Analog Search of Different Lateral Load Resisting System for High Rise Building

Tejas N. Kothari, Udaysingh Patil, Sharda P. Siddh

Abstract*— As the rate of growth of population is increasing day by day, the requirement of land is increasing for different purposes. To accommodate this increased population, the height of building is increasing thereby subsequently increasing the importance of lateral load resisting system which provide adequate strength against lateral loading arising due to earthquake and wind. In present study various lateral load resisting system have been introduced which can resist the lateral forces and safely transfer them to soil thereby improving the strength and stiffness of column structures. The lateral load resisting systems that are widely used are conventional beam column system, shear wall system, tube system, outrigger system, tubular system etc. Diagrid structural system is generally adopted in tall buildings due to its structural efficiency and flexibility in planning. Compared to closely space vertical columns in Conventional Beam column system, diagrid structure consists of inclined columns on the exterior surface of building. The concrete diagrids member is used in both precast and cast in-situ type. An exhaustive study has been performed on the performance of 20 storey RCC building with plan size 18 m × 18 m using E-TAB software. All structural members are designed as per IS 456:2000 and all the load combinations of seismic forces are considered as per IS 1893(Part 1): 2002. Finally, Parameter such as storey displacement, storey stiffness and time period are compared and obtained results were presented in both graphically and tabular format.

Index Terms*— Diagrid structural system, Shear wall system, Tube system, Beam Column System, High rise buildings, storey displacement, storey stiffness and Time period.

I. INTRODUCTION

Nowadays taller structures are preferred due to increase in population growth and limitation in availability of land therefore taller structures are better choice available now to avoid congestion. Construction of high rise structure is further complex without using any lateral load resisting system as it attracts large lateral forces arising may be due to earthquake and wind, thus this system makes the structure earthquake resistant by increasing strength and stiffness. This is in contrast with conventional structural system that resists gravitational loads. Many countries like Dubai, London, New York etc. are famous for construction of tall structures they are using lateral load resisting system to resist lateral forces subsequently increasing durability and reliability.

Lateral forces generated due to earthquake can cause larger stresses in structural elements, lateral sways or any other damaging effects which will lead to failure of structure thereby endangers the safety of individual. Thus to improve the seismic performance of building the provision of lateral

load resisting system is must. Thus in present study the emphasis is given to know the effectiveness of various systems available like shear wall system, tube system, outrigger system, tubular system etc. which can resist the force and safely transfer them to soil and to improve the strength and stiffness of column structures. Stiffness is directly proportional to deformation, larger is the stiffness larger is the force required to deform it. Increase in rigidity or stiffness at bottom of building decreases the top storey displacement and vice versa.

II. BUILDING CONFIGURATION

In present study model of 20 storey tall building, having 18 m × 18 m plan dimension is developed using ETAB software with 4 types of lateral load resisting system i.e. conventional beam column system, shear wall system, tube system and diagrid system. In shear wall system, shear wall is at the center of structure in outer periphery. The tube system concept it as a building by designing it as a hollow cantilever perpendicular to ground, In diagrid structures, pair of braces is located on the periphery of the building. The angle of inclination of diagrid member is kept uniform throughout the height the structure. The inclined columns are provided at spacing of 3 m along the perimeter of structure. The interior structural frame of the diagrid structures is designed only for gravity load. The design dead load and live loads on floor slab are 2 kN/m^2 and 1.5 kN/m^2 respectively.

The design earthquake load is computed based on the zone factor of 0.36, medium soil, importance factor of 1 and response reduction factor of 5 (IS: 1893 (Part-I), 2002). Modeling, analysis and design of all the structure are carried out using ETABS software. All structural members are designed using IS 456:2000.

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A. Plan

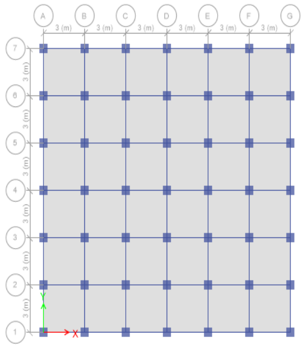

Figure 1: Beam Column System

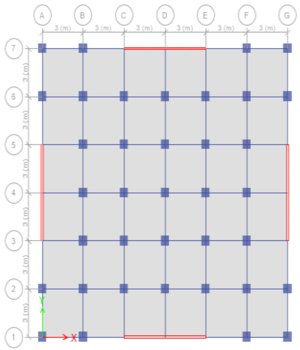

Figure 2: Shear Wall System

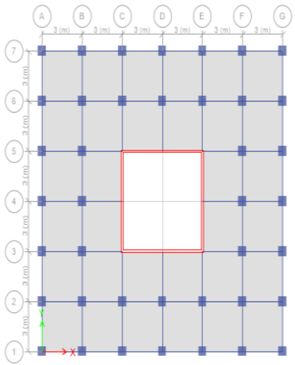

Figure 3: Frame Tube System

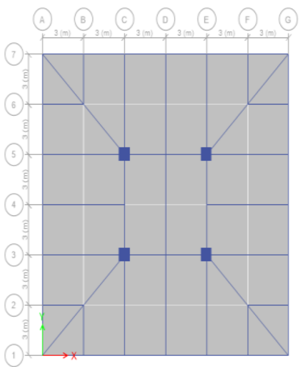

Figure 4: Diagrid System

B. Elevation

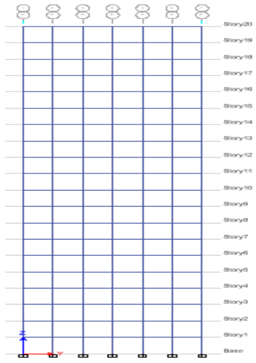

Figure 5: Beam Column System

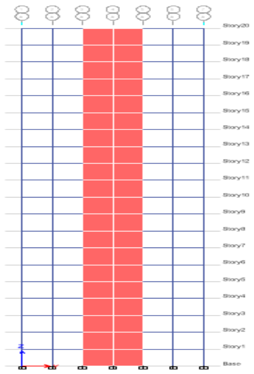

Figure 6: Shear Wall System

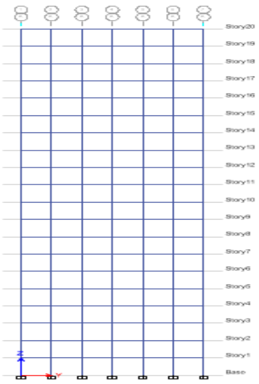

Figure 7: Frame Tube System

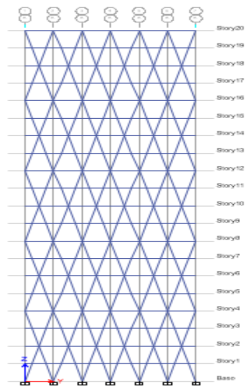

Figure 8: Diagrid System

C. 3D-Model

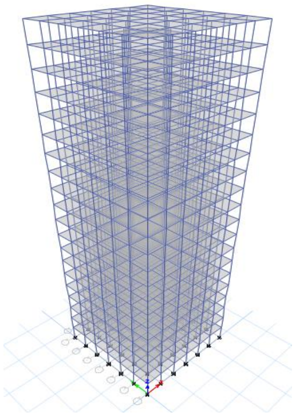

Figure 9: Beam Column System

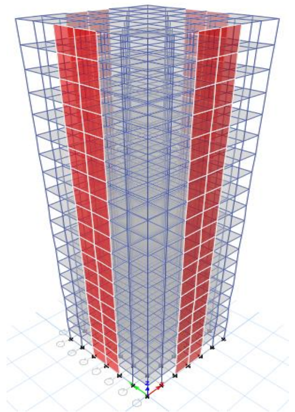

Figure 10: Shear Wall System

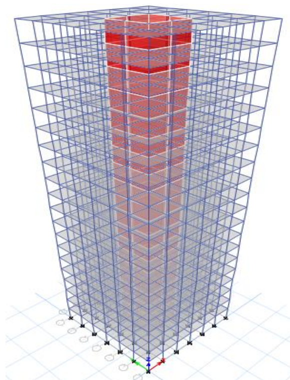

Figure 11: Frame Tube System

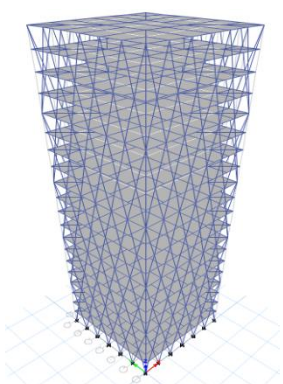

Figure 12: Diagrid System

Table 1:- Member sizes for all models (All Dimension in mm)

Systems	Beam	Column	Diagrid	Slab Thickness	Shear wall Thickness
Beam Column	450x300	600x600	-	130	-
Shear Wall	450x300	600x600	-	130	130
Tube System	450x300	600x600	-	130	130
Diagrid System	B1-650x400 B2-500x300 B3-450x300	800x800	500x500	130	-

III. RESULTS AND DISCUSSIONS

The comparative analysis is carried out for Conventional structural system, Shear wall system, Tube system and diagrid structural system in terms of modal Time period, Storey Displacement and Storey Stiffness.

A. Modal Time Period

The time period for Conventional structure system, Shear wall system, Tube system and diagrid structure are shown in Fig. The first mode time period of Beam Column system is 2.027 seconds, for Shear wall system time period is 1.678 second, for Tube system time period is 1.494 second and for diagrid structural system time period is 1.089. It can be seen that for conventional structural system the time period is more when compared with other lateral load system. The maximum reduction in time period is 53.72% compared to beam column system which will directly affect the displacement of structure.

Table 2:- Modal Time Period

Mode	Beam Column System	Shear Wall System	Tube System	Diagrid System
1	2.027	1.678	1.494	1.089
2	2.027	1.678	1.494	1.085
3	1.837	1.228	1.151	0.568
4	0.657	0.509	0.425	0.341
5	0.657	0.509	0.425	0.34
6	0.604	0.375	0.382	0.19
7	0.371	0.264	0.227	0.185
8	0.371	0.264	0.209	0.184
9	0.353	0.196	0.209	0.13
10	0.255	0.167	0.161	0.13
11	0.255	0.167	0.132	0.115
12	0.244	0.121	0.132	0.101

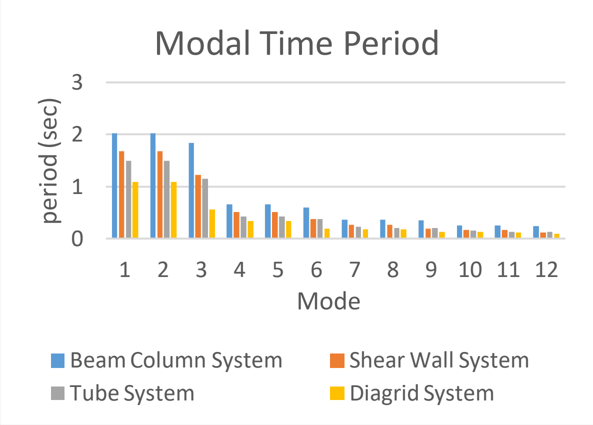

Figure 13: Modal Time Period

B. Storey Displacment

Storey displacement for conventional structure system, shear wall system, tube system and diagrid structure is shown in Fig.14 It is observed that displacement for conventional structure due earthquake is higher compared to all lateral system. It can be observed that amongst 3 lateral systems, diagrid system shows less displacement.

The 20th storey displacement of Beam Column system is 37.1 mm, for Shear wall system storey displacement is 32.3 mm, for Tube system storey displacement is 30.2 mm and for diagrid structural system storey displacement is 22.4 mm.

Table 3:- Storey Displacement

Storey	Beam Column System	Shear Wall System	Tube System	Diagrid System
Storey1	0	0	0	0
Storey2	3.6	2	1.6	1.8
Storey3	6.2	3.8	2.9	3
Storey4	8.9	5.7	4.5	4.3
Storey5	11.4	7.8	6.1	5.6
Storey6	13.9	10	7.9	6.8
Storey7	16.4	12.1	9.7	8.1
Storey8	18.7	14.2	11.5	9.5
Storey9	20.9	16.2	13.4	10.7
Storey10	23	18.2	15.2	12
Storey11	25	20.1	17	13.3
Storey12	26.9	21.8	18.7	14.5
Storey13	28.7	23.5	20.4	15.7
Storey14	30.4	25.1	22	16.9
Storey15	31.9	26.6	23.6	18
Storey16	33.3	28	25.1	19
Storey17	34.5	29.2	26.5	20
Storey18	35.6	30.4	27.8	20.9
Storey19	36.4	31.4	29	21.7
Storey20	37.1	32.3	30.2	22.4

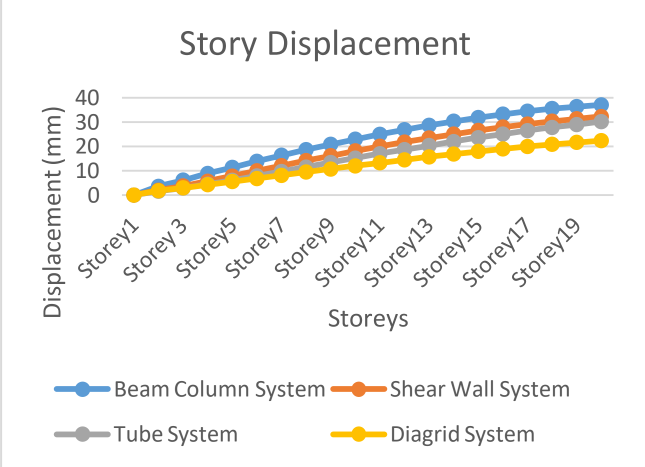

Figure 14: Storey Displacement

C. Storey Stiffness

The distribution of story Stiffness along the height for Beam Column System, Shear wall system, Tube system and diagrid structure due earthquake is shown in Fig.15. The stability of RCC-structure increases with increase in stiffness of column. It is observed that story stiffness for diagrid structure due to earthquake load is higher compared to conventional structure, shear wall system and tube system. Since stiffness is directly proportional to displacement. Due to increase in stiffness diagrid structures shows less displacement as given in table 3.

Table 4:- Story Stiffness

Story	Beam Column System	Shear Wall System	Tube System	Diagrid System
Story20	373452.34	335514.1	318790.1	526656.3
Story19	571710.02	581916.8	573648.5	908241.2
Story18	652646.73	724678.6	746805	1235631
Story17	690190.17	799803.5	855545.3	1393332
Story16	710463.15	839979.3	924587.2	1589717
Story15	724043.23	863466.7	971588.6	1672432
Story14	735148.48	878977.7	1007277	1814122
Story13	745100.64	890302.3	1037697	1872799
Story12	754435.4	900141.1	1067426	1958290
Story11	763985.8	911686.5	1101332	2026878
Story10	774738.69	927992.6	1144192	2180544
Story9	787110.5	950846.6	1199620	2260647

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Story8	800728.91	981080.5	1270316	2310742
Story7	815073.18	1020477	1360148	2422902
Story6	830266.31	1073865	1476923	2675213
Story5	847496.79	1151029	1635286	2820932
Story4	870313.88	1271115	1862900	2828528
Story3	912211.62	1483253	2219616	2981627
Story2	1039164.7	1930004	2881873	3366003
Story1	1927283.8	3952617	5103672	5694295

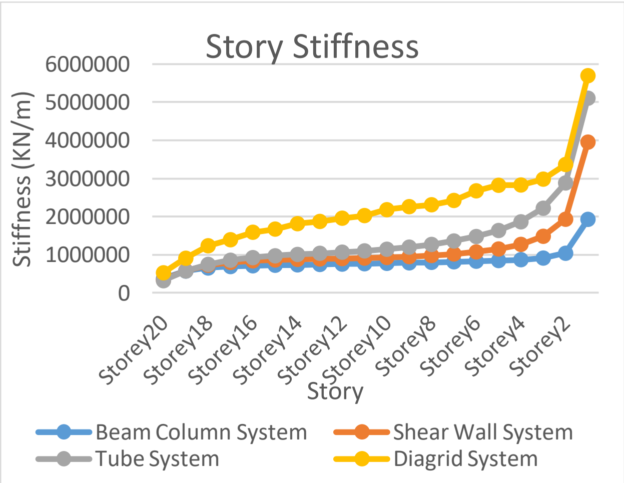

Figure 15: Story Stiffness

IV. CONCLUSION

In this paper, comparative analysis and design of 20-storey diagrid structural system building, shear wall system, tube system and simple frame building is presented. A Regular symmetrical plan of 18m x 18m size is considered. ETABS software is used for modelling, analysis and design of structure. Analysis results like story displacement, story stiffness and modal time period are presented here. Also design of all the structures is done and optimum member sizes are decided to satisfy the code criteria. From the detail analysis following conclusions can be drawn.

a. Top story displacement is much less in diagrid structure compared to other lateral system therefore it is much effective in resisting lateral loads.
b. Diagrid provides more resistance to lateral loads in the building which makes system more effective. Also weight of diagrid structure is more due to which base shear increases but eventually gives better performance under seismic loading.
c. The stability of structure increases with increase in stiffness of column. As the stiffness of column increases, displacement of structure decreases.
d. The design of both structures are done by using same member size but that member sizes are not fulfilling the design criteria in case of simple frame structure and failure occurs with excessive top story displacement. So the higher member size are used to prevent the criteria of failure and satisfy IS provisions.
e. It can be concluded that stiffness of diagrid system is more compared to beam column, shear wall and tube system. Due to increase in stiffness, story displacement and modal time period are reduced, that means damping of structure is increased, i.e., stresses induced due to displacement is reduced.
f. Diagrid structure system provides more economy in terms of consumption of steel and concrete as compared to simple frame building.
g. Diagrid structural system provides more flexibility in planning interior space and façade of the building

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