Dynamic modal analysis of high rise steel building

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Abstract— High rise steel buildings are anticipated to be primary choice of buildings in future for residential and commercial establishments. Steel is the choice of building material due to its high strength to weight ratio. In present study modal characteristic of one such high rise steel building is presented. The building is 72m high and designed as per standards. The various modal parameters are given.

Key words: High Rise, Steel Structure, Building Structure, Modal Analysis

I. INTRODUCTION

Some of major high rise steel structure buildings can be found in Chicago, New York, Tokyo etc. cities of the world. Highrise Steel frame building is also well establishing in metropolitan cities of world as well as India.

For construction of high rise building bracing are made for stiffness and lateral load resistance purpose. Steel frame sometimes refers to a building technique with a "skeleton frame" of vertical steel columns and horizontal I-beams, made in a very rectangular grid to support the floors, roof and walls of a building that are all hooked up to the frame. [1]

The event of this system created the construction of the building attainable. Bracings are sturdy in compression. Bracing with their surrounding frames has got to be thought-about for increase in lateral load resisting capability of structure. [2-3]

When bracings are placed in Steel frame it behaves as diagonal compression strut and transmits compression force to a different joint. Variations within the column stiffness will influence the mode of failure and lateral stiffness of the bracing [4-5].

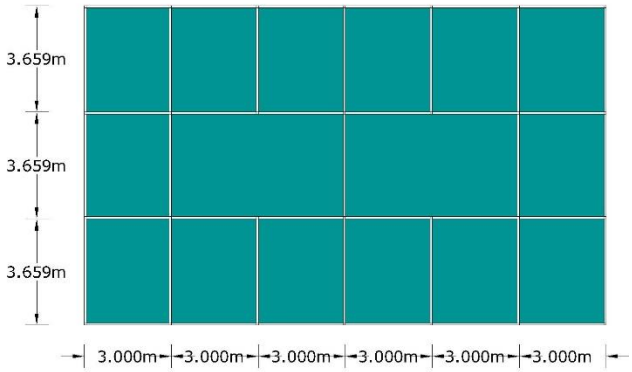


Fig. 1: Building plan used in the study

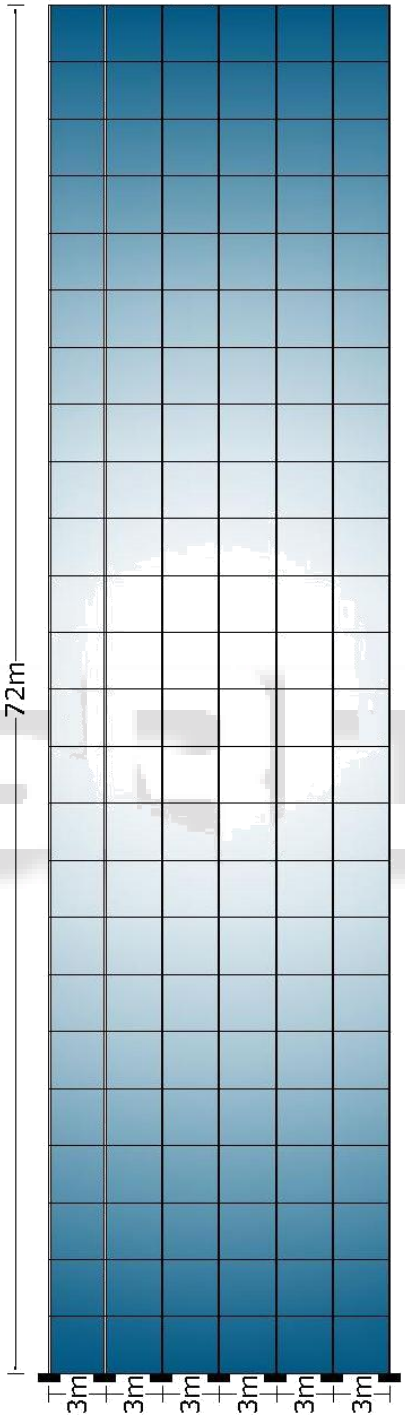


Fig. 2: 24 storey steel building use for study

The nonlinear seismic analysis is also becoming quite popular. The steel is though fairly linear material hence it is more popular in concrete as performed in some studies [7] and [8].

II. BUILDING GEOMETRY

The steel high rise building chosen for this study is of 24 storey high rise building. The plan of this building is shown in Fig. 1.

The dimension of building is 11m×18m. The elevation is shown in Fig. 2

The floor is assumed to be consisting of rigid diaphragm so as to reduce degree of freedom of structure. The building is designed as per recommendations of IS 1893:2002 for earthquake, IS 875 part 3 for wind load and according to IS 800:2007 limit state based design methodology.

III. METHODOLOGY FOR MODAL ANALYSIS

The free vibration equation for a single degree of freedom structure is given by following equation :

$$m\ddot{u} + c\dot{u} + ku = 0 \qquad (1)$$

Where, m = mass of structure, u, single accent u and double accent u is displacement, velocity and acceleration respectively.

The solution of this equation gives response of structure for a given initial excitation.

For multiple degree of freedom, the same equation of motion is applied in terms of matrices. The order of matrix equals to degree of freedom of structure.

The equation in terms of matrices is as follows

$$[m][\ddot{u}] + [c][\dot{u}] + [k][u] = 0 \qquad (1)$$

The solutions for this equation gives various modal results which is same as eigen solution of equation.

The modelling and analysis is performed in CSI SAP2000 software [9].

IV. RESULTS AND DISCUSSIONS

For the chosen high rise building, results are given in terms of displacement, mode shapes, modal period etc.

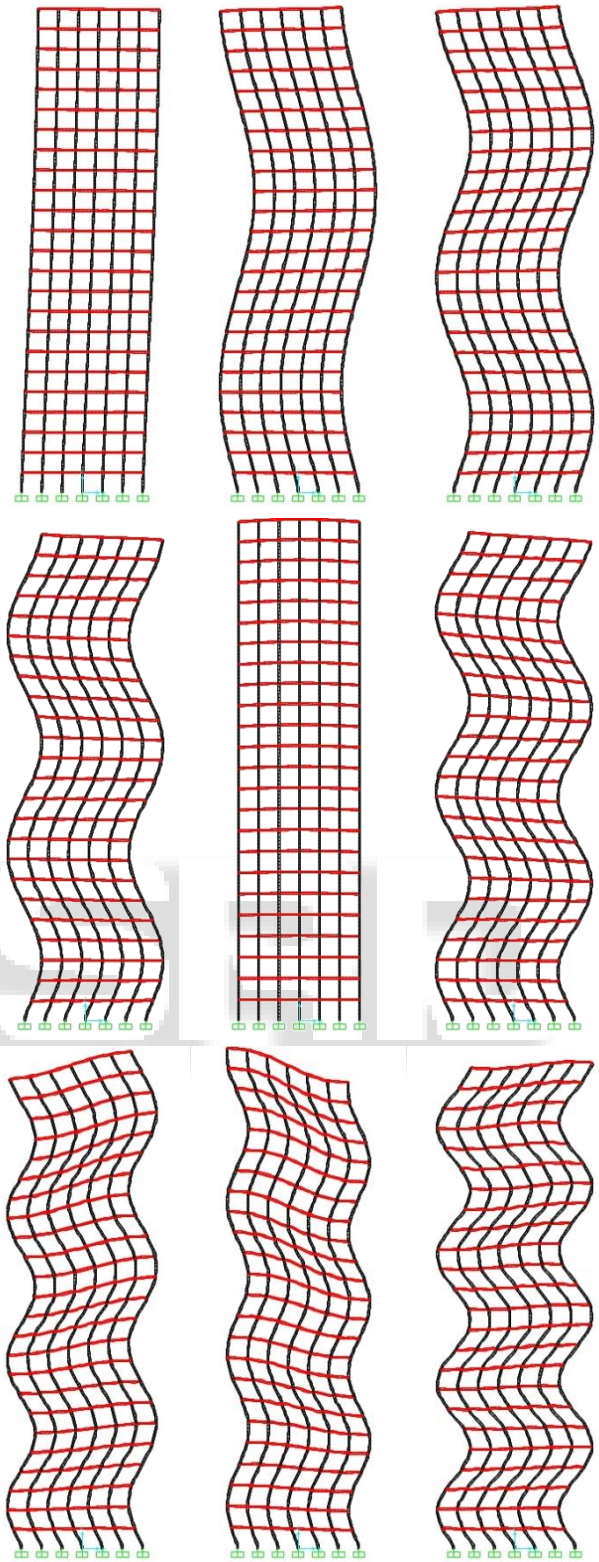
A. Displacements at each mode:

The displacement at each mode and at each storey is tabulated in Table 1. The displacement are obtained by standard procedure of dynamics of structure by providing unit excitation at one degree of freedom and evaluating response.

Mode -> Storey	1	2	3	4	5	6	7	8	9	10	11
Base	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0009	-0.0034	-0.0058	0.0081	0.0104	0.0000	-0.0125	-0.0122	-0.0096	-0.0168	-0.0189
2	0.0022	-0.0079	-0.0132	0.0176	0.0213	0.0000	-0.0234	-0.0212	-0.0154	-0.0248	-0.0235
3	0.0036	-0.0122	-0.0195	0.0237	0.0255	0.0000	-0.0231	-0.0169	-0.0100	-0.0112	-0.0024
4	0.0050	-0.0162	-0.0239	0.0251	0.0212	0.0000	-0.0115	-0.0019	0.0030	0.0122	0.0213
5	0.0065	-0.0195	-0.0258	0.0213	0.0099	0.0000	0.0059	0.0140	0.0143	0.0246	0.0214
6	0.0079	-0.0222	-0.0250	0.0132	-0.0046	0.0000	0.0205	0.0203	0.0158	0.0151	-0.0022
7	0.0094	-0.0241	-0.0218	0.0023	-0.0175	0.0000	0.0251	0.0129	0.0064	-0.0080	-0.0234
8	0.0108	-0.0251	-0.0163	-0.0090	-0.0246	0.0000	0.0176	-0.0034	-0.0071	-0.0240	-0.0185
9	0.0123	-0.0252	-0.0091	-0.0186	-0.0233	0.0000	0.0015	-0.0177	-0.0152	-0.0188	0.0069
10	0.0137	-0.0244	-0.0011	-0.0244	-0.0142	0.0000	-0.0152	-0.0207	-0.0119	0.0031	0.0247
11	0.0151	-0.0228	0.0070	-0.0253	-0.0003	0.0000	-0.0244	-0.0104	0.0002	0.0222	0.0151
12	0.0164	-0.0203	0.0143	-0.0212	0.0137	0.0000	-0.0216	0.0065	0.0126	0.0214	-0.0113
13	0.0177	-0.0171	0.0201	-0.0128	0.0233	0.0000	-0.0081	0.0188	0.0163	0.0016	-0.0251
14	0.0190	-0.0132	0.0238	-0.0018	0.0251	0.0000	0.0094	0.0185	0.0086	-0.0197	-0.0111
15	0.02	-0.	0.02	0.00	0.01	0.00	0.02	0.00	-0.	-0.	0.01

	02	089	49	94	86	00	24	58	049	235	52
16	0.2133	-0.0042	0.2334	0.1887	0.0060	0.0000	0.2455	-0.1110	-0.1447	-0.0064	0.2466
17	0.2244	0.0007	0.1944	0.2422	-0.0086	0.0000	0.1477	-0.2007	-0.1337	0.1644	0.0667
18	0.2334	0.0056	0.1333	0.2477	-0.2022	0.0000	-0.0222	-0.1700	-0.0027	0.2466	-0.1887
19	0.2433	0.1044	0.0558	0.2001	-0.2500	0.0000	-0.1779	-0.0023	0.1044	0.1099	-0.2334
20	0.2552	0.1488	-0.0024	0.1144	-0.2144	0.0000	-0.2488	0.1388	0.1622	-0.1255	-0.0021
21	0.2599	0.1888	-0.1044	0.0033	-0.1066	0.0000	-0.1955	0.2066	0.1055	-0.2477	0.2144
22	0.2666	0.2222	-0.1744	-0.1099	0.0399	0.0000	-0.0455	0.1388	-0.0266	-0.1499	0.2111
23	0.2722	0.2499	-0.2277	-0.2000	0.1722	0.0000	0.1288	-0.0233	-0.1399	0.0833	-0.0288
24	0.2777	0.2699	-0.2588	-0.2555	0.2533	-0.0001	0.2477	-0.1777	-0.1600	0.2566	-0.2544

Table 1: Modal displacement values



B. Mode shapes:

Since building consists of 24 storey and assuming floor to be rigid, there will be 24 degree of freedom and hence corresponding 24 modes of freedom.

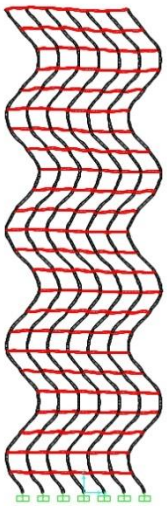


Fig. 3: Mode shapes of building, modes are from first mode to tenth mode serially

C. Modal period of building and participation factors:

The natural period and participation factors are shown in Table 1. The participation factor of 78% shows that higher mode participation is significant in case of high rise steel building.

Mode	Period (sec)	Participation ratio
1	0.96867	0.78053
2	0.314177	0.12262
3	0.175679	0.03603
4	0.123675	0.01814
5	0.094794	0.01073
6	0.07889	.00934
7	0.077013	0.00716
8	0.065268	0.0036
9	0.062228	0.00202
10	0.054873	0.00377
11	0.048092	0.00305
12	0.045298	2.81×10^{-17}

Table 1: Period and participation ratio values

D. Dynamic characteristics of building:

The various dynamic characteristics like, frequencies and eigenvalue are tabulated in following table

Mode	Frequency	Circular Frequency	Eigenvalue
	Cyc/sec	rad/sec	rad^2/sec^2
1	1.0323	6.4864	42.073
2	3.1829	19.999	399.95
3	5.6922	35.765	1279.1
4	8.0857	50.804	2581
5	10.549	66.282	4393.4
6	12.676	79.645	6343.3
7	12.985	81.586	6656.2
8	15.321	96.268	9267.5
9	16.07	100.97	10195
10	18.224	114.5	13111
11	20.793	130.65	17069
12	22.076	138.71	19240

Table 2: Dynamic characteristics of building

V. CONCLUSIONS

The dynamic character of high rise building is evaluated in present investigation. For this purpose a 24 storey high rise steel building is chosen. Modal analysis is performed in commercial software package SAP2000 and results are discussed.

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