compared span of cantilever frame (1, 3, and 6) of Earthquake analysis in Y-direction of shear force and bending moment at both fixed end support and a free end, the span of cantilever frame - 1 and cantilever frame - 6 the values are more when compared to the span of middle cantilever frame - 3.

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