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Design and Lateral Load Analysis of Steel Structure with and without using Bracing System using CYPE

Sharanabasava[1], Smitha Rao[2]
M.Tech Student[1], Assistant Professor[2]
Department of Civil Engineering
SCEM, Mangalore, India

Abstract:
In last decades steel structures 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. Steel braced frame is one of the structural systems used to resist earthquake loads in structures. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. Bracing can be used as retrofit as well. There are various types of steel bracings such as Diagonal, X, K, V, inverted V type or chevron and global type concentric bracings. In the present study, it was shown that modelling of the G+20 steel bare frames with various bracings (X, V, inverted V, and diagonal bracing) by computer software response spectrum results are obtained. Comparison between the seismic parameters such as base shear, roof displacement, time period, storey drift, performance point for steel bare frame with different bracing patterns are studied. It is found that the X type of steel bracings significantly contributes to the structural stiffness and reduces the maximum interstory drift of steel building than other bracing systems.

Keywords: Vertical bracings, CYPE, Steel frames, time period, Storey displacement, Storey drift, Time period, Equivalent static analysis, Response spectrum analysis.

1. INTRODUCTION

Generally, Structures are analyzed and designed to resist frequently occurring earthquakes. Since, the building should have sufficient strength & stiffness to resist deformation or collapse. However, sometimes it is uneconomical to design the structure for elastic designs. The damping property can be used to avoid yielding of structural elements which will lower the cost by optimizing the member sizes. The ductility of the structures avoids the instant brittle failure of the structure. In steel structures, the column beam moment resisting frame & concentric braced frames, which are used to resist earthquake loads. The moment frame and bracing possess ductility to the structure. It is very much required for a structure to perform very well under earthquake. The steel bracing will automatically increase the shear capacity of the structure. These bracings can also be used for retrofitting of the structure. There are many structural configurations such as X, diagonal, V and Eccentric bracing.

Earthquake analysis is the part of the structural analysis. In recent days, the high rise steel structures are well established in metropolitan cities. Bracings system are very much important for the construction of such a high rise structures. Steel fame constitutes the vertical column member and horizontal beam member, constructed to support the rectangular floor system horizontally. This advanced techniques, makes achievement for construction of skyscrapers. The steel bracings are very strong in compression. The time the bracings are placed in a frame, it behaves as compression strut. Thus altering the column stiffness.

The main purpose of all types of structural system is to transmit the gravity load effectively. The major gravity loads are Dead load, Self-weight, Live load and snow load sometimes. Other than these vertical loads, there are few horizontal loads which create problems such as wind, Blasting and earthquake loads. These loads mainly cause vibrations in the structure. Hence, it is very important for the structure to have more stiffness to resist lateral and vertical loads. Strengthening of the building can be done instead of replacement of the building. i.e., retrofitting techniques. During an earthquake, the bracing systems play an important role in resisting earthquake forces. It is an economical solution for resisting earthquake forces.

There are 2 types of bracing systems,

- Concentric Bracing System
- Eccentric Bracing System.

If the center line of the bracing intersects, then it is a concentric else it will be eccentric. The concentric bracings increase natural frequencies by increase in lateral stiffness. The center line of the bracing will connect to some other members in structures, may be column or beam. There are various bracing systems in practice such as diagonal, X, inverted V, V and knee bracing system.

1.1EARTHQUAKE RESISTANT DESIGN OF STRUCTURES

The earth crust will release lot of energy, which causes the structure to vibrate continuously. The simply connected beam and column system is not stable for seismic forces. This is not desirable. Thus the structure has to be designed for seismic resistant. There are many structural configurations are in practice, these are adopted based on the severity of the zone, structure type, type of loads, They are.

- Moment Resisting Frames.
- Braced frames.
- Shear walls.

- Dual structural system.
- Coupled shear wall.
- Outrigger structures.
- Diagrid.

2. OBJECTIVES AND METHODOLOGY

The main objective of the project is to find the optimum bracing type for steel building.

- To study the seismic response of building G+20 high rise steel building.
- To analyses the building for equivalent static and Response spectrum analysis.
- To study and compare the variation in response after introducing the bracing system.
- To evaluate the effectiveness for different types of bracings.
- To various parameters such as displacement, story drift, time period and base shear are compared and assessing the performance of structure.

2.1 METHODOLOGY

- CYPE Software is used for the modeling and analysis of different building configurations.
- Analyze the models using Static (Equivalent static analysis) and Dynamic (Response spectrum analysis) using IS 1893-2016.
- Concrete mix of M30 grade and steel of Fe-500 and structural steel of Fe345 will be considered for the analysis of the structural system.
- Preliminary member sizes are assumed for beams and columns, later member sizes are economized and based on the system adopted.
- Conclusions are made based on the performance of each system under study.

3.MODELLING

To achieve the aim of the study four models are carried out in CYPE software and results are compared.

3.1 Assumed material properties

Young's Modulus (steel), Es = 2, 10,000 MPa

Young's. Modulus (concrete), E_C = 27386 MPa

Characteristic compressive strength of concrete, f_{ck} = 30 MPa

Yield stress for reinforcing steel, f_y = 500 MPa.

3.2 Assumed Section properties

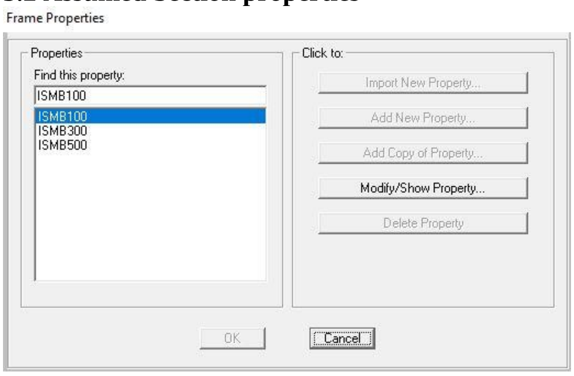

FIG.3.1. Frame properties

3.2 Assumed Loads

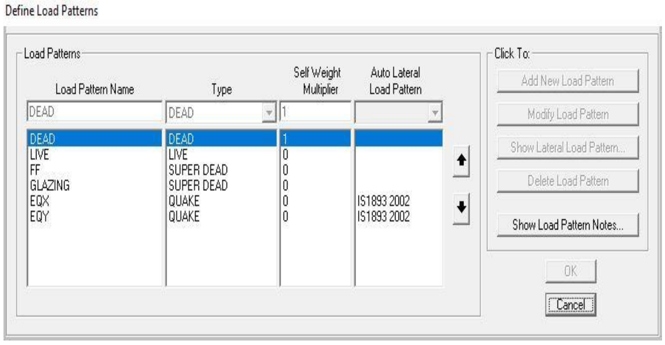

FIG.3.2. Define load patterns

3.3Building Information:

After defining the load patterns following information can be considered.

Table 1 Building information

Structure		Steel Structure.
No. of storey		G+20 Storey.
Storey height	First storey	3.0 m
	Upper storey	3.0 m
TYPE of building use		Commercial
Foundation Type		Isolated footing / Fixed support
Seismic zone		Z-5
Assumed Dead Load Intensities		
Roof finishes		1.50 KN/m^2
Floor finishes		1.50 KN/m^2
Live Load Intensities		
Roof		3.0 KN/m^2
Floor		3.0 KN/m^2

3.4 Standard model

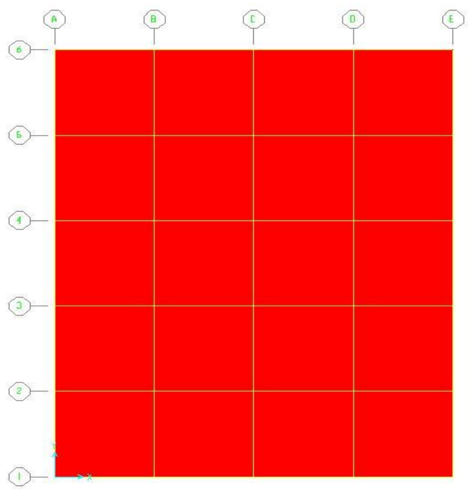

FIG.3.3. Plan view

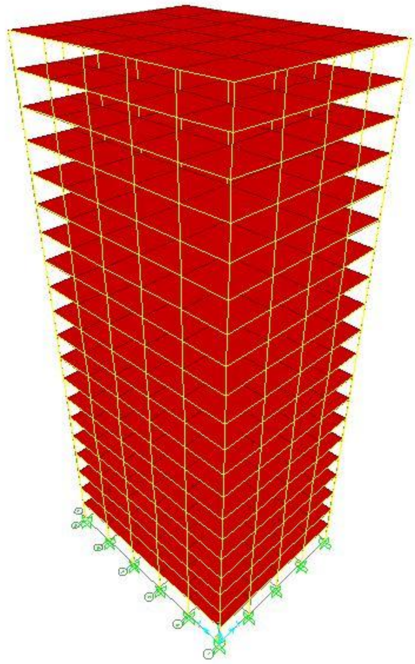

FIG.3.3. 3D view of model 1

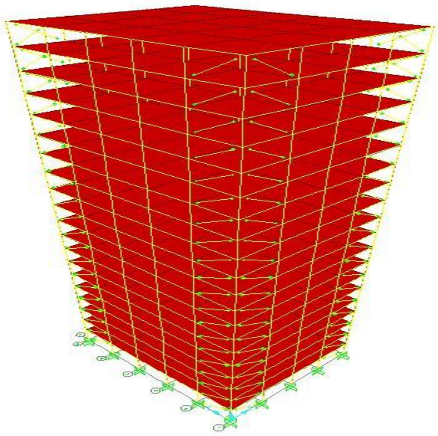

FIG.3.4. 3D view of model 2

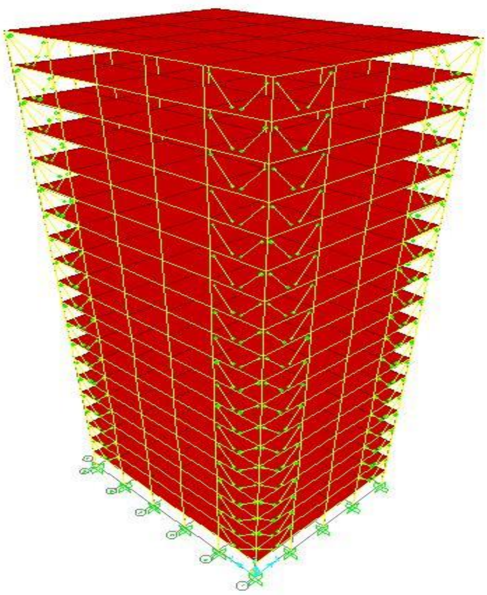

FIG.3.5. 3D view of model 3

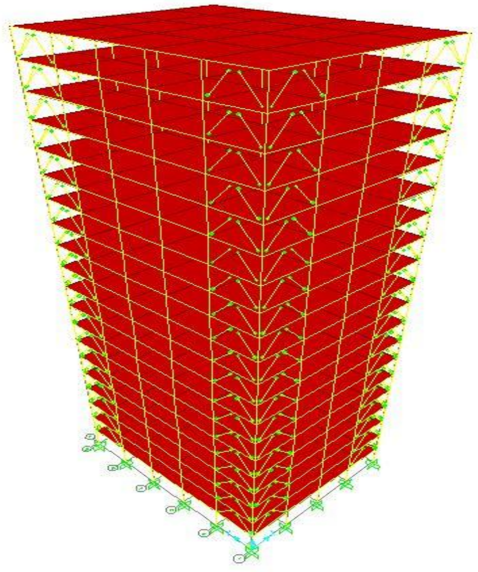

FIG.3.6. 3D view of model 4

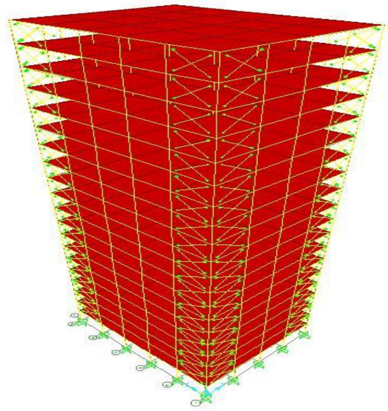

FIG.3.7. 3D view of model 5

4. RESULTS AND DISCUSSION:

The Models are given no's to identify it further:

Model 1 – Regular building without Bracing.
Model 2 – Regular building with inclined Bracing.
Model 3 – Regular building with V Bracing.
Model 4 – Regular building with Inverted V Bracing.
Model 5 – Regular building with X Bracing.

Once the analysis is finished, the results are extracted. The response of the different configuration structures is obtained from SAP2000 software. The regular model and different structural systems are studied for different load cases. The response spectrum analysis is carried out to compare the model response.

4.1 Comparison of different models of building

4.1.1 Equivalent Static analysis results

Displacement of building

Table 2 Displacement results

STOREY	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
20	358.86	247.72	244.66	233.10	232.59
19	352.32	239.66	235.81	224.68	223.65
18	343.72	230.32	225.85	215.14	213.69
17	332.86	219.85	214.97	204.69	202.93
16	319.83	208.37	203.27	193.42	191.45
15	304.82	196.00	190.84	181.40	179.31
14	288.08	182.86	177.77	168.76	166.60

13	269.82	169.07	164.15	155.58	153.41
12	250.28	154.77	150.11	141.99	139.86
11	229.66	140.09	135.77	128.11	126.06
10	208.16	125.17	121.25	114.09	112.14
9	185.97	110.15	106.68	100.05	98.23
8	163.26	95.18	92.21	86.15	84.48
7	140.18	80.39	77.97	72.53	71.03
6	116.89	65.94	64.12	59.36	58.05
5	93.55	51.98	50.80	46.79	45.69
4	70.37	38.67	38.19	35.02	34.14
3	47.75	26.19	26.46	24.22	23.58
2	26.51	14.81	15.78	14.55	14.19
1	8.77	5.20	6.35	6.07	5.99
0	0.0	0.0	0.0	0.0	0.0

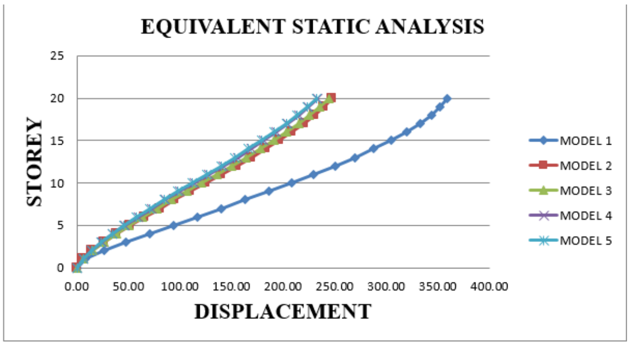

FIG.4.1. ESA comparison graph

4.1.2Inter storey drift results

Table 3Inter storey drift results

STOREY	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
20	6.5	8.1	8.9	8.4	8.9
19	8.6	9.3	10.0	9.5	10.0
18	10.9	10.5	10.9	10.5	10.8
17	13.0	11.5	11.7	11.3	11.5
16	15.0	12.4	12.4	12.0	12.1
15	16.7	13.1	13.1	12.6	12.7
14	18.3	13.8	13.6	13.2	13.2
13	19.5	14.3	14.0	13.6	13.6
12	20.6	14.7	14.3	13.9	13.8
11	21.5	14.9	14.5	14.0	13.9
10	22.2	15.0	14.6	14.0	13.9
9	22.7	15.0	14.5	13.9	13.8
8	23.1	14.8	14.2	13.6	13.4
7	23.3	14.4	13.9	13.2	13.0
6	23.3	14.0	13.3	12.6	12.4
5	23.2	13.3	12.6	11.8	11.6
4	22.6	12.5	11.7	10.8	10.6
3	21.2	11.4	10.7	9.7	9.4
2	17.7	9.6	9.4	8.5	8.2
1	8.8	5.2	6.4	6.1	6.0
0	0.0	0.0	0.0	0.0	0.0

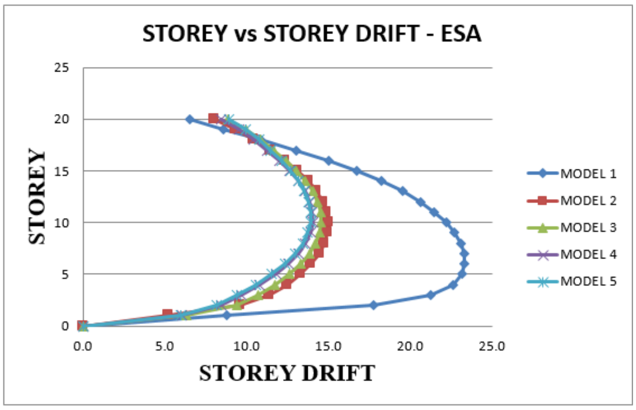

FIG.4.2. Inter storey drift comparison graph

4.1.3Time period results

Table 3Time period results

MODE	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
1	10.16	5.74	6.03	5.82	5.82
2	5.56	4.26	4.17	4.06	4.04
3	5.30	3.13	3.02	2.90	2.87
4	3.38	1.72	1.95	1.95	1.91
5	2.02	1.31	1.25	1.24	1.20
6	1.81	0.96	0.94	0.94	0.89
7	1.72	0.90	0.91	0.90	0.86
8	1.44	0.70	0.65	0.65	0.62
9	1.12	0.62	0.60	0.59	0.55
10	1.04	0.51	0.47	0.47	0.44
11	0.97	0.47	0.43	0.43	0.41
12	0.92	0.47	0.43	0.43	0.39

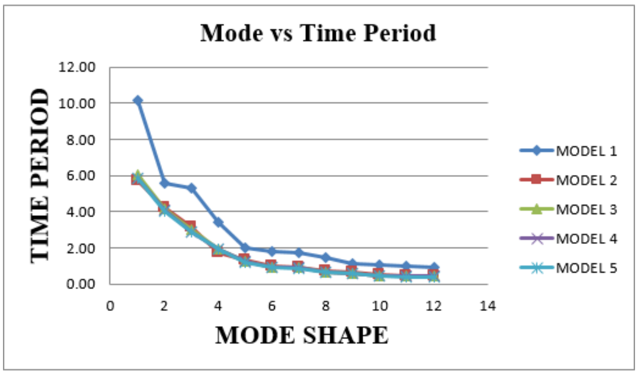

FIG.4.3. Time period results comparison graph

4.1.4Base shear results

Table4Base shear results

	BASE SHEAR (kN)
Model 1	2114.3
Model 2	2117.1
Model 3	2117.8
Model 4	2117.8
Model 5	2119.6

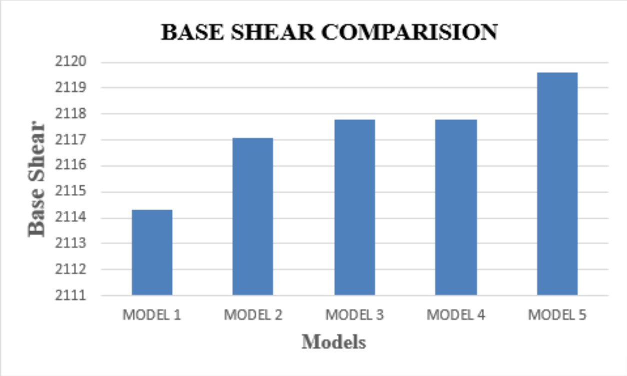

FIG.4.4. Base shear comparison graph

4.1.5Response spectrum results

STOREY	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
20	282.3	177.8	171.0	161.1	156.3
19	277.9	172.2	165.0	155.4	150.4
18	272.3	165.9	158.3	149.0	143.9
17	265.2	158.9	151.1	142.2	137.0
16	256.6	151.3	143.4	134.9	129.7
15	246.6	143.2	135.4	127.2	122.1
14	235.3	134.6	127.0	119.2	114.2
13	222.7	125.6	118.3	110.9	106.1
12	208.9	116.2	109.2	102.3	97.7
11	194.0	106.5	100.0	93.4	89.1
10	178.0	96.5	90.5	84.4	80.4
9	161.2	86.3	80.9	75.3	71.6
8	143.4	76.0	71.1	66.2	62.8
7	124.9	65.5	61.4	57.0	54.0
6	105.6	55.0	51.6	47.9	45.3
5	85.7	44.5	42.0	38.9	36.7
4	65.3	34.0	32.5	30.1	28.4
3	44.8	23.7	23.3	21.6	20.4
2	25.1	13.8	14.4	13.5	12.8
1	8.3	5.0	6.0	5.8	5.7
0	0.0	0.0	0.0	0.0	0.0

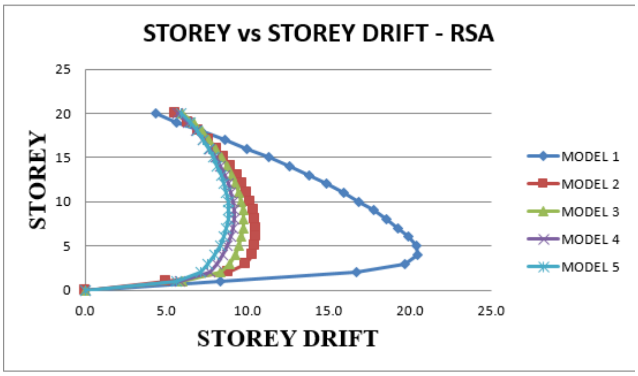

FIG.4.5. RSA comparison graph

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6. CONCLUSIONS

- The results shown from dynamic analysis can be considered as practical and gives the lesser deformations compared to Equivalent static analysis.
- The values obtained from static analysis are comparatively high, the ESA will give more lateral resistant design, thereby increase in design of structure. Which will further increase the self-weight and also the construction cost.
- The displacement values are pretty higher in model i.e. without the bracings. The models with bracings showing comparative reduction in the displacement value and the maximum reduction is found to be 35%, 44% reduction for ESA and RSA respectively.
- The interstory drift increases for lower level stories, however, the maximum reduction in the drift is found in model on with out bracings. The model 4, 5 shows very minor variations, this indicates equal distribution of strength due to bracings.
- The Time period and base shear value will not change for static and dynamic analysis, as the parameters depends on the model dynamics not on the analysis type.
- The base shear will not vary, as all the models are same mass and same dynamics.
- The difference in the ESA and RSA is significant. In terms of displacement the difference is around 21.2%.

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