A Study on Behavior of Structural Systems for Tall Buildings Subjected To Lateral Loads

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***Abstract*—In General, the structure in high seismic areas may be susceptible to the severe damage. Along with gravity load structure has to withstand to lateral load which can develop high stresses. Steel is by far most useful material for building construction in the world and in last decades steel structure has played an important role in construction industry. Providing strength, stability and ductility are major purposes of seismic design. It is necessary to design a structure to perform well under seismic loads. Now a day, shear wall in R.C. structure and steel bracings in steel structure are most popular system to resist lateral load due to earthquake, wind, blast etc.The basic modelingtechnique and assumptions are made by "ETABS" Program, in2-D modeling. Design considerations are made according toIndian Standards. This comparative analysis has been aimed to select the optimal structural system for a certain building height.**

***IndexTerms*— High Rise Steel Frame, shear wall, outrigger, response spectrum method, joint Displacement, Base Shears, Etc.**

I. INTRODUCTION

The plan layout of a building plays a vital role in its resistance to lateral forces and the distribution of earthquake forces. Experience has shown that the buildings with an unsymmetrical plan have a greater vulnerability to earthquake damage than the symmetrical ones. Therefore, symmetry in both axes, not only for the building itself but also for the arrangement of wall openings, columns, and shear walls is very important. For irregular featured buildings, such as asymmetry in plan or vertical discontinuityassumptions different from the buildings with regularfeatures should be used in developing seismic criteria. Today, however, by the advances in structural design/systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake. Specifically for the tall buildings, as the slenderness, and flexibility increases, buildings are severely affected from the lateral loads resulting from wind and earthquake. Hence, it becomes more necessary to identify the proper structural system for resisting the lateral loads depending upon the height of the building. There are many structural systems that can be used for the lateral resistance of tall buildings like Braced frame systems, Rigid frame systems, Outrigger systems, Shear-walled frame systems.

II. METHODOLOGY

The main objective of this study is to carry out the analysis of g+20,30,40 multi storedbuilding against earthquake and wind loads as per Indian standard codes of practice IS 1893(Part 1):2002 and IS 875(Part 3):1987. The wind loads and earthquake loads on the building are calculated assuming the building to be located at Nagpur. The member forces are calculated with load combinations for Limit State Method given in IS 456: 2000 and the members are optimized for the most critical member forces among them. The building is subjected to self weight, dead load, live load as per IS 875(Part 1, Part 2):1987 Here, dynamic analysis is carried out using response spectrum method.

III SCOPE OF STUDY

- The study is to be restricted to a study of steel space frames only.
- Whether a building requires provision of shear wall and bracings or not depends not only on the height of the building but also on the intensity of lateral loads. So it is proposed to carry out this comparison for wind speeds of 44m/sec.
- To carry out analysis of the chosen building for heights of 33, 93, and 123 m to be constructed in wind speeds 44m/sec.
- This structure is modeled in a plan area of 16 m x 20m with 3m each floor level.
- For the analysis ETAB 2016 software is used.

IV .OBJECTIVE OF THE STUDY

- The study is to be restricted to a study of steel space frames only
- The main objective of this work is to contribute to the development of the design guidance for high rise buildings to control wind excitation and earthquake load as a reference for architects, engineers, developers, and students.
- In this research, theconcept of high rise building, which includes the definition, basic design considerations, and lateralloads of tall buildings, are studied.
- Then the results for different shear wall and outrigger positions areinterpreted and conclusions are made as to which condition buildings taken in theconsideration are most stable.
- The results of different parameters such asdisplacement, drift, Base shear and time period arestudied.
- The reduction in drift, deflections and fundamental timeperiod of the regular and irregular building are studied.

V PROBLEM STATEMENT

Problem statement

The building considered in the present report is G+20, 30, 40 storied steel framebuilding of symmetrical rectangular plan configuration. Complete analysis is carried out for dead load, live load, wind load& seismic load using ETAB 2016 software. Response spectrum method of seismic analysis is used. All combinations areConsidered as per IS 1893:2002.

Typical plan of building is shown in Fig.

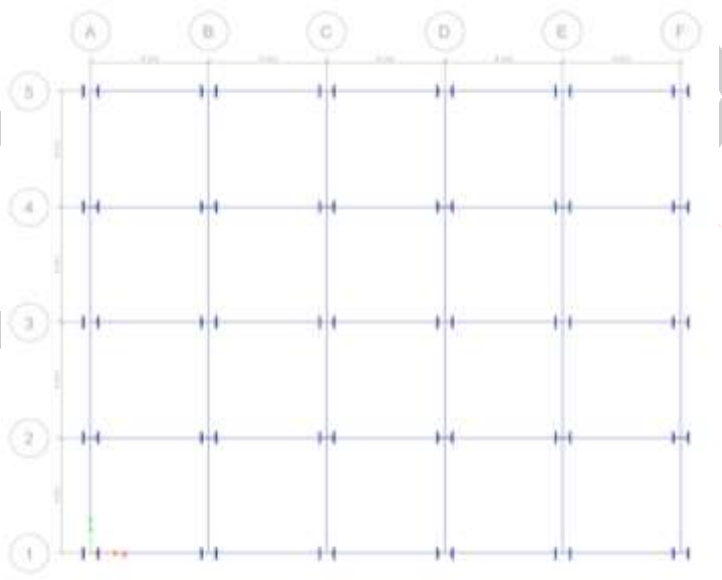

Fig: Plan of steel framed structure

4.2 Mathematical Modeling

Risk coefficient factor K1:: 1

Terrain & height factor K2:: from IS 875:1987(part 3)

Topography factor K3 ::1

Seismic load:: Seismic Zone IV

4.3 Load Combinations

Load combinations that are to be used for Limit state Design of steel structure are listed below.

1. 1.5(DL+LL)
2. 1.2(DL+LL±EQ-X)
3. 1.2(DL+LL±EQ-Y)
4. 1.5(DL±EQ-X)
5. 1.5(DL±EQ-Y)
6. 0.9DL±1.5EQ-X
7. 0.9DL±1.5EQ-Y
8. 1.2(DL+LL)±0.6windload
9. 1.2(DL+LL±windload)
10. 1.5(DL±windload)
11. 0.9DL±1.5windload

Case I –G+20 steel frame building.

Preliminary Sizes of members

Column:: Built up ISHB 450 with 350mm X 25mm and 450mm X 25mm plates.

Beam:: Built up ISHB 400 with 350mm X 25mm plates.

Slab thickness:: 120mm

Shear wall thickness:: 250mm

Bracing:: Built up ISHB 350 with 250mm X 10mm plates.

Case II –G+30 steel frame building.

Preliminary Sizes of members

Column:: Built up ISHB 450 with 350mm X 30mm and 450mm X 30mm plates.

Beam:: Built up ISHB 400 with 350mm X 25mm plates.

Slab thickness:: 120mm

Shear wall thickness:: 250mm

Bracing:: Built up ISHB 350 with 250mm X 10mm plates.

Case III –G+40 steel frame building.

Preliminary Sizes of members

Column:: Built up ISHB 450 with 350mm X 25mm and 450mm X 25mm plates.

Beam:: Built up ISHB 400 with 350mm X 25mm plates.

Slab thickness:: 120mm

Shear wall thickness:: 250mm

Bracing:: Built up ISHB 350 with 250mm X 10mm plates.

Model 1 - steel structure with shear wall

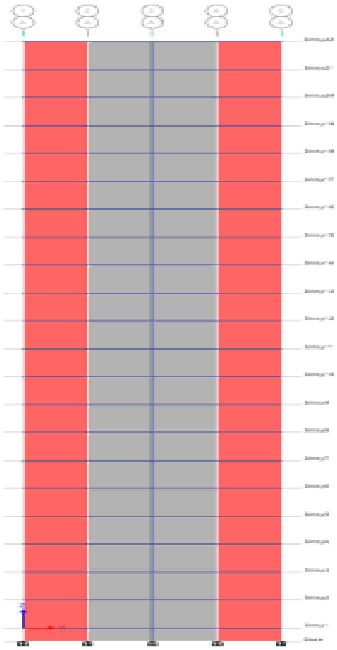

Fig.4.3Elevation of steel framed structure with shear wall 1

Model 2 - steel structure with diagonal outrigger @ 15m

Fig :Elevation of steel framed structure with diagonal outrigger @ 15m

Model 3 - steel structure with x type outrigger @ 15m

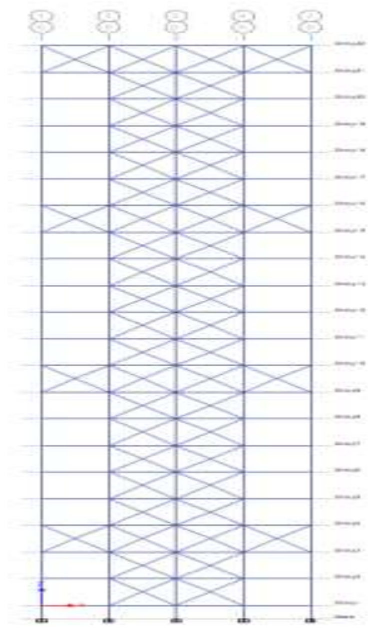

Fig:Elevation of steel framed structure with x type outrigger @ 15m

Model 4 - steel structure with x type outrigger @ 30m

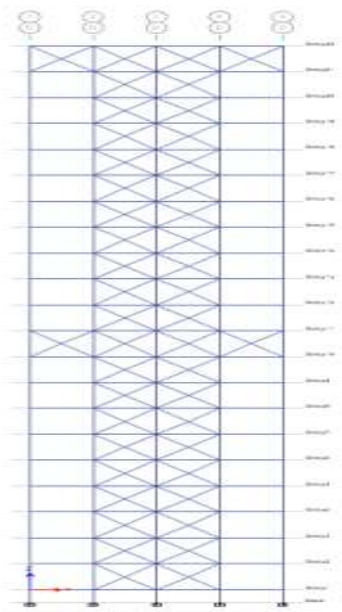

Fig: Elevation of steel framed structure with x type outrigger @ 30m

VI ANALYSIS & RESULTS

Table-Base Shear

TABLE : Base Shear (kN)			
Type of structure	G+20	G+30	G+40
Normal steel structure	1330.15	1529.01	2030.97
steel structure with shear wall 1	2041.27	1869.16	1828.513
steel structure with shear wall 2	2030.52	1982.27	1833.074
steel structure with shear wall 3	2158.91	1912.05	1880.229
steel structure with diagonal outrigger @ 15m	1803.73	1686.29	1751.48
steel structure with diagonal outrigger @ 21m	1757.03	1666.38	1709.432
steel structure with diagonal outrigger @ 30m	1708.75	1648.86	1700.227
steel structure with x type outrigger @ 15m	1860.83	1778.86	1850.184
steel structure with x type outrigger @ 21m	1873.84	1754.03	1790.887
steel structure with x type outrigger @ 30m	1799.19	1726.62	1770.376
steel structure with inverted v type outrigger @ 15m	1854.45	1720.8	1787.157
steel structure with inverted v type outrigger @ 21m	1802.22	1701.66	1738.863
steel structure with inverted v type outrigger @ 30m	1742.8	1683.31	1723.866

Table –Joint Displacements

TABLE 5.1.1 : Joint Displacements Ux (mm)			
Type of structure	G+20	G+30	G+40
Normal steel structure	55.8	146.1	269.6
steel structure with shear wall 1	43.6	98.2	206.6
steel structure with shear wall 2	41.6	95.7	201.3
steel structure with shear wall 3	44.7	70.4	192.2
steel structure with diagonal outrigger @ 15m	46.9	116.2	211.8
steel structure with diagonal outrigger @ 21m	48	119.4	222.1
steel structure with diagonal outrigger @ 30m	49.1	123.5	226
steel structure with x type outrigger @ 15m	44.2	100	184.4
steel structure with x type outrigger @ 21m	43.4	103.9	198.3
steel structure with x type outrigger @ 30m	45.2	108.9	203.8
steel structure with inverted v type outrigger @ 15m	42.5	105.9	195.2
steel structure with inverted v type outrigger @ 21m	44.2	109.6	208
steel structure with inverted v type outrigger @ 30m	46	114	212.9

Table- Base Reactions

TABLE 5.4.1 : Base Reactions FX (kN)			
Type of structure	G+20	G+30	G+40
Normal steel structure	3753.2513	5924.293	8237.3496
steel structure with shear wall 1	3753.2514	5924.293	8237.3487
steel structure with shear wall 2	3753.2514	5924.293	8237.3485
steel structure with shear wall 3	3753.2514	3858.089	8237.3485
steel structure with diagonal outrigger @ 15m	3753.2514	5924.293	8237.3491
steel structure with diagonal outrigger @ 21m	3753.2514	5924.293	8237.3492
steel structure with diagonal outrigger @ 30m	3753.2514	5924.293	8237.3492
steel structure with x type outrigger @ 15m	3753.2514	5924.293	8237.349
steel structure with x type outrigger @ 21m	3753.2514	5924.293	8237.3491
steel structure with x type outrigger @ 30m	3753.2514	5924.293	8237.3491
steel structure with inverted v type outrigger @ 15m	3753.2514	5924.293	8237.3491
steel structure with inverted v type outrigger @ 21m	3753.2514	5924.293	8237.3492
steel structure with inverted v type outrigger @ 30m	3753.2513	5924.293	8237.3492

Table – Maximum Base Moment

Table : Maximum base Moment MX (kNm)			
Type of structure	G+20	G+30	G+40
Normal steel structure	1407119	2316087	3405242
steel structure with shear wall 1	1381863	2190752	3166675
steel structure with shear wall 2	1373335	2163711	3142837
steel structure with shear wall 3	1378510	2084953	3010100
steel structure with diagonal outrigger @ 15m	1281720	1950689	2915399
steel structure with diagonal outrigger @ 21m	1297320	2011649	2946599
steel structure with diagonal outrigger @ 30m	1312920	2208573	2962199
steel structure with x type outrigger @ 15m	1294694	1968474	2939550
steel structure with x type outrigger @ 21m	1308645	2027812	2967505
steel structure with x type outrigger @ 30m	1322718	2223114	2981482
steel structure with inverted v type outrigger @ 15m	1287326	1958554	2926079
steel structure with inverted v type outrigger @ 21m	1302370	2018796	2955844
steel structure with inverted v type outrigger @ 30m	1317253	2215003	2970726

Table – Maximum Axial Force

TABLE 10.1: Axial Force P (kN)			
Type of structure	G+20	G+30	G+40
Normal steel structure	1034.1	11151	17396.6
steel structure with shear wall 1	563.172	9790.75	14720.2
steel structure with shear wall 2	774.635	9772.73	15163.1
steel structure with shear wall 3	774.505	7333.28	13105.9
steel structure with diagonal outrigger @ 15m	486.682	11764	17283.6
steel structure with diagonal outrigger @ 21m	430.145	12121.4	18296.2
steel structure with diagonal outrigger @ 30m	501.085	13206.6	18321.6
steel structure with x type outrigger @ 15m	562.376	11571.6	17098
steel structure with x type outrigger @ 21m	521.379	11900.1	18238.1
steel structure with x type outrigger @ 30m	545.92	12958.7	18227.6
steel structure with inverted v type outrigger @ 15m	521.456	11530.1	17075.4
steel structure with inverted v type outrigger @ 21m	463.5	11857	18048.3
steel structure with inverted v type outrigger @ 30m	513.528	12851.7	18067.9

VII CONCLUSIONS

- The usage of outrigger truss system in the buildingincreases the efficiency when compared to thebuilding without outtrigger truss under the action ofseismic and wind loads.
- Belt truss plays a vital role in increasing structuralstiffness by increasing base shear under the action ofwind and dynamic loads.
- Provision of shear wall in the buildingplays vital role by increasing the % reduction ofdisplacement and storey drift in 20 storey building but for 40 storey building outrigger truss system is proves to be effective by reducing more displacement than shear wall.
- The introduction of belt trusses with shear core willincrease % reduction of storey drift in the top,middle and bottom storey.
- By observing results of graph we can tell that abuilding with X type of belt truss is best forall models.
- Axial force, shear force and momentis found to be minimum for frame with inner position (position 3) shear wall.
- Storey drift is found to be minimum for frame with inner position (position 3) shear wall.
- So it is concluded that provision of shear wall is effective for 20 storey building but for 30 storey and 40 storey building x type outrigger system is found to be more effective.

VIII FUTURE SCOPE

- The building models can also compared by changingthe type of soil to provide better % reduction ofdisplacement and storey drift.
- The behavior of building with irregular shape canalso be studied.
- Providing different type of belt truss to the setbackbuilding under different seismic zone can also bechecked.
- The base isolation can be used along with belt trusswithout outrigger.
- The building models with concrete belt truss can be used.

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