IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

EFFECT OF EARTHQUAKE RESISTANT SYSTEM ON VERTICALLY GEOMETRIC IRREGULAR RC TALL BUILDING

Vijay Morale, Dr. Ravindra M Desai

[1]P.G. Student of Civil Engineering Department of Sanjay Ghodawat university, Kolhapur, India

[2] Assistant Professor of Civil Engineering Department Sanjay Ghodawat university, Kolhapur, India

Abstract: Earthquake is a natural disaster which is experienced throughout the world. The effect of earthquake depends on the magnitude with which the earthquake occurs. There are many lives which are claimed due to earthquake and loss of property. With modernisation high rise buildings are seen everywhere due to vertical expansion. The high-rise building possesses more danger to earthquake. Uncertainties involved and behaviour studies are vital for all civil engineering structures. The presence of vertical irregular frame subject to devastating earthquake is matter of concern. A high-rise building can have various types of irregularities such as vertical irregularity, mass irregularity, stiffness irregularity, re-entrant corner irregularity and torsional irregularity. A vertically irregular building can be provided with bracing or base isolation device to reduce the seismic activity and reduce the loss during earthquake. The seismic analysis of the various vertical irregularities namely setback irregularity, open grounded storey irregularity and multiple setback irregularity will be done by CSI ETABS software. The seismic analysis will be performed by dynamic analysis. Dynamic analysis is performed with the help of response spectrum method in both x and y direction.

Keywords– Vertical Irregularity, Mass Irregularity, Stiffness Irregularity, Torsional Irregularity

1.0 INTRODUCTION

There are various natural hazards present amongst which earthquake is one of the most dangerous hazards which influences the structure as well as the occupants inside the structure. Due to urbanisation and the growth in population congestion in land has been seen. To overcome these tall buildings are been constructed. The tall buildings which are constructed should be safe against the strong ground motions produced during an earthquake which may cause the tall rise structure to collapse and is a life threat to the occupants in the structure. After an earthquake has occurred the structure remains unusable for a longer period but there are some important buildings such as hospitals, fire stations, police stations and emergency stations which cannot remain closed for a longer period. A structure cannot be made earthquake proof but with proper design considerations and lateral force resisting system the structure can be made earthquake resistant. Modern tall rise buildings are constructed with irregularities. There are various types of irregularities namely the vertical irregularities and horizontal irregularities. An irregularity is introduced in a building for both aesthetic purpose and utility purpose. Seismic behaviour of a building depends on the arrangement of the structural elements of the structure. In an irregular structure the eccentricity is developed because the centre of mass does not coincide with the centre of stiffness. Torsion is developed due to eccentricity. As there is occurrence of eccentricity and the irregular placement of structural components a significant impact on torsional coupling is seen which result in damage of the structure. Different structural irregularities show different seismic performance. To make building earthquake resistant the system should be such that it resists the ground motion. There are various methods such as providing bracing, base isolation device, strong column-weak beam, outrigger, and belt truss system. The structure having a discontinuity is called as an irregular building. Due to the irregularities, seismic performance of that building is more important as irregular buildings are prone to more damages. As per IS 1893:2002 there are two types of irregularities namely plan irregularities and vertical irregularities. In this project vertical geometric irregularity is studied. As per IS 1893:2002 any building in which the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

2.0 FUTURE SCOPE

In this research topic seismic analysis of three different types of irregularities is carried with fixed base, bracing and base isolation due to limitation of the proposed work the following point is for the future work.

1. The further structural designing of all the nine models.
2. Checking applicability of other techniques such as strong column- weak beam, shear wall and outrigger system.
3. Considering other types of vertical and geometric irregularities.

3.0 METHODOLOGY

3.1 General

Dynamic linear analysis is carried on structures to study the seismic response of each structure. Dynamic linear analysis is carried on with the help of response spectrum method. For reaching to a conclusion various parameter such as base shear, storey drift, storey displacement and time will be studied.

3.3.1 Response spectrum method

Response spectrum method is a type of analysis which measures the result from each mode of vibration to show the maximum seismic response of an elastic structure. Response spectrum analysis gives information of the dynamic behaviour of a structure by measuring the velocity, displacement or the acceleration for a given damping. In response spectrum analysis if the period of structure is shorter it provides greater acceleration and if the period of structure is larger it provides larger displacement. Horizontal forces are applied in both the direction and the seismic response of the structure is studied. Response spectrum method is advantageous because this involves the calculation of only the maximum values of displacements in each mode of vibration that are the average of the other seismic motions. The disadvantages of other method were that it gives large amount of data which are difficult to check and the other being that the analysis should be carried such that all the frequencies are excited, which is performed in response spectrum analysis.

3.3 Specification of structure

Table 3.1: Specification of structure

Sr. No.	Parameter	Dimension
1	Height of building	59 m
2	Type of structure	Multi storey RC frame
3	Soil type	Type I
4	Number of stories	G + 18
5	Plan dimension	48 m x 30 m
6	Size of column	600 mm x 600 mm
7	Size of beam	350 mm x 450 mm
8	Thickness of slab	125 mm
9	Location	Pune
10	Seismic Zone	III

3.4 Different types of models

For this research we have selected three different types of irregularities. The three different types of irregularities are irregularity on sides, multiple setback irregularity and irregularity on one side as shown in Table 3.2. The models will be designed and analysed for seismic stability on the computer software ETABS. Figure 3.1 shows the different types of models which will be considered for carrying out the research work. The criterion required for a building to be vertically irregular as defined by IS 1893:2016 for various models is described briefly below:

a. Model 1- Irregularity on both sides:

From IS 1893:2016 it is observed that for a building to be vertically irregular as shown in Figure 1.3 the ratio of A/L should be greater than 0.15. In our model considered for the research work the ratio A/L is 0.25. So the model which have considered for proposed work is vertically irregular.

b. Model 2- Multiple setback irregularity:

From IS 1893:2016 it is observed that for a building to be vertically irregular in terms of multiple setback irregularity A i.e. the total setback should be greater than 0.25 times the length of the building. In the model considered in the research work the value of A is 20 which is greater than 0.25 times the length i.e. 8. Hence the model considered for the proposed work passes the criteria for multiple setback irregularity.

c. Model 3- One sided irregularity:

From IS 1893:2016 it is observed that for a building to be vertically irregular with one sided irregularity the total length of the building L2, should be less than 1.25 times the total length of the irregularity i.e. L1 present in the structure. In our proposed work the model which is considered has a total length L2 of 32 m which is greater than 1.25 times the total length of irregularity i.e. 20 m. Therefore, the model which is considered for the proposed work is said to vertically irregular with one sided irregularity.

3.5 Loading Details

On the model different types of loads will act. Table 3.3 shows the type of load and the intensity with which the load will be applied on the various components of the structure.

Table 3.3: Loading details

Sr. No.	Type of Load	Intensity of Load
1	Floor Finish	1 KN/m^2
2	Live Load	3 KN/m^2
3	Wall Load	14.28 KN/m^2
4	Waterproofing Load	3 KN/m^2
5	Parapet Load	6.72 KN/m^2

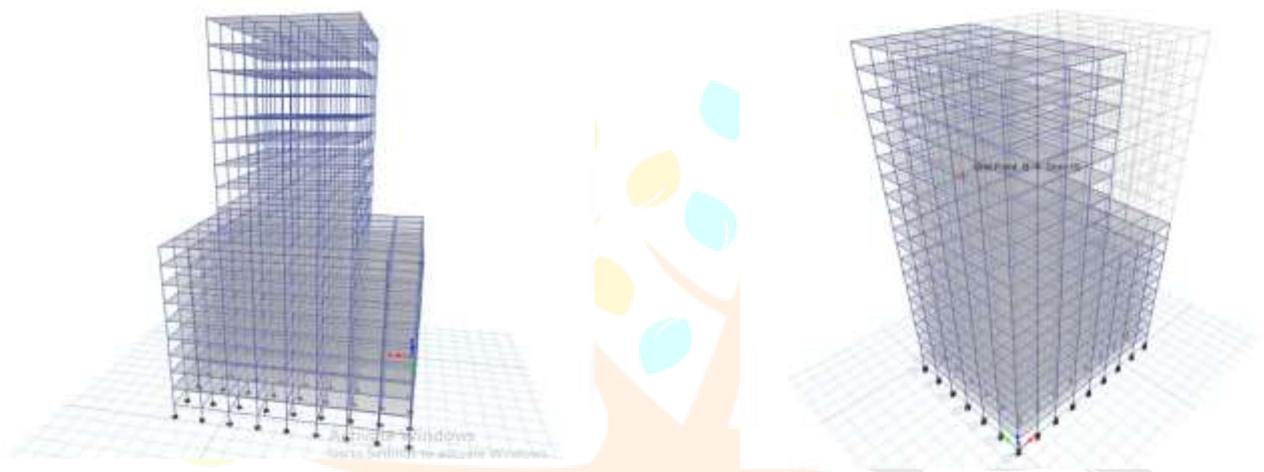

Figure 3.1: Representation of models

4.0 Experiments

4.1 General

Dynamic response spectrum analysis is carried out on the three geometrically vertical irregular frames. Each model is analysed with fixed base, base isolation, and bracing system. This analysis is carried out by using the commercial computer software ETABS. The objectives of this research work will be completed with the use of ETABS.

4.2 Modelling of structure and analysis procedure

Model initialization is the first step in which the settings of the models with the IS codes are selected. 2. The dimensions of the model and storey heights are mentioned. where dimension of models, grid lines in x and y direction and storey height is entered. The concrete and steel materials properties are defined. HYSD 500 and M30 are the grade of materials defined. the rebar and concrete properties being entered in ETABS. The section properties such as the beams, columns and slabs are defined. The size of beam defined is 350 mm x 450 mm and column size are 600 mm x 600 mm. Slab section of 125 mm thickness is defined section properties of beam and the reinforcement properties of beam section properties of column and the reinforcement properties of column. how’s the rotational properties of slab. The following loads are defined. Wall load of 1 kN/m and a live load of 3 kN/m is applied on the floors. A wall load 14.28 kN/m is applied on the walls. A parapet load 6.72 kN/m is also applied. various load patterns. properties of seismic loads in x and y direction. Response Spectrum function is defined according to the properties defined in IS code. As for this research work it is decided to perform response spectrum analysis properties which are defined to perform response spectrum analysis. The load case data for response spectrum function in x and y direction is defined. definition of response spectrum in x direction which is denoted as SPFx while definition of response spectrum in y direction which is denoted as Spy.

5.0 RESULTS AND DISCUSSION

5.1 General

To analyse the G + 18 RC structure using ETABS 17, three vertical irregularities i.e. irregularities on both sides, multiple setback and one side is considered in the proposed work. These types of irregularities are subjected to fixed base, bracing and base isolation.

5.2 Results

The seismic performance of the vertically irregular structures with each vertical irregularity having fixed base, bracing and base isolation is done using ETABS by dynamic analysis. For this proposed work dynamic analysis is performed using the linear method called response spectrum method. The parameters studied for the seismic performance of all the three types of irregularities with fixed base and with earthquake resistance systems are base shear, storey displacement, storey drift, modal time, and overturning moment. The conclusion on the result is discussed in the next section after reviewing the results.

5.2.1 Seismic analysis of models with fixed base

1. Base Shear

The base shear for fixed base case is shown in Table 5.1. The graphical representation of base shear in the form of bar chart is shown in Figure 5.1.

Table 5.1: Base shear in kN for fixed base

Sr. No.	Model	Load case	Fixed base
1	Model 1	SPx	1019.2174
		SPy	1014.9007
2	Model 2	SPx	1109.5064
		Spy	887.3162
3	Model 3	SPx	1217.6389
		SPy	991.6942

Sr. No.	Model	Load case	Fixed base
1	Model 1	SPx	1019.2174
		SPy	1014.9007
2	Model 2	SPx	1109.5064
		Spy	887.3162
3	Model 3	SPx	1217.6389
		SPy	991.6942

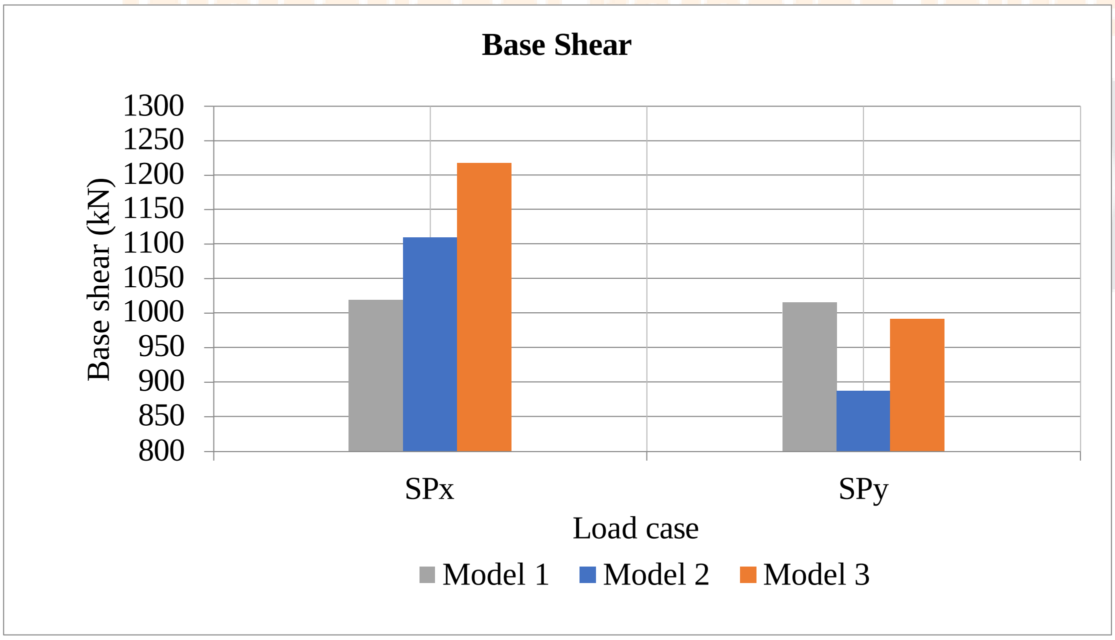

Figure 5.1: Base shear

5.2.2. Modal time period

Modal time period for G + 18 RC structures with fixed base is presented in Table 5.2.

Table 5.2: Modal time period in s for fixed base

Sr. No.	Mode	Model 1	Model 2	Model 3
1	1	2.67	2.97	2.96
2	2	2.64	2.67	2.67
3	3	2.10	2.08	2.00
4	4	1.13	1.01	1.17
5	5	1.11	1.00	1.13
6	6	1.07	0.89	1.00
7	7	0.58	0.59	0.58
8	8	0.57	0.58	0.58
9	9	0.51	0.53	0.51
10	10	0.42	0.41	0.42
11	11	0.41	0.40	0.42
12	12	0.39	0.38	0.39

5.2.3. Storey displacement

Storey displacement for all the models with fixed base is presented in Table 5.3 and Figure 5.2 represent behaviour of storey displacement for models with fixed base.

Table 5.3: Storey displacement in mm for fixed base

Storey No.	Model 1 (SPx)	Model 2 (SPx)	Model 3 (SPx)	Model 1 (SPy)	Model 2 (SPy)	Model 3 (SPy)
Base	0	0	0	0	0	0
1	01.042	01.054	01.247	01.082	01.324	01.563
2	02.187	02.221	02.615	02.278	02.802	03.303
3	03.370	03.44	04.028	03.518	04.360	05.135
4	04.507	04.628	05.387	04.712	05.895	06.937
5	05.576	05.759	06.665	05.837	07.374	08.675
6	06.573	06.828	07.859	06.889	08.788	10.341
7	07.499	07.832	08.969	07.865	10.133	11.929
8	08.354	08.768	09.999	08.767	11.404	13.44
9	09.16	09.634	11.018	09.614	12.598	14.898
10	10.228	10.461	12.333	10.206	13.719	16.333
11	11.457	11.241	13.835	11.311	14.76	17.716
12	12.697	11.991	15.345	12.402	15.721	19.003
13	13.878	12.691	16.786	13.43	16.592	20.171
14	14.963	13.35	18.113	14.367	17.369	21.207
15	15.932	13.948	19.301	15.199	18.044	22.106

16	16.766	14.488	20.329	15.91	18.613	22.859
17	17.448	14.95	21.175	16.487	19.066	23.459
18	17.961	15.322	21.818	16.919	19.403	23.900
19	18.315	15.599	22.275	17.214	19.634	24.2

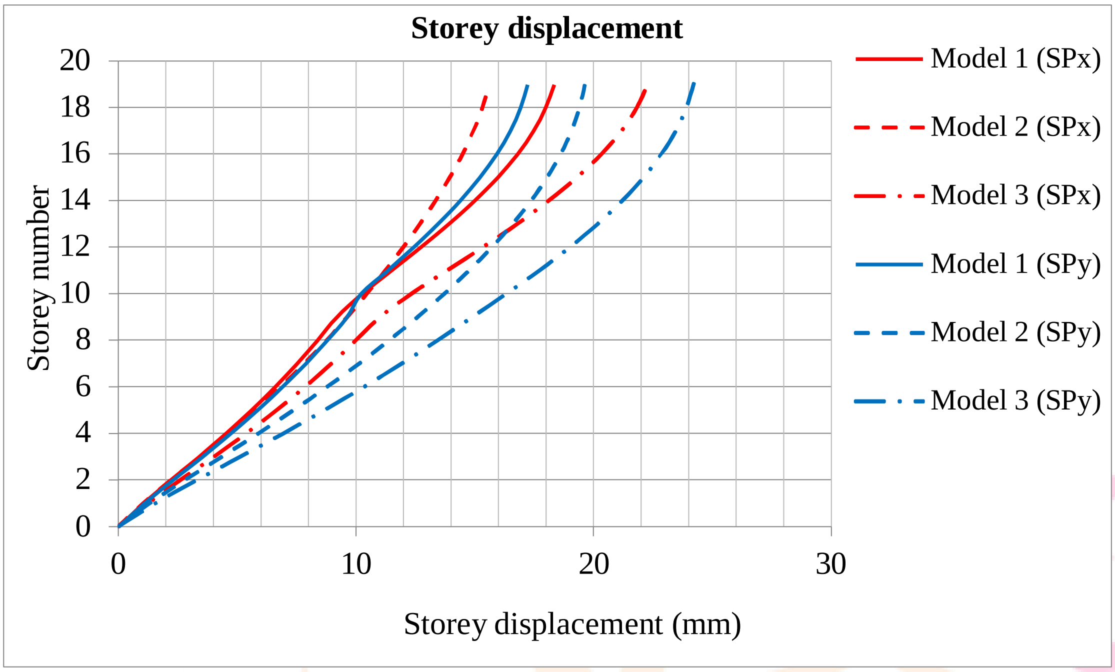

Figure 5.3: Storey displacement

5.2.4. Storey drift

Storey drift is for fixed base is presented in Table 5.4. The graphical representation of storey drift is shown in Figure 5.3.

Table 5.4: Storey drift in m for fixed base

Storey No.	Model 1 (SPx)	Model 2 (SPx)	Model 3 (SPx)	Model 1 (SPy)	Model 2 (SPy)	Model 3 (SPy)
Base	0	0	0	0	0	0
1	0.00029	0.00014	0.00034	0.00013	0.00012	0.00043
2	0.00038	0.00029	0.00046	0.0003	0.00036	0.00058
3	0.0004	0.00039	0.00047	0.0004	0.00049	0.00061
4	0.00039	0.00041	0.00046	0.00042	0.00052	0.00061
5	0.00037	0.0004	0.00044	0.00041	0.00052	0.00059
6	0.00036	0.00039	0.00043	0.00039	0.00051	0.00058
7	0.00034	0.00038	0.0004	0.00037	0.00049	0.00056
8	0.00032	0.00036	0.00038	0.00035	0.00047	0.00053
9	0.00031	0.00034	0.0004	0.00033	0.00045	0.00052
10	0.00043	0.00032	0.00055	0.00032	0.00043	0.00051
11	0.0005	0.00031	0.00061	0.00041	0.00041	0.0005
12	0.0005	0.00031	0.00061	0.00045	0.00039	0.00049
13	0.00047	0.0003	0.00058	0.00044	0.00037	0.00047
14	0.00044	0.00029	0.00054	0.00042	0.00034	0.00043

15	0.0004	0.00028	0.00049	0.00039	0.00031	0.0004
16	0.00036	0.00027	0.00044	0.00035	0.00028	0.00036
17	0.0003	0.00026	0.00037	0.00031	0.00025	0.0003
18	0.00023	0.00023	0.00028	0.00026	0.00021	0.00023
19	0.00016	0.00019	0.00019	0.0002	0.00017	0.00015

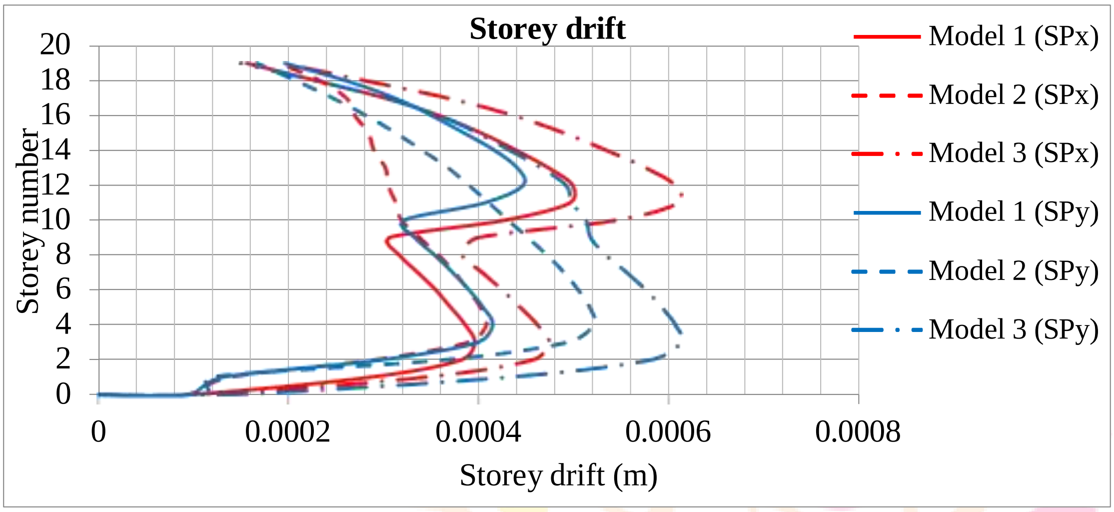

Figure 5.3: Storey drift

Results obtained from the analysis performed on CSI ETABS are discussed below. Base shear, storey displacement, storey drift and model time is studied.

6.0 CONCLUSION

The conclusions from the study are as follows.

1. When models are applied with a fixed base it is observed that model 1 which is irregularity on both sides performs seismically better without any earthquake resistant device. Model 1 performs seismically better after reviewing the results of all the four parameters which are base shear, storey displacement, storey drift and modal time period. Hence it is concluded that as the irregularity increases the seismic stability of the building decreases, which represent hazard to structure and its occupants.
2. For the models modified with earthquake resistant system i.e. bracing and base isolation, it is observed that base isolation shows better seismic performance as compared to fixed base and bracing. Base isolation assists in reducing the base shear and increases the modal time period. Increase in displacement and storey drift nearer to base of a structure makes the structure flexible. Hereof it is concluded that base isolation is a better earthquake resistant system as compared to bracing for an irregular building.
3. From the results it is concluded that the base isolator designed for different types of irregularities performs seismically better hence it is concluded that the objective of designing of a base isolator is successfully achieved.

7. REFERENCE

1. A. Hasan and S. Pal, "Performance analysis of base isolation and fixed base building", International Conference in Emerging Technology in Structural Engineering, Nagpur, India, pp.1-5, 2017.
2. George Georgoussisa, Achilleas Tsompanos and Triantafyllos Makariosb, "Approximate seismic analysis of multi-storey buildings with mass and stiffness irregularities," The 5th International Conference of Euro Asia Civil Engineering Forum, Surabaya, East Java, Indonesia, pp.959-966, 2015.
3. Han-Seon Lee and Dong-Woo Ko, "Seismic response characteristics of high-rise RC wall buildings having different irregularities in lower stories", Journal of Engineering Structures, Vol. 29, pp.3149-3167, 2007.
4. IS 16700, Criteria for structural safety of tall concrete building, Bureau of Indian Standards New Delhi, 2017.
5. IS 1893 (Part 1), Criteria for earthquake resistant design of structures, Bureau of Indian Standards New Delhi, 2016.
6. Jack P. Moehle "Seismic response of vertically irregular structures" Journal of Structural Engineering, Vol. 110, pp. 2002-2014, 1984.
7. O. V. Mkrtychev, G. A. Dzhinchvelashvili and A. A. Bunov, "Study of lead rubber bearings operation with varying height buildings at earthquake," Journal of Theoretical Foundation of Civil Engineering, pp.48- 53, 2014.
8. Sanyogita and B. Saini, "Seismic analysis of vertical irregularities in buildings," International Conference on Sustainable Waste Management through Design, Switzerland, Europe, pp.537-546, 2019.
9. Uniform Building Code, International Conference of Building Officials, California 1997.
10. Z. A. Siddiqi, Rashid Hameed and Usman Akmal," Comparison of different bracing systems for tall buildings" Pakistani Journal of Engineering & Applied Science, Vol. 14, pp.17-26, 2014.