SEISMIC BEHAVIOUR OF REINFORCED CONCRETE STRUCTURES WITH VERTICAL AND PLAN IRREGULARITIES

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Abstract: Now a days due to process of urbanization and many employment opportunities in cities population is increasing day by day. Due to this, the need for residential and commercial buildings has increased drastically. In order to compensate this problem, tall buildings came into existence. But in cities there is lack of more free space available for construction. So in order to construct tall buildings within limited space so many architectural changes were made which probably leads to irregularities in structure. So the structures which are irregular are more prone to damage during earthquakes. The structure in which parameters like mass, stiffness, geometry and plan are not uniform is known as irregular structure.

In the present study, vertical irregularities (stiffness, mass, vertical geometrical) and plan irregularities (reentrant corner) and their combinations will be considered. For modeling and analysis ETABS software will be used. Dynamic analysis (response spectra method) will be carried out on 25 storey building with different combinations of irregularities. Parameters like storey displacement, storey drift, and total base shear effects will be studied.

Keywords*:* Irregular Structure, Vertical Irregularity, Plan Irregularity, Dynamic analysis

I. INTRODUCTION

1.1 GENERAL

Earthquake is defined as the shaking or vibration of ground due to movement of tectonic plates beneath the surface of earth. Earth quake may be caused due to both natural and manmade activities Earthquake leads to lot of destruction to life and property. In India north and eastern states are prone to earthquakes frequently every year leading to destruction of structures. Many advanced techniques came into existence to overcome the effects of earthquake.

India is basically classified into four seismic zones based on past seismic history .among them seismic zone 2 is least vulnerable to earthquakes and seismic zone 5 is most vulnerable to earthquakes

During earthquakes high rise building structures are more prone to damage .among them structures with sequential and proper alignment of components are less prone to damage where as structures with improper arrangement of components are more prone to damage leading loss to life and property

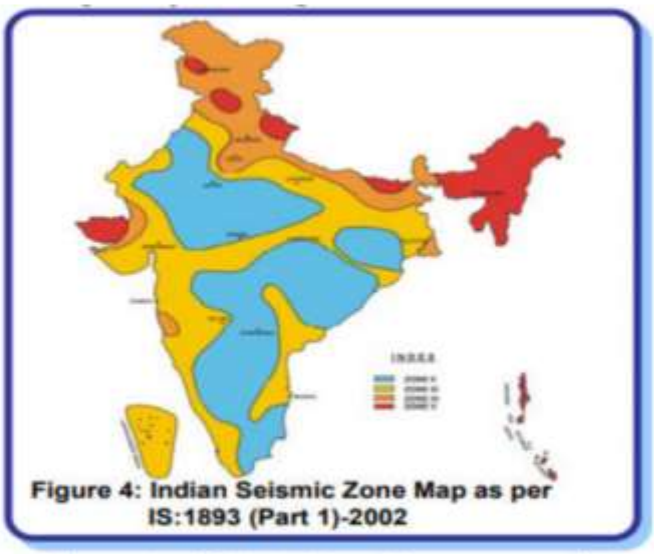


FIG 1SEISMIC ZONES OF INDIA

1.2 INTRODUCTION TO REGULAR AND IRREGULAR STRUCTURES

The performance of reinforced concrete structure depends on the orientation and arrangement of structural components. When a building is subjected to dynamic loads, inertia forces are developed and gets concentrated at the center of mass of the structure. Usually, the vertical members such as columns and shear walls resist the horizontal inertia forces and the resultant of these forces gets concentrated at a point called center of stiffness.

1.2.1 REGULAR STRUCTURE

A structure is said to be regular when geometry , mass , stiffness and plan is uniform through out the structure .In regular structure center of mass and center of stiffness coincide and no eccentricity develops in structure. Regular structures have no significant discontinuities in plan or in vertical configurations and perform well during lateral loads. Regular structure can be analyzed using equivalent static method

In this project G+25 storeyed regular building is considered

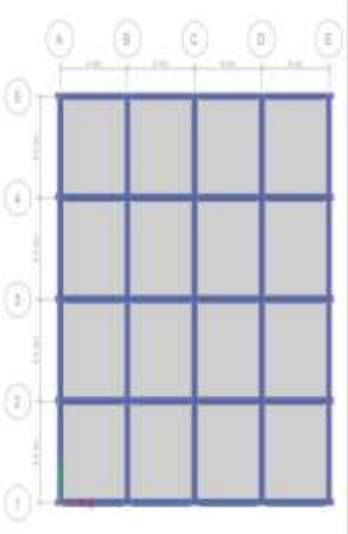


FIG 2 PLAN VIEW OF REGULAR STRUCTURE FIG 3 3D VIEW

1.2.2 IRREGULAR STRUCTURE

A structure is said to be irregular when geometry , mass, stiffness and plan is not uniform throughout the structure .In irregular structure center of mass and center of stiffness do not coincide. When the center of mass doesn't coincide with the center of stiffness, eccentricity develops in the structure. Location and size of structural elements have significant effect on torsion coupling which results in damage of structures.. Irregular structures have certain physical discontinuities either in plan or in elevation or both which affect the performance of the structure subjected to lateral loads. Irregular structure can be analyzed using dynamic methods irregularities in structure can be classified into two types

1. Vertical irregularity and

2 .plan or elevation irregularities

1.3 INTRODUCTION TO VERTICAL AND PLAN IRREGULARITIES:

Irregularities in structure may be grouped as plan and vertical irregularities

Irregularities in the distribution of mass, stiffness and geometry along the height of any building are grouped as vertical irregularities. Horizontal irregularities can be attributed to the presence of discontinuities in plan.

Different structural irregularities affect the seismic response of structures in different ways. Irregularities are introduced in real structures for both aesthetics and utility. The magnitude of variation in response depends on the type, degree and location of irregularities present. The judicious choice of these parameters in the design of structures improves performance of the structure.

1.4 VERTICAL IRREGULARITIES:

- If structure has uneven distributed stiffness and mass and if it has geometric un symmetry it is called as vertical irregularity

Types:

- Mass irregularity
- Stiffness irregularity
- Vertical geometry irregularity and
- Strength irregularity

STRENGTH IRREGULARITY :

- A weak storey is a storey whose lateral strength is less than that of storey above

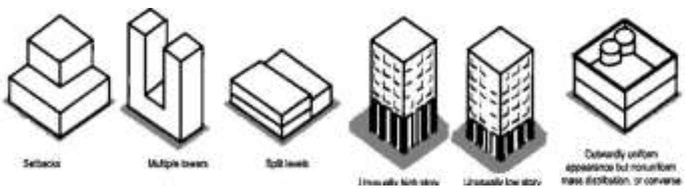


FIG 3 DIFFERENT TYPES OF VERTICAL IRREGULARITIES

1.5 OBJECTIVES OF PROJECT

- To understand the behavior of 25 storey building with vertical irregularity
- To understand the behavior of 25 storey building with plan irregularity
- To understand the behavior of 20 storey building with combined irregularities

II. LITERATURE REVIEW

A nine storied regular frame is modified by incorporating irregularities in various forms in both plan and elevation to form 34 configurations with single irregularity and 20 cases with combinations of irregularities. Along with the regular configuration, 54 irregular configurations are analyzed and compared. All the frames are subjected to seismic loads and the response of the structures is computed numerically. Among the cases having combinations of irregularities, the configuration with mass, stiffness and vertical geometric irregularities has shown maximum response

The configurations with vertical geometric irregularity have given maximum response. The combination of stiffness and vertical geometric irregularities has shown maximum displacement response whereas the combination of reentrant corner and vertical geometric irregularities has shown less displacement response.

In the modern world, where people are not ready to compromise with their needs, incorporation of combinations of irregularity in structures is inevitable. As the structural response depends on the type, location and degree of irregularity, these factors need to be taken care while designing any structure. This would help in incorporating irregularities in structures without compromising their performance.

A setback multi storey building with mass and stiffness irregularities is considered. an approximate analysis which provides basic dynamic data (frequencies and peak values of base resultant forces) .This methodology is based on South well's formula and the concept of the equivalent single story system. This has been introduced by the authors in earlier papers for assessing the response of uniform along the height of buildings.sap software is used

In the computer analyses, the out of plane stiffness of the bents was neglected and in the wide column analogy used to simulate the CW bents the clear span of the coupling beams was increased by the depth of the beams . The above estimates are quite satisfactory for practical applications

III. METHODOLOG

3.1 MODELING OF REGULAR STRUCTURE:

- REGULAR STRUCTURE:

- Buildings with simple regular geometry and uniformly distributed mass and stiffness are called as regular buildings
- So in this project a regular G+ 25 storey building is considered
- Parameters considered for regular building

TABLE 1

Soil type	Medium Type II
Length in x direction	18m
Width	16 m
Soil type	Medium Type II
Number of stories	G+25
Ground Storey height	3.5m
Storey height	3m
Grade of the Concrete	M30
Grade of steel	FE415
Beam dimension	250 x 380 mm
Column dimension	300 x 600mm
Slap depth	150mm
Seismic Zone	4

- According to IS 1893(PART 1):2016 the following below parameters were considered

Zone factor Z	**0.24**
Importance factor I	**1.5**
Response reduction factor R	**5**

3.2 MODELLING OF IRREGULAR STRUCTURE:

- A structure is said to be irregular if it has uneven distribution of stiffness, mass ,geometrical configuration and plan irregularities

- ETABS software is used for modeling of irregular structure

3.2.1MODELLING OF VERTICAL IRREGULAR STRUCTURE

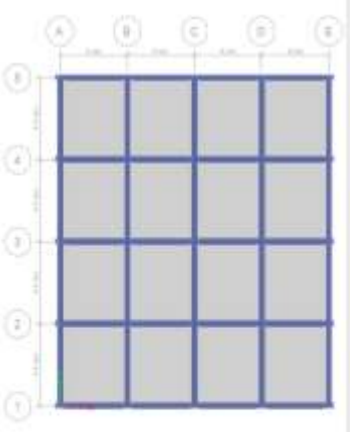
- For vertical irregularities mass ,stiffness and vertical geometry irregularities are considered
- For mass and stiffness irregularity regular 25 storey building is considered and irregularities are induced into it by varying weight of slabs and stiffness of column

TABLE 2 Mass irregularity

s.no	No of stories	Slab weight
1	Upto 15	200 mm
2	15 to 25	150 mm

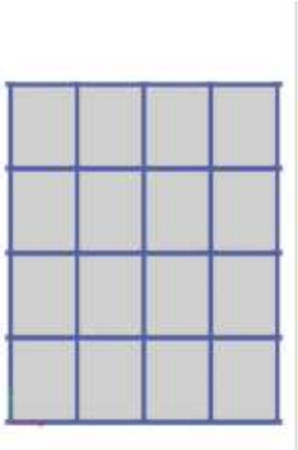
TABLE 3 Stiffness irregularity

s.no	No of stories	Column size	Beam size
1	Upto 15	450 mm*600mm	300mm*500mm
2	15 to 25	300mm*600mm	230mm*38omm



VERTICAL GEOMETRICAL IRREGULARITY:

For vertical geometrical irregularity building having setbacks is considered



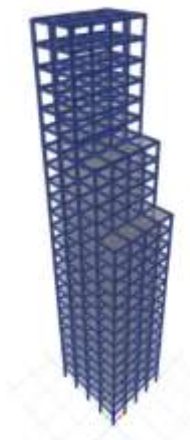


FIG 4 PLAN VIEW OF VGI FIG 7 3D VIEW OF VGI

TABLE 4 Dimensions for vertical geometrical irregularity

S.no	Column size	Beam size	Depth of slab
1	**300mm*600mm**	**230mm*380mm**	**200mm**

TABLE 5 Combination of mass, stiffness and vertical geometrical irregularity

s.no	No of stories	Column size	Beam size	Depth of slab
1	Upto 15	300mm*600mm	230mm*380mm	200mm
2	15 to 25	450mm*600mm	300mm*500mm	130mm

3.2.2 **PLAN OR ELEVATIONAL IRREGULARITY**

For this reentrant corner irregularity is considered having L SHAPE

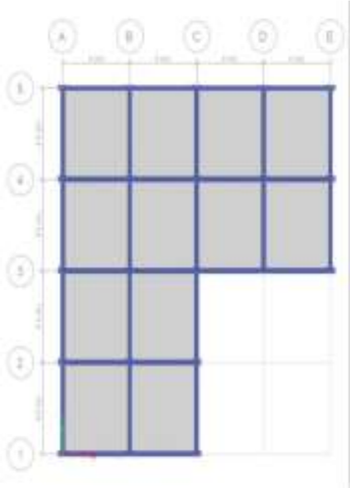


FIG 5 PLAN VIEWOF L SHAPED BUILDING FIG 9 3D VIEW OF L SHAPE

TABLE 6 DIMENSIONS

s.no	Column size	Beam size	Depth of slab
1	300mm*600mm	238mm*380mm	200mm

Combination of plan with vertical irregularities

In this mass stiffness and reentrant corner irregularities are considered

RESPONSE SPECTRUM METHOD:

- In this method all the basic parameters required are considered according to IS 1893(part 1):2016.
- For loads consider IS 875

3.3 ANALYSIS OF MODELS:

3.3.1 ANALYSIS OF REGULAR G+25 STOREY BUILDING (MODEL 1)

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RSM X, TABLE 1

STOREY	DISPLACEMENT	DRIFT	SHEAR
Base	0	0	0
Story1	2.51	0.000722	1532.0572
Story2	6.619	0.000843	1502.6657
Story3	11.016	0.00096	1461.0677
Story4	15.459	0.001057	1416.5956
Story5	19.896	0.001137	1376.4338
Story6	24.316	0.001206	1338.9498
Story7	28.713	0.001265	1301.5695
Story8	33.081	0.001316	1265.1929
Story9	37.409	0.00136	1225.4657
Story10	41.688	0.001398	1184.4084
Story11	45.907	0.001429	1144.4981
Story12	50.054	0.001454	1104.2446
Story13	54.12	0.001474	1063.8573
Story14	58.095	0.00149	1024.4536
Story15	61.968	0.001503	983.6816
Story16	65.727	0.001513	938.4594
Story17	69.357	0.00152	889.1432
Story18	72.844	0.001523	837.2207
Story19	76.173	0.001521	781.7928
Story20	79.326	0.001516	721.4054
Story21	82.286	0.001509	656.091
Story22	85.036	0.001498	582.7599
Story23	87.554	0.001474	489.9713
Story24	89.821	0.001373	362.8773
Story25	91.84	0.000837	195.1054

RSM Y, TABLE 2

STOREY	DISPLACEMENT	DRIFT	SHEAR
Base	0	0	0
Story1	5.768	0.001923	1465.5977
Story2	13.309	0.002521	1441.4897
Story3	20.921	0.002556	1415.5268
Story4	28.494	0.002555	1387.1016
Story5	36.01	0.002549	1359.8782
Story6	43.452	0.002534	1329.6436
Story7	50.799	0.002512	1297.0245
Story8	58.028	0.002481	1260.2744
Story9	65.117	0.002444	1222.5815
Story10	72.042	0.0024	1182.4912
Story11	78.784	0.002348	1139.6442
Story12	85.32	0.00229	1095.0895
Story13	91.629	0.002225	1047.4574
Story14	97.69	0.002151	996.656
Story15	103.482	0.002071	944.2246
Story16	108.983	0.001984	889.5529
Story17	114.173	0.001889	831.3128
Story18	119.031	0.001786	770.0564
Story19	123.537	0.001674	705.7623
Story20	127.667	0.001552	636.6644
Story21	131.402	0.001419	562.9814
Story22	134.719	0.001275	486.3013
Story23	137.597	0.001113	401.4103
Story24	140.013	0.000922	294.8157
Story25	141.966	0.000709	157.3596

3.3.2 ANALYSIS OF REGULAR BUILDING WITH MASS AND STIFFNESS IRREGULARITY (MODEL2)

RSM X, TABLE 3

STOREY	DISPLACEMENT	DRIFT	SH
Base	0	0	0
Story1	1.899	0.000633	1460.6143
Story2	5.211	0.001107	1426.1443
Story3	8.813	0.001208	1377.5153
Story4	12.44	0.001225	1333.8259
Story5	16.025	0.001221	1288.3193
Story6	19.554	0.001216	1251.052
Story7	23.024	0.001208	1212.6171
Story8	26.431	0.001199	1175.1842
Story9	29.772	0.001188	1138.4285
Story10	33.041	0.001173	1097.8946
Story11	36.231	0.001155	1056.0981
Story12	39.334	0.001136	1015.9834
Story13	42.348	0.001115	973.7732
Story14	45.289	0.0011	925.9555
Story15	48.257	0.001127	876.6471
Story16	52.117	0.001507	833.7059
Story17	56.809	0.00185	795.9748
Story18	61.61	0.001894	751.2035
Story19	66.234	0.001831	702.6135
Story20	70.551	0.001725	650.3973
Story21	74.483	0.001592	591.8173
Story22	77.974	0.001436	527.8605
Story23	80.976	0.001252	454.2361
Story24	83.459	0.001029	350.9585
Story25	85.453	0.000791	197.5936

RSM Y, TABLE 4

STORY	DISP	DRIFT	SHEAR
Base	0	0	0
Story1	2.544	0.000848	1400.2155
Story2	6.631	0.001367	1370.2039
Story3	10.919	0.00144	1331.5427
Story4	15.18	0.00144	1291.6176
Story5	19.37	0.001429	1257.5268
Story6	23.485	0.001416	1224.5518
Story7	27.521	0.0014	1189.9656
Story8	31.471	0.001382	1155.3301
Story9	35.327	0.001358	1116.3174
Story10	39.078	0.001332	1075.6605
Story11	42.715	0.001303	1035.5699
Story12	46.229	0.001271	993.3552
Story13	49.612	0.001235	947.6249
Story14	52.862	0.001199	899.4277
Story15	56.048	0.001192	851.4402
Story16	61.637	0.00216	809.8822
Story17	68.353	0.002603	770.5778
Story18	74.916	0.002543	724.7932
Story19	81.055	0.002391	672.8014
Story20	86.665	0.002211	616.5312
Story21	91.67	0.002008	554.712
Story22	96.002	0.001779	485.2002
Story23	99.593	0.001521	410.9255
Story24	102.376	0.001205	318.6548
Story25	104.337	0.000813	180.3419

3.3.3 ANALYSIS OF STRUCTURE WITH VERTICAL GEOMETRICAL IRREGULARITY (model 3)

RSM X, TABLE 5

STORY	DISP	DRIFT	SHEAR
Base	0	0	0
Story1	4.13	0.001377	1030.4771
Story2	11.98	0.002624	966.3634
Story3	20.891	0.002982	915.8382
Story4	30.033	0.003072	891.1117
Story5	39.144	0.003073	866.6951
Story6	48.116	0.003037	836.2071
Story7	56.894	0.002984	812.8841
Story8	65.44	0.002918	786.822
Story9	73.719	0.002838	753.7728
Story10	81.698	0.00275	721.1564
Story11	89.347	0.002655	690.3131
Story12	96.64	0.002552	654.8147
Story13	103.553	0.002439	611.6963
Story14	110.064	0.002321	564.5884
Story15	116.172	0.002204	517.4832
Story16	121.918	0.002089	470.8186
Story17	127.317	0.001982	429.6876
Story18	132.417	0.00189	402.5749
Story19	137.251	0.001805	373.9213
Story20	141.805	0.001698	347.2315
Story21	145.956	0.001559	313.9162
Story22	149.591	0.00138	277.5932
Story23	152.659	0.001203	230.8908
Story24	155.151	0.000986	168.3778
Story25	157.13	0.00076	89.2958

RSM Y, TABLE 6

STORY	DISP	DRIFT	SHEAR
Base	0	0	0
Story1	6.341	0.002114	1125.6714
Story2	16.279	0.003322	1102.5114
Story3	26.599	0.003466	1080.9958
Story4	36.818	0.003449	1055.3341
Story5	46.841	0.0034	1030.6825
Story6	56.622	0.00333	999.7469
Story7	66.117	0.003247	967.0728
Story8	75.285	0.003149	929.6124
Story9	84.085	0.00304	890.6988
Story10	92.478	0.002915	846.9223
Story11	100.42	0.002772	797.6117
Story12	107.865	0.002616	745.4515
Story13	114.773	0.002445	689.291
Story14	121.112	0.002262	628.5965
Story15	126.861	0.002074	563.9425
Story16	132.753	0.002169	496.8876
Story17	138.477	0.002142	445.9339
Story18	143.852	0.002034	416.0163
Story19	148.879	0.001924	384.89
Story20	154.618	0.00223	352.4739
Story21	160.338	0.002251	309.854
Story22	165.385	0.002023	265.9709
Story23	169.61	0.001734	220.6955
Story24	172.948	0.001384	165.2258
Story25	175.409	0.000984	90.2214

IV. RESULTS AND DISCUSSION

In the present study vertical and plan irregularities are induced into regular 25 storeyed building and their seismic behavior is determined .The major outputs are storey drift , storey displacement and base shear. Comparative study is conducted and for what combination of irregularities the building is more prone to damage is determined

STOREY DRIFT

The difference between the lateral displacements of two adjacent floors of the surface is called storey drift. In the present study storey drift of structure with different combinations of irregularities is analyzed using response spectra method. Storey drift values are shown below

STOREY DISPLACEMENT

The difference between the displacements of two adjacent bays of structure is called as storey displacement .In the present study storey displacement of structure with different combinations of irregularities is analyzed using response spectra method

STOREY SHEAR

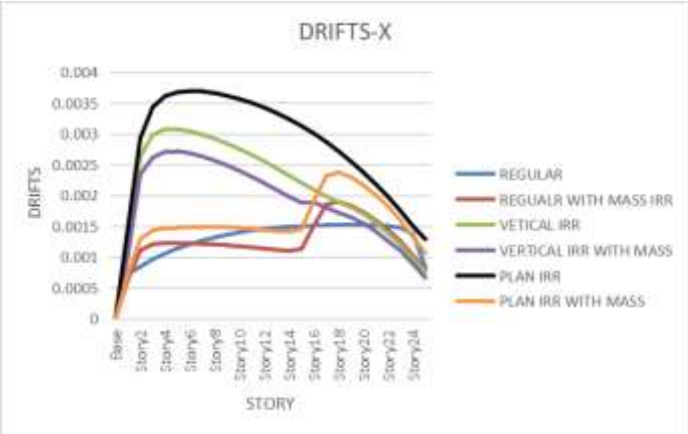
The algebraic sum of design lateral forces at all levels is called as storey shear. in this study storey shear of structure with different combinations of irregularities is analyzed using response spectra method

4.1 MAXIMUM STOREY DRIFT:

The comparison is been done for storey drift for RC structures for different combinations of irregularities. mass stiffness and vertical geometrical irregularities are considered as vertical irregularities and reentrant corner irregularity for plan irregularity. Comparison is shown in below the graph

GRAPH 1

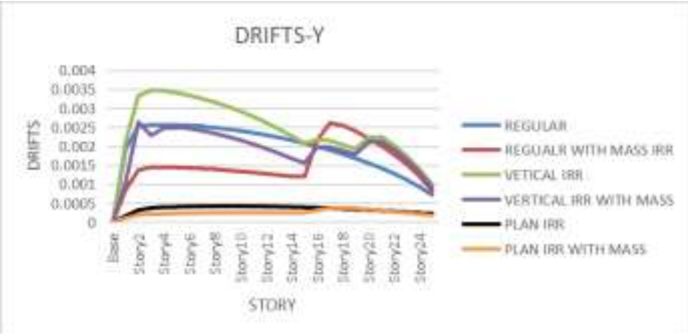
SHOWING MAXIUM STOREY DRIFT IN X



- From the above graph we observe that plan irregularity with reentrant corner L Shaped structure has shown maximum drift in x direction
- From the above graph we observe that regular structure has least storey drift

GRAPH 2

SHOWING MAXIMUM DRIFT IN Y



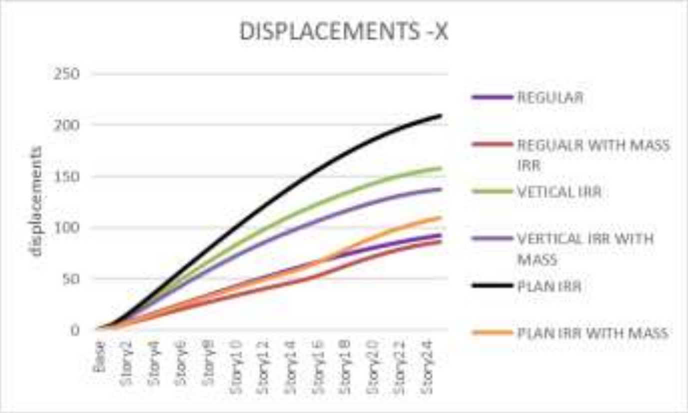
- From the above graph we observe that plan irregularity and its combination with mass and stiffness irregularity has shown least drift in y
- From the above graph we observe that structure with vertical geometrical irregularity has shown maximum drift in y

4.2 Maximum storey displacement

The comparison is been done for storey displacements for RC structures for different combinations of irregularities .mass stiffness and vertical geometrical irregularities are considered as vertical irregularities and reentrant corner irregularity for plan irregularity. Comparison is shown in below the graph

Graph 3

SHOWING MAXIMUM STOREY DISPLACEMENT IN X

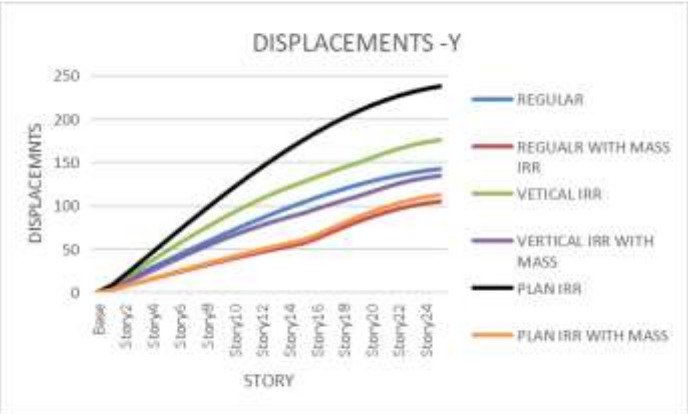


- From the above graph we observe that structure with plan irregularity reentrant corner L SHAPED has shown maximum displacement in x

From the above graph we observe that structure with mass and stiffness irregularity has showm least displacement in x

GRAPH 4

SHOWING DISPLACEMENT IN Y



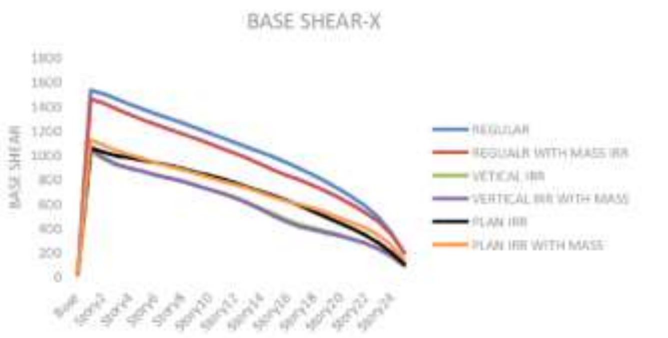
- From the graph above we observe that structure with plan irregularity has shown maximum displacement in y also
- From the above graph we observe that structurewith mass and stiffness irregularity has showm least displacement in y also

4.3 MAXIMUM BASE SHEAR

The comparison is been done maximum base shear for RC structures for different combinations of irregularities. Mass stiffness and vertical geometrical irregularities are considered as vertical irregularities and reentrant corner irregularity for plan irregularity. Comparison is shown in below the graph

Graph 5

SHOWING BASE SHEAR IN X



- From the above graph we observe that regular 25 storeyed building has shown maximum base shear in x
- From the above graph we observe that structure with vertical geometry irregularity and mass and stiffness has shown least base shear in x

V. CONCLUSIONS

The response spectra technique of dynamic analysis is used in this work to investigate the seismic behavior of reinforced concrete buildings with vertical and plan abnormalities. The analysis is carried out utilising the ETABS programme to conduct the investigation. It is necessary to identify the different characteristics for RC framed buildings, such as the maximum storey drift, the maximum storey displacement, and the maximum base shear, which will then be compared further.

- It is discovered that the maximum storey drift of 0.004 occurs in a building with L shape reentrant corner plan irregularity in the x direction and 0.0035 in vertical geometrical irregularity in y direction
- When considering a structure with plan irregularities reentrant corner L SHAPED structure in both the x and y directions, it is discovered that there is a maximum storey displacement of 200mm
- The maximum base shear is found in a typical G+25-story structure with no special features.
- According to the findings of the research mentioned above, regular buildings are more successful at withstanding earthquake loads.
- Those with irregularities in their mass and stiffness are more successful at withstanding earthquake stresses as compared to structures with irregularities in their vertical geometry and plan.
-

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