Comparative Study on the Behaviour of Tubular Structure and Diagrid Structure Subjected to Dynamic Loading

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Abstract— The high cost of land and the rapid growths of urban population and to avoid a continuous urban sprawl, and the need to preserve important agricultural production have to contributed to drive residential buildings upward. Diagrid is a particular form of space truss. It consists of perimeter grid made up of a series of triangulated truss system. Study has been carried out for Steel tubular structure provided with 60^0 angle diagrid. Modelling Study has been carried out for Steel tubular structure provided with 60^0 angle diagrid. Modelling and analysis is carried out in ETABS using dynamic time history analysis and Bhuj data and analysis is carried out in ETABS using dynamic time history analysis and Bhuj data. Study has been carried out for Steel tubular structure provided with 60^0 angle diagrid. Modelling and analysis is carried out in ETABS using dynamic time history analysis and Bhuj data. Comparison is carried on tubular steel building and tubular diagrid building with respect to base shear, displacement, drift and time period are found. It was concluded that tubular diagrid structures are economical when storey height is more. The study gives a clear view that diagrid structures are much effective in reducing the response of the structure.

Keywords: Dynamic Loading, ETABS, Tubular Structure and Diagrid Structure

I. Introduction

A. General

High-rise buildings with mixed constructions (shear-wall, braced-tube, tube-in-tube) are formed with the combination of several load-bearing structures. The application of particular types of load-bearing systems is determined by the height and geometric form of the building. Due to very complex geometric forms of tall buildings, it has recently been very popular to use the diagrid system for both steel and reinforced concrete. Diagrid is a particular form of space truss. It consists of perimeter grid made up of a series of triangulated truss system.

Diagrid is formed by intersecting the diagonal and horizontal components. Diagrid has good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduce the number of structural element required on the facade of the buildings, therefore less obstruction to the outside view. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, therefore allowing significant flexibility with the floor plan. Perimeter “diagrid” system saves approximately 20 percent of the structural steel weight when compared to a conventional moment-frame structure.

The diagonal members in diagrid structural systems can carry gravity loads as well as lateral forces due to their triangulated configuration. Diagrid structures are more effective in minimizing shear deformation because they carry lateral shear by axial action of diagonal members. Diagrid structures generally do not need high shear rigidity cores because lateral shear can be carried by the diagonal members located on the periphery.

B. Diagrid as a Structural System

Diagrids are the supporting frames which are placed diagonally and made by the connections of different materials like concrete, steel or wooden beams, which are used for the construction of roofs and structures. These diagonal members that are narrow which help in resisting both in gravity and in lateral loads. Diagrid buildings with steel members are very well-organized in providing solution for both strength and stiffness. Diagrid buildings with steel members are very well-organized in providing solution for both strength and stiffness.

Fig. 1.1: Diagrid Structure in Hong Kong

C. Properties of Diagrid Buildings

A diagonal in diagrid buildings understand the moments and shears, not only the lateral load, but also due to the vertical loads. The optimum angle is 35º that is taken for braced building which is composed of straight up columns and of diagonals. Also the equivalent optimum angle in the region 90º is assumed for the frame in which axial forces are carried by the columns.

The range of optimum angle range increases with the increase in height of building. This is because, with less aspect ratio i.e. height to width being lesser the short buildings act like a shear beam. And with more aspect ratio, the tall buildings act as bending beams.

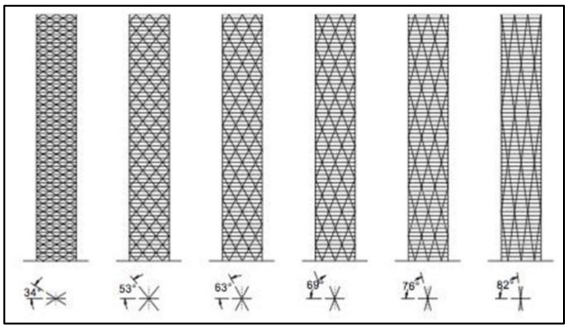


Fig. 1.3: Diagrid structure with Varying Angle

II. Objectives

- Understand the behavior of angled diagrid in comparison with tubular steel structure.
- Study has been carried out for Steel tubular structure and Steel tubular structure provided with 60º angle diagrid.
- Modelling and analysis are carried out in ETABS with high seismic zone and dynamic time history analysis.
- Efficiency of tubular steel buildings with respect to base shear, displacement, drift are found out for the respective geometric configurations.
- The behaviour of the building on implementation of diagrids to tubular buildings will be summarized based on the obtained results.

III. Methodology

- E-tabs is used for modelling and analysis of buildings.
- Desirable steel sections are used for modelling.
- Two models with steel moment resisting frames will be considered and analysis is done for tubular steel structures with diagrids and structures without diagrids.
- Time history method is used for analyzing and the response Quantities like displacements, base shear, drift and time period are noted.

To study the behavior of diagrid buildings, a building with G+30 storeys is been modelled. The diagrid steel structure with the diagrid angle being 60º and conventional steel structure is examined. The modelling and analysis is carried out using ETABS with Bhuj Time history data.

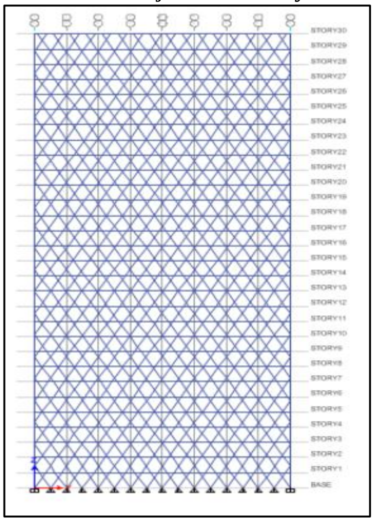


Fig. 3.1: 2D Elevation of Tubular Diagrid Structure with 60º Angle

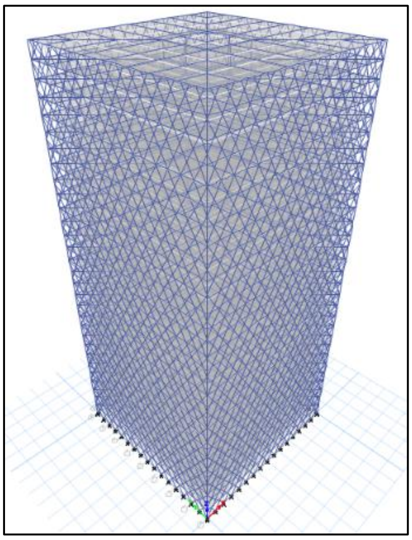


Fig. 3.2: 3D Elevation of Tubular Diagrid Structure with 60º Angle

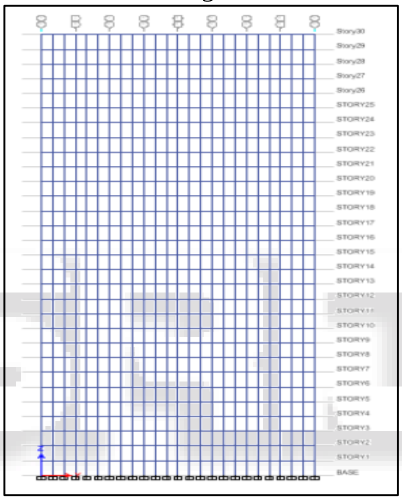


Fig. 3.3: 2D Elevation of Tubular Steel Structure

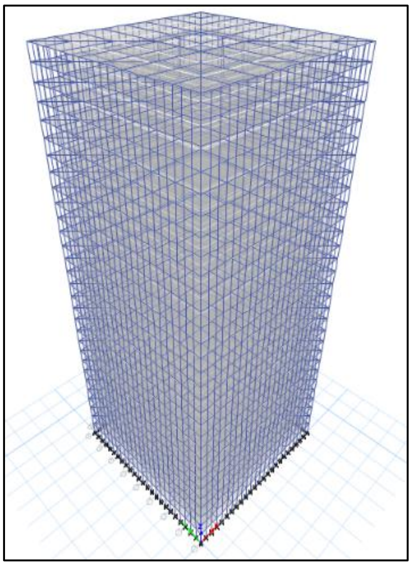


Fig. 3.4: 3D Elevation of Tubular Steel Structure

A. Description of Analytical Model

No of storeys	G+30
Building type	Tubular steel section
Building Dimension	40mx40m

Typical Storey Height	3m
Seismic Zone	Zone V
Soil Type	Type 2
Response Reduction Factor	5
Importance Factor	1

Table 3.1: General details of the buildings

Thickness of Deck	0.2m
Beam	ISMB
Column	ISWB
Wall Thickness	Glazing load is considered

Table 3.2: Structural members of the buildings

Grade of concrete	M30
Grade of Steel	Fe350
Density of Concrete	25 kN/m^3
Young's modulus of concrete	27386x10^{3}kN/m^2
Poisson's ratio	0.2

Table 3.3: Material properties of the buildings

Slab live load	4kN/m^2
Floor finish	1.5kN/m^2
Glazing load	1kN/m^2

Table 3.4: Assumed load intensities

IV. Results and Discussion

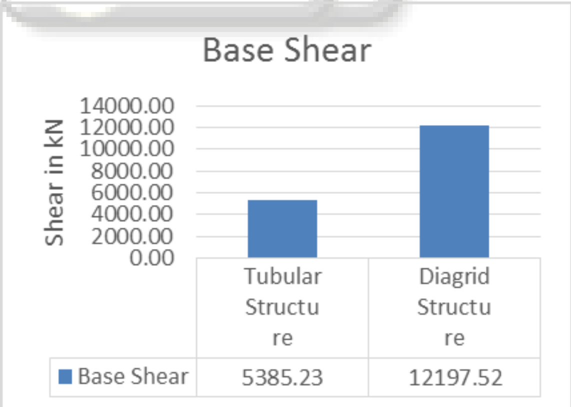
Comparative study on the behavior of tubular structure and diagrid structure subjected to dynamic loading is carried out for the Base shear, Storey displacement, Storey stiffness, Storey stiffness, Storey Drift, Time period.

A. Base Shear

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity.

	Tubular Structure	Diagrid Structure
Base Shear	5385.23	12197.52

Table 4.1: Base shear



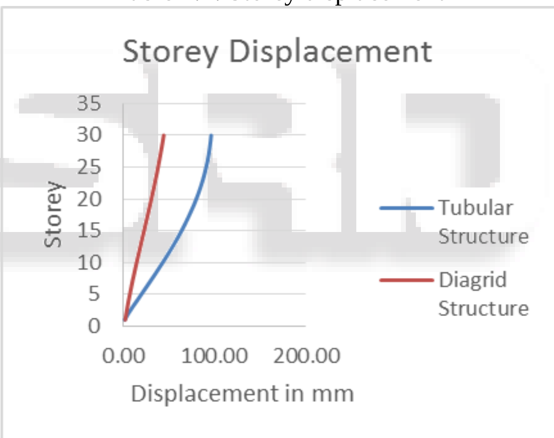
Graph 4.1: Base Shear

B. Storey Displacement

Storey Displacement is the total displacement of ith storey with respect to ground.

Storey	Tubular Structure	Diagrid Structure
30	96.72	44.87
29	96.03	43.72
28	95.18	42.54
27	94.11	41.31
26	92.83	40.02
25	91.33	38.69
24	89.61	37.31
23	87.66	35.88
22	85.49	34.42
21	83.11	32.91
20	80.50	31.38
19	77.68	29.81
18	74.65	28.22
17	71.42	26.62
16	67.98	24.99
15	64.36	23.36
14	60.55	21.72
13	56.57	20.09
12	52.43	18.46
11	48.15	16.84
10	43.74	15.25
9	39.21	13.68
8	34.59	12.13
7	29.89	10.63
6	25.14	9.18
5	20.35	7.75
4	15.55	6.42
3	10.80	5.14
2	6.22	3.95
1	2.20	2.00

Table 4.2: Storey displacement



Graph 4.2: Storey Displacement

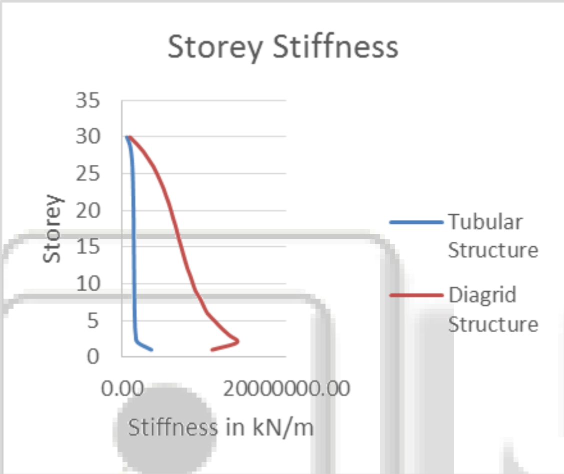
C. Storey Stiffness

Storey stiffness is the degree to which an object resists deformation in response to an applied force.

Storey	Tubular Structure	Diagrid Structure
30	660383.44	1022266.57
29	1014187.43	1927082.24
28	1179761.68	2681813.90
27	1271107.83	3289197.09
26	1328667.35	3870381.99
25	1368379.21	4319258.40
24	1397490.84	4734805.65
23	1419806.44	5121551.47
22	1437542.42	5417781.89
21	1452092.50	5757448.93
20	1464384.80	6026353.71
19	1475066.83	6268610.80
18	1484609.30	6555439.53
17	1493368.01	6785964.82

16	1501622.70	7020043.87
15	1509602.69	7280526.46
14	1517504.57	7525232.82
13	1525505.30	7781363.11
12	1533772.70	8052089.64
11	1542475.18	8406765.07
10	1551792.83	8693335.09
9	1561934.78	9012111.39
8	1573176.83	9556060.49
7	1585965.77	9979129.39
6	1601249.79	10437649.00
5	1621602.45	11300597.00
4	1655241.20	12123228.00
3	1731850.36	13107631.00
2	1982037.65	14055442.00
1	3637682.14	11028239.00

Table 4.3: Storey Stiffness



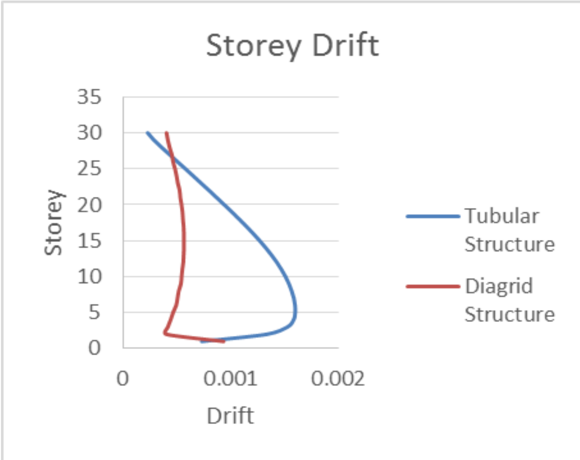
Graph 4.3: Storey Stiffness

D. *Storey Drift*

Storey Drift is defined as ratio of displacement of two consecutive floors to height of that floor.

Storey	Tubular Structure	Diagrid Structure
30	0.00023	0.000404
29	0.000288	0.000417
28	0.000358	0.000433
27	0.000432	0.000454
26	0.000506	0.000465
25	0.00058	0.000484
24	0.000654	0.000498
23	0.000726	0.00051
22	0.000799	0.000526
21	0.00087	0.000533
20	0.000941	0.000544
19	0.001011	0.000553
18	0.001079	0.000557
17	0.001145	0.000563
16	0.001209	0.000566
15	0.001269	0.000566
14	0.001326	0.000567
13	0.001379	0.000564
12	0.001428	0.000561
11	0.001471	0.000551
10	0.001509	0.000545
9	0.001541	0.000538
8	0.001566	0.000518
7	0.001586	0.000507
6	0.001597	0.000494
5	0.001599	0.000465
4	0.001584	0.000443
3	0.001526	0.000417
2	0.00134	0.000402
1	0.000732	0.000934

Table 4.4: Storey Drift



Graph 4.4: Storey Drift

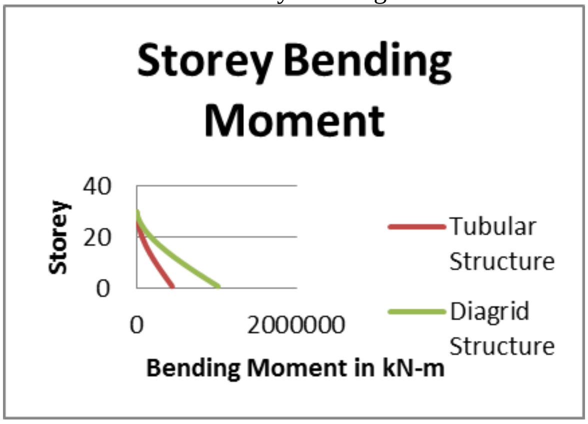
E. *Storey Bending Moment*

A bending moment is the reaction induced in a structural element when an external force or moment is applied to the element causing the element to bend.

Storey	Tubular Structure	Diagrid Structure
30	1139.5572	2996.6144
29	3447.0617	9008.1832
28	6905.0675	17961.1318
27	11492.9856	29780.8131
26	17188.7923	44389.2373
25	23970.9461	61704.0849
24	31819.7778	81636.6865
23	40718.4414	104091.2292
22	50653.0031	128965.8031
21	61611.9756	156150.7279
20	73584.9898	185532.6463
19	86561.0926	216994.7941
18	100526.4132	250418.9524
17	115462.5109	285688.7305
16	131345.4171	322692.2229
15	148145.3302	361322.1042
14	165826.4425	401477.5685
13	184346.1047	443065.4935
12	203653.425	485996.066
11	223688.6239	530183.8503
10	244383.0188	575544.7333
9	265660.5731	621992.7363
8	287440.2542	669434.736
7	309639.3773	717773.2721
6	332176.9946	766900.2533
5	354976.5348	816695.4414
4	377967.7556	867034.1478

3	401086.9223	917779.119
2	424278.1129	968790.4367
1	447494.2814	1019930

Table 4.5: Storey Bending Moment



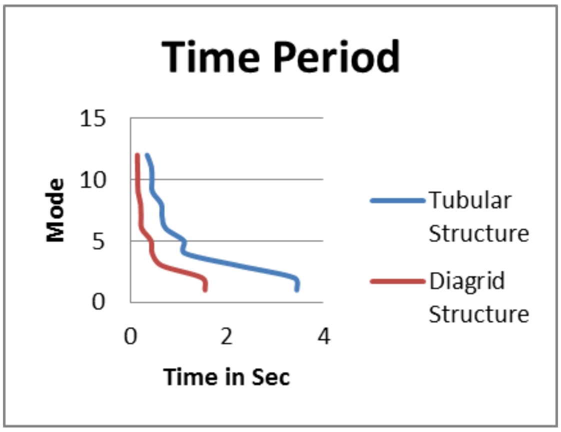
Graph 4.5: Storey Bending Moment

F. *Time Period*

A system is said to be vibrating in a normal mode when all its masses attain maximum values of displacements and rotations simultaneously, and pass through equilibrium positions simultaneously.

Mode	Tubular Structure	Diagrid Structure
1	3.448	1.551
2	3.393	1.488
3	2.226	0.654
4	1.134	0.454
5	1.114	0.433
6	0.74	0.239
7	0.658	0.225
8	0.645	0.215
9	0.461	0.163
10	0.451	0.157
11	0.441	0.153
12	0.35	0.147

Table 4.6: Time Period



Graph 4.6: Time Period

V. Conclusion

In this study a structural model with tubular structure and tubular structure with diagrid of 60º angles is considered as the building models, where in these models are analyzed using Time history method and the data corresponding to Bhuj data are considered, their corresponding behaviors and results are extracted and interpreted. Various parameters such as displacements, storey drifts, storey acceleration, storey force, storey Stiffness, base shear, time period and storey bending moment have been grouped. Hence from the obtained results the following conclusions are made.

1) Storey Displacement was found less in diagrid structure than that in structure without diagrid system.
2) The angled diagrids provided proper stiffness to structure that intern result in decreasing the storey displacement.
3) Tubular diagrid structure with 60º gives lesser storey shear and less storey drift than that for conventional tubular structure.
4) In terms of utilization of steel and concrete, the angled diagrid structure is found to be more economical.
5) The base shear for the diagrid model is found to be more than the tubular steel structure, which imply higher stiffness to the structure that interns offer higher resistance against overturning, higher stability and assure safety to the occupants.
6) Also, tubular diagrid structures are economical when storey height is more.
7) The comparative study on tubular steel structure and tubular diagrid steel structure with 60º give a clear view that diagrid structures are much effective in reducing the response of the structure and is compatible.

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