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SEISMIC ANALYSIS ON A PLAN IRREGULAR MULTISTOREY COMMERCIAL BUILDING USING ETABS

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Abstract— It is an attempt to investigate the effect of Irregular plan configuration for multistoried reinforced concrete building model.This paper mainly emphasizes on analysis of a multi-storey building (G+25) which is irregular both in plan and elevation. Modelling of 25 storeyed R.C.C. framed building is done on the ETABS v13.2.0 software for analysis. Post analyses of the structure such as Maximum Storey Displacement, Base Shear, Storey Drift, Maximum base reactions, Torsion and Over-turning moments are computed and then compared for all the analysed cases.
ETABS is an engineering software product that caters to multi-story building analysis and design. ETABS stands for Extended Three dimensional Analysis of Building Systems. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. Design of steel and concrete frames (with automated optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls is included, as is the capacity check for steel connections and base plates. ETABS provides an unequaled suite of tools for Structural Engineers designing buildings, whether they are working on one-story industrial structures or the tallest commercial high-rises.
Key words: ETABS, G+25, R.C.C

I. Introduction

Earthquakes are the most undesirable and distressing of all natural calamities. From this, it is very difficult to save the structural properties and life. To overcome these concerns, we need to find the seismic performance of the built environment by developing various analytical procedures, which safeguard the structures to withstand during numerous minor earthquakes and also provide enough caution at the time of major earthquake. The behavior of a building during an earthquake depends on several factors such as stiffness, adequate lateral strength, ductility, configuration etc... During an earthquake, buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But in present days, need and demand of the latest generation according to growing population has made the architects or engineers inescapable towards planning of irregular configurations.

II. Objective of the study

To obtain the Seismic performance of an irregular building located in various earthquake zones and in different types of soils of India.

III. Scope of the study

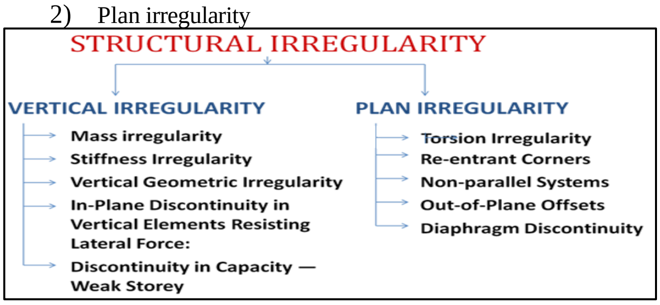
The Present work is focused on the study of Seismic demands of an irregular R.C building for various seismic zones and different types of soils in India. The configuration involves plan irregularities such as diaphragm discontinuity, re-entrant corners and vertical irregularities such as geometrical irregularity, buildings resting on sloping ground. The performance was studied in terms of time period, base shear, lateral displacements, storey drifts and eccentricity in linear analysis using the code – IS1893 (Part 1):2002 . The entire modelling, analysis and design was carried out by using ETABS 13.2.0 version software.

IV. Irregularity

The system of components of the building, which are able to resist the seismic forces, is known as lateral force resisting system (L.F.R.S). They are of different types. The most familiar forms of these systems used in a structure are special moment resisting frames (SMRF), shear walls and frame-shear wall dual systems. Generally, the damage in a structure initiates at a location where the weak planes are present in the building systems. These weaknesses activate further structural deteriorations, which leads to the structural collapse. These weaknesses often occur due to the presence of structural irregularities in stiffness, strength and mass in a building system.

As per IS 1893:2002(part I), the structural irregularity can be broadly classified as,

1) Vertical irregularity and
2) Plan irregularity



(a) Classification of Structural Irregularity

Here, we just focus on Plan irregularity and study the structural behavior of the structure with irregular Plan configuration.

V. Modeling of the building

In this study, entire analysis for all the 3D models has been done using ETABS 13.2.0 version software. The results are tabulated in order to focus the parameters such as Lateral Displacement, Base shear, Storey drift, Torsion and Base reactions acting on the building. Here, the entire analysis process is carried out by linear analysis.

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In this study a Commercial building of 25 storey having different plan configurations at different levels (i.e. storeys 1-10, storeys 11-17, storeys 18-25) of the structure which is further analysed in different zones and different soil types (as per IS 1893 (Part I): 2002). Here, the structure in different zones and different soils is consider to study the effect of lateral deflection, storey drifts, bending moment, shear force and axial force caused due to lateral load (i.e. due to quake load).

VI. BUILDING PARAMETERS

The building has irregular plan configuration. A floor to floor height of 3.0m is assumed. The location of the building is assumed to be at different zones and different type of soils. An elevation and plan view of a typical structure is shown in fig. 2.1 (a) and 2.1 (b).

Size of Structural Members:

A. Column Size:

1) Rectangular Columns:

- C 610mm x 915mm
- C 700mm x 1100mm
- C 800mm x 1250mm

2) Circular Columns:

- C 1220mm dia
- C 1300mm dia
- C 1350mm dia

B. Beam Size:

- B 460mm x 610mm
- B 460mm x 760mm
- B 540mm x 760mm
- B 610mm x 950mm
- B 610mm x 1200mm
- B 650mm x 950mm
- B 850mm x 1200mm

C. Slab Thickness: 115 mm

D. Grade of Concrete: M40

E. Grade of Steel:

1) For Beams:

- Longitudinal Reinforcement: Fe500
- Shear Reinforcement : Fe250

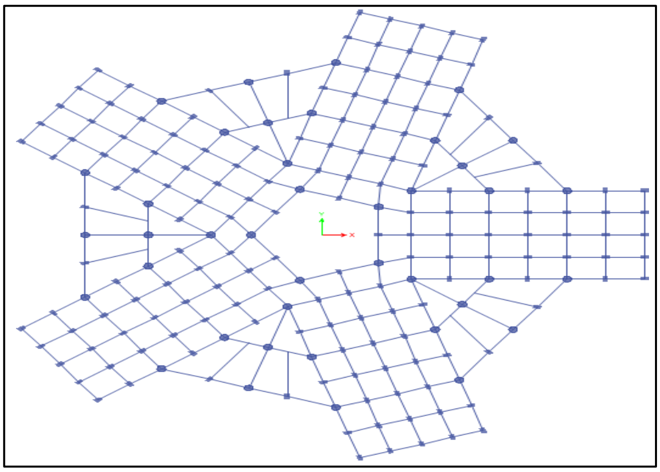
2) For Columns:

- Longitudinal Reinforcement: Fe550
- Shear Reinforcement : Fe415

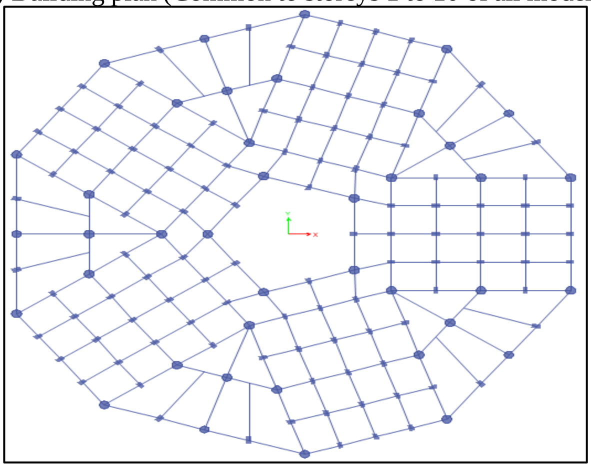
F. In this, all the Analyses has been carried out using Dynamic analysis procedure as per IS 1893-2002.

VII. PLAN AND ELEVATION OF MODEL

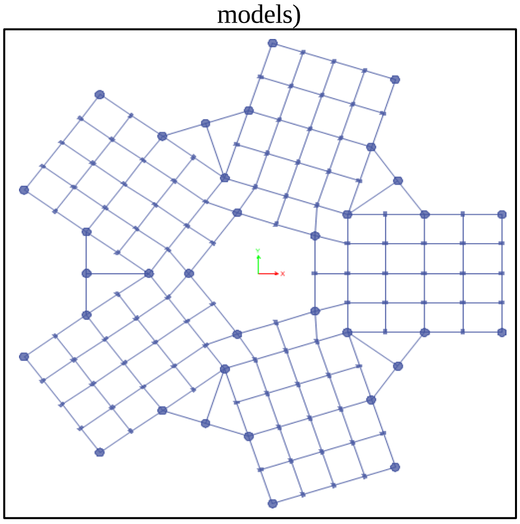
Plans of the model considered with 3 different plan configurations along the height of the building (i.e. storeys 1-10, storeys 11-17, storeys 18-25) is shown below.



(b) Building plan (Common to storeys 1 to 10 of all models)



(c) Building plan (Common to storeys 11 to 17 of all models)



(d) Building plan (Common to storeys 18 to 25 of all models)

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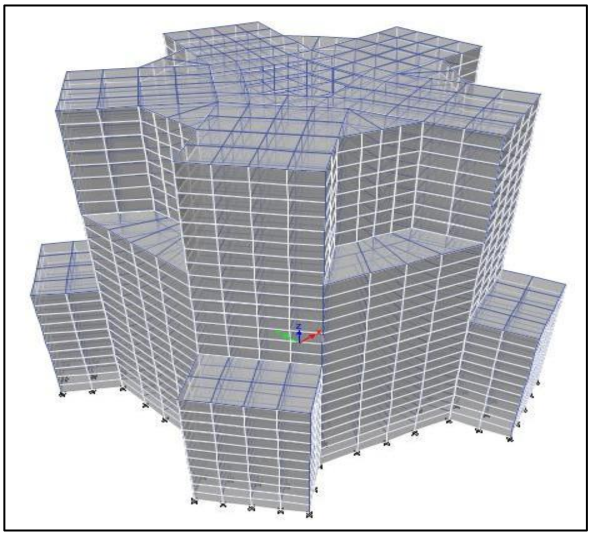

(d) 3D view of G+25Storey Building

VIII. Model Data

The design data shall be as follows:

A. Live load :

- 3kN/m2 at typical floor
- 1.5 kN/m2on terrace

B. Wall load:

- Exterior walls : 12kN/m
- Interior walls : 6kN/m
- Parapet wall : 6kN/m

C. Wind Load:

As per IS: 875(Part 3)-1987

D. Earthquake Load:

As per IS-1893 (Part 1) – 2002

E. Type of Soil:

Checked for all the 3 Types as per IS: 1893(Part 1) – 2002

F. Storey Height:

- Typical floor: 3 m,
- Ground floor: 3m

G. Floors:

G.F. + 25 upper floors.

IX. Load Combinations

Here, we have two types of Load Combinations for the analysis of the structure. Namely,

A. Static Load Combination:

- 1.2(DL + LL – Wx)
- 1.2(DL + LL + Wy)
- 1.2(DL + LL – Wy)

B. Dynamic Load Combination:

- 1.2(DL + LL + Sx)
- 1.2(DL + LL + Sy)
- 1.2(DL + Sx)
- 1.2(DL + Sy)

- 1.5(DL+LL)
- 1.2(DL + LL + Ex)
- 1.2(DL + LL – Ex)
- 1.2(DL + LL + Ey)
- 1.2(DL + LL – Ey)
- 1.2(DL + LL + Wx)

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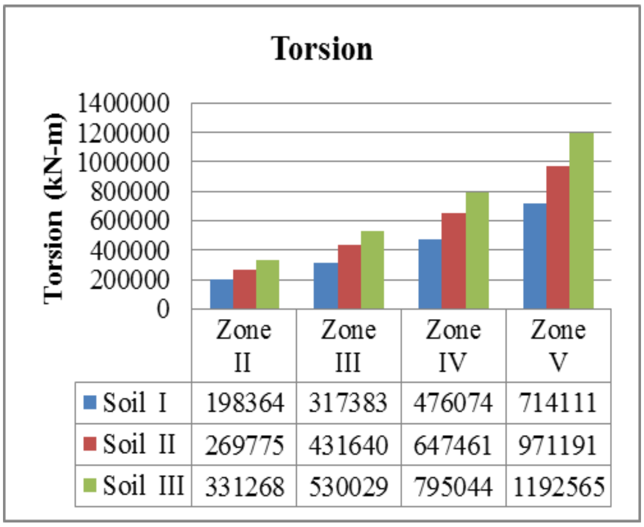
X. RESULTS AND DISCUSSION

In the present study, seismic response of high rise building (G+25) with irregular plan configuration at different levels using ETABS v13.2.0 under loading has been carried out. The objective of this study is to see the variation of load- displacement graph and check the maximum base shear and displacement of the. Following are the graphs drawn for the irregular G+25 storey building using ETABS.

A. *Torsion:*

Story	Load Case/Combo	T (kN-m)	Location
Plinth	1.2(DL+LL+Ex) Max	198364.2	z2 s1
Plinth	1.2(DL+LL+Ex) Max	269775.3	z2 s2
Plinth	1.2(DL+LL+Ex) Max	331268.2	z2 s3
Plinth	1.2(DL+LL+Ex) Max	317382.7	z3 s1
Plinth	1.2(DL+LL+Ex) Max	431640.4	z3 s2
Plinth	1.2(DL+LL+Ex) Max	530029.1	z3 s3
Plinth	1.2(DL+LL+Ex) Max	476074	z4 s1
Plinth	1.2(DL+LL+Ex) Max	647460.7	z4 s2
Plinth	1.2(DL+LL+Ex) Max	795043.6	z4 s3
Plinth	1.2(DL+LL+Ex) Max	714111	z5 s1
Plinth	1.2(DL+LL+Ex) Max	971191	z5 s2
Plinth	1.2(DL+LL+Ex) Max	1192565	z5 s3

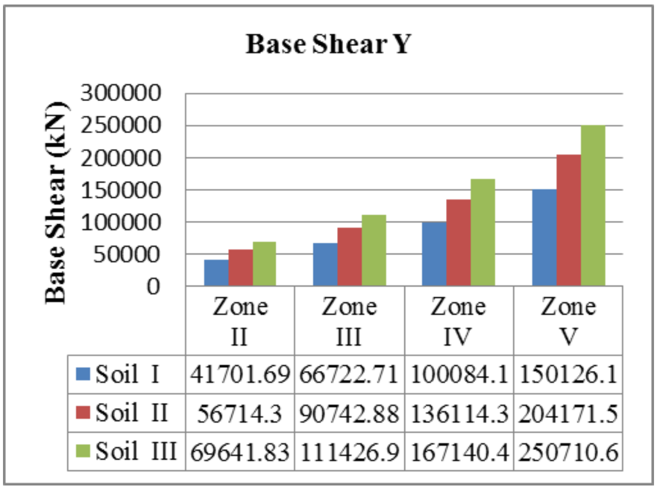


B. *Base Shear:*

Base Shear values for different zones and different soils for the load case Ex 3 along X–axis and Ey 3 along Y-axis respectively.

C. *Storey Displacement:*

Maximum Storey displacement values for the load case



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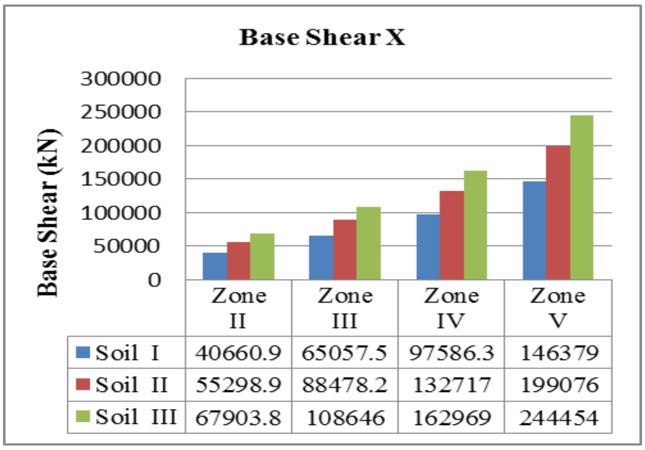
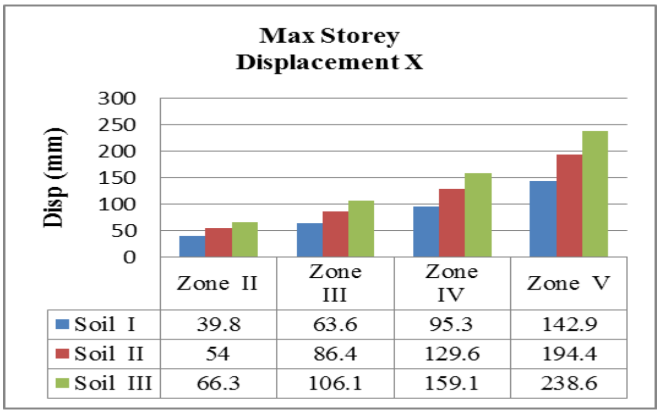
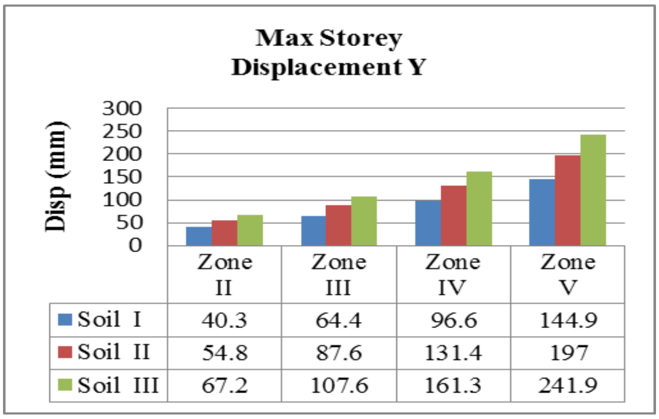
Storey	Shear X	Shear Y	Location
Plinth	40660.9449	41701.69	z2 s1
Plinth	55298.885	56714.3	z2 s2
Plinth	67903.778	69641.83	z2 s3
Plinth	65057.5118	66722.71	z3 s1
Plinth	88478.2161	90742.88	z3 s2
Plinth	108646.0447	111426.9	z3 s3
Plinth	97586.2677	100084.1	z4 s1
Plinth	132717.3241	136114.3	z4 s2
Plinth	162969.0671	167140.4	z4 s3
Plinth	146379.4016	150126.1	z5 s1
Plinth	199075.9862	204171.5	z5 s2
Plinth	244453.6006	250710.6	z5 s3

Story25	40.3	39.8	z2 s1
Story25	54.8	54	z2 s2
Story25	67.2	66.3	z2 s3
Story25	64.4	63.6	z3 s1
Story25	87.6	86.4	z3 s2
Story25	107.6	106.1	z3 s3
Story25	96.6	95.3	z4 s1
Story25	131.4	129.6	z4 s2
Story25	161.3	159.1	z4 s3
Story25	144.9	142.9	z5 s1
Story25	197	194.4	z5 s2
Story25	241.9	238.6	z5 s3





1.2(DL+LL+Ex)Max along X-direction and for 1.2(DL+LL+Ey) Max along Y-direction for different zones and different soils.



D. Max. Storey Drift:

Maximum Storey Drift values for different zones and different soils for the load case 1.2(DL+LL+Ex) Max along X-direction and for 1.2(DL+LL+Ey) along Y-direction.

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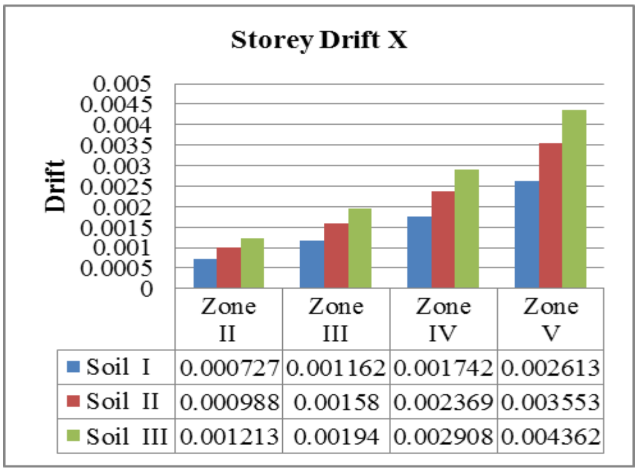
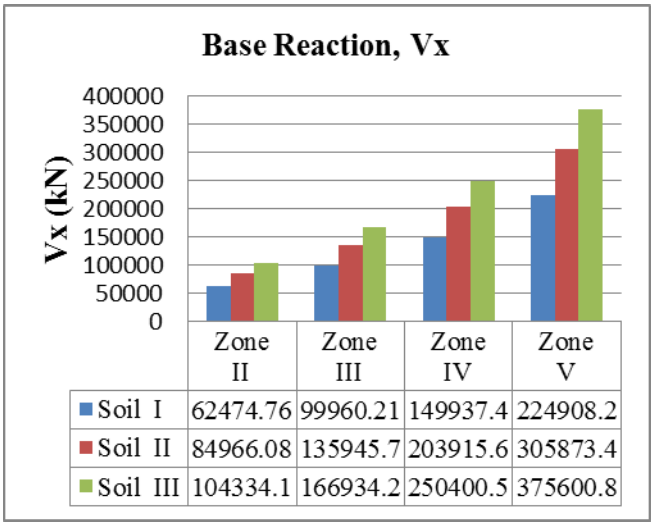
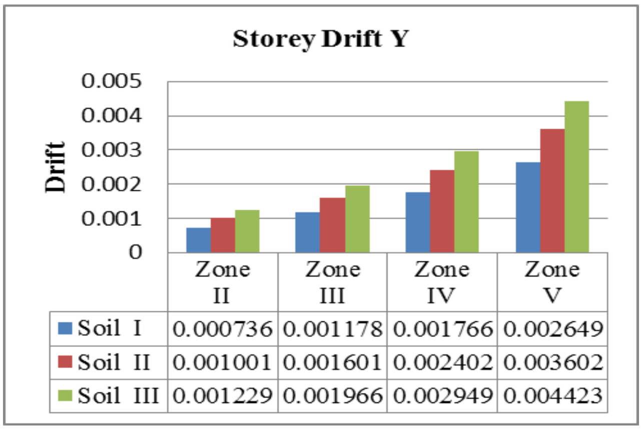
Storey	Max Disp X (mm)	Max Disp Y (mm)	Locatin
Story19	0.001162	0.00118	z3 s1
Story19	0.00158	0.0016	z3 s2
Story19	0.00194	0.00197	z3 s3
Story19	0.001742	0.00177	z4 s1
Story19	0.002369	0.0024	z4 s2
Story19	0.002908	0.00295	z4 s3
Story19	0.002613	0.00265	z5 s1
Story19	0.003553	0.0036	z5 s2
Story19	0.004362	0.00442	z5 s3

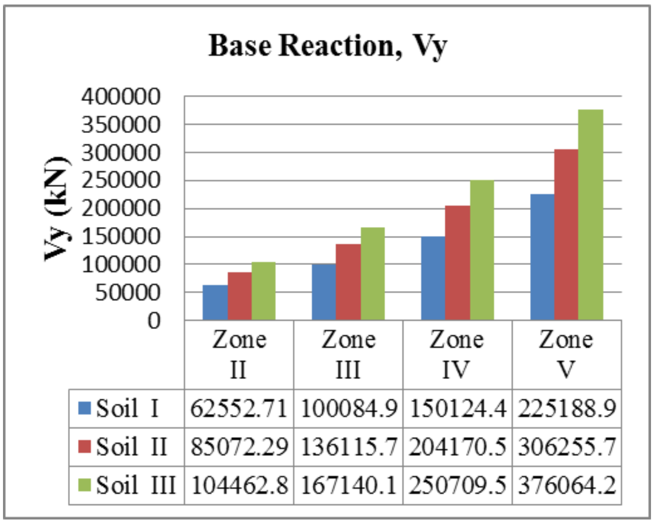
Plinth	149937.35	150124.4	z4 s1
Plinth	203915.58	204170.5	z4 s2
Plinth	250400.53	250709.5	z4 s3
Plinth	224908.24	225188.9	z5 s1
Plinth	305873.38	306255.7	z5 s2
Plinth	375600.79	376064.2	z5 s3

Storey	Drift X	Drift Y	Location
Story19	0.000727	0.00074	z2 s1
Story19	0.000988	0.001	z2 s2
Story19	0.001213	0.00123	z2 s3









E. Max. Base Reactions:

Max Base reactions values along X axes and Y axes for the load case 1.5(DL+Sy) Max for different Zones and different Soils.

Storey	Vx (kN)	Vy (kN)	Location
Plinth	62474.765	62552.71	z2 s1
Plinth	84966.081	85072.29	z2 s2
Plinth	104334.05	104462.8	z2 s3
Plinth	99960.209	100084.9	z3 s1
Plinth	135945.73	136115.7	z3 s2
Plinth	166934.18	167140.1	z3 s3

XI. Comparison of Different Zones in Same Type of Soil (Say Type III (Soft) Soil)

A. Max. Storey Displacement:

Max. storey displacement values along X-direction for Load case 1.2(DL+LL+Ex) Max

Story	Zone 5	Zone 4	Zone 3	Zone 2
Plinth	0	0	0	0
Story1	12.3	8.2	5.5	3.4
Story2	21.2	14.1	9.4	5.9
Story3	30.4	20.3	13.5	8.4
Story4	39.8	26.5	17.7	11
Story5	49.2	32.8	21.9	13.7

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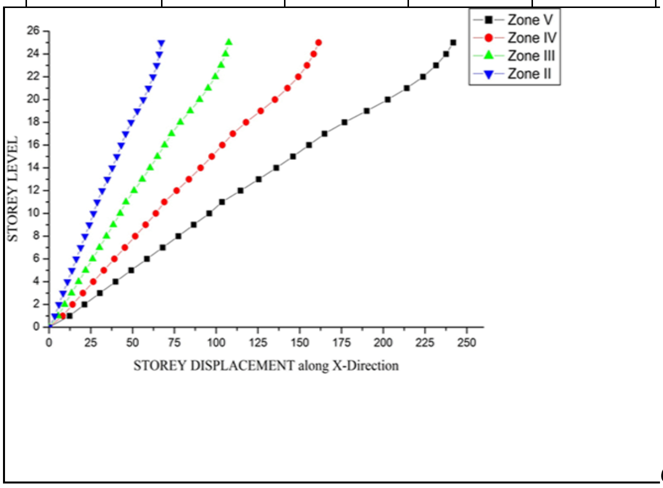
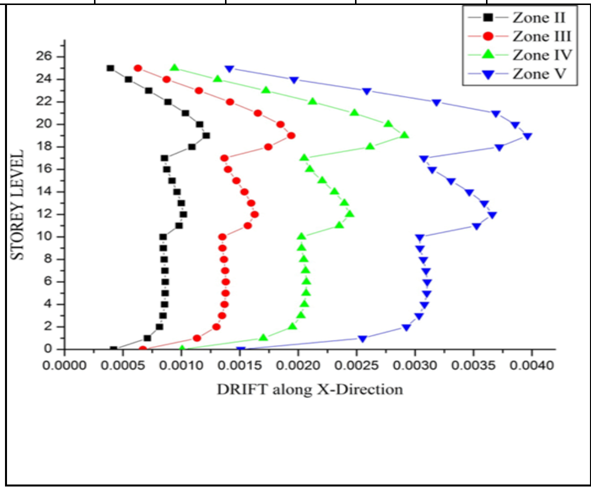
Story6	58.6	39.1	26.1	16.3
Story7	68	45.4	30.2	18.9
Story8	77.4	51.6	34.4	21.5
Story9	86.6	57.8	38.5	24.1
Story10	95.9	63.9	42.6	26.6
Story11	103.5	69	46	28.8
Story12	114.6	76.4	50.9	31.8
Story13	125.5	83.7	55.8	34.9
Story14	136	90.7	60.5	37.8
Story15	146	97.4	64.9	40.6
Story16	155.6	103.7	69.2	43.2
Story17	164.9	110	73.3	45.8
Story18	176.8	117.9	78.6	49.1
Story19	190.1	126.7	84.5	52.8
Story20	202.7	135.2	90.1	56.4
Story21	214.1	142.7	95.2	59.5
Story22	223.8	149.2	99.5	62.2
Story23	231.6	154.4	103	64.4
Story24	237.6	158.4	105.6	66
Story25	241.9	161.3	107.6	67.2



B. Storey Drift:

Storey Drifts of the structure along X-Direction for Load case 1.2(DL+LL+Ex) Max

Story	Zone 2	Zone 3	Zone 4	Zone 5
Plinth	0.00042	0.000671	0.001006	0.001509
Story1	0.000709	0.001134	0.001701	0.002551
Story2	0.000813	0.0013	0.00195	0.002925
Story3	0.000843	0.001348	0.002023	0.003034
Story4	0.000856	0.001369	0.002053	0.00308
Story5	0.000861	0.001378	0.002067	0.0031
Story6	0.000862	0.00138	0.00207	0.003104
Story7	0.000859	0.001375	0.002063	0.003094
Story8	0.000853	0.001365	0.002047	0.003071
Story9	0.000845	0.001352	0.002028	0.003042
Story10	0.000844	0.001351	0.002027	0.00304
Story11	0.00098	0.001568	0.002351	0.003526
Story12	0.001017	0.001627	0.00244	0.00366
Story13	0.000999	0.001597	0.002395	0.003592
Story14	0.000963	0.00154	0.00231	0.003464
Story15	0.00092	0.001471	0.002205	0.003307
Story16	0.000875	0.001399	0.002098	0.003146
Story17	0.000855	0.001368	0.002051	0.003075
Story18	0.00109	0.001744	0.002615	0.003721
Story19	0.001213	0.00194	0.002908	0.003962
Story20	0.001156	0.001848	0.002771	0.003856
Story21	0.001035	0.001655	0.002481	0.003691
Story22	0.000885	0.001416	0.002123	0.003183
Story23	0.00072	0.00115	0.001724	0.002586
Story24	0.000547	0.000874	0.00131	0.001964
Story25	0.000393	0.000628	0.000941	0.001411

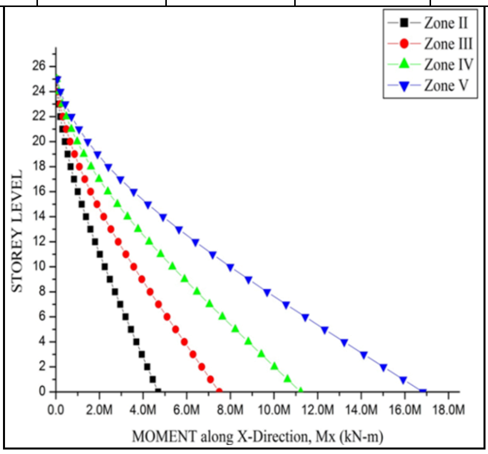


C. Over-turning Moment:

Over-turning Moment values of the structure along X-axis (M_x) for the Load case 1.2(DL+LL+Ex) Max

Storey	Zone 2	Zone 3	Zone 4	Zone 5
Plinth	4690852	7490315	11222932	16821857
Story1	4440140	7089176	10621224	15919297
Story2	4189902	6688538	10020054	15017327
Story3	3939928	6288325	9419520	14116312
Story4	3690552	5889066	8820418	13217445
Story5	3442236	5491504	8223861	12322397
Story6	3195577	5096594	7631282	11433315
Story7	2951306	4705502	7044431	10552825
Story8	2710282	4319608	6465377	9684029
Story9	2473502	3940503	5896505	8830508
Story10	2242091	3569989	5340521	7996318

Story11	2017310	3210083	4800448	7185994
Story12	1797373	2859653	4276026	6400585
Story13	1584685	2520821	3769002	5641274
Story14	1380505	2195602	3282397	4912591
Story15	1186193	1886171	2819474	4219430
Story16	1003207	1594862	2383736	3567046
Story17	833109.8	1324175	1978928	2961058
Story18	677561.2	1076766	1609038	2407448
Story19	538618.9	855502	1278013	1911779
Story20	412229.1	654322.4	977113.4	1461300
Story21	299748.1	475396.8	709595	1060892
Story22	202601.5	321006.1	478879	715688.3
Story23	122284.4	193542.8	288554	431070.8
Story24	60361.59	95510.31	142375.3	212672.7
Story25	18467.37	29523.55	44265.12	66377.49

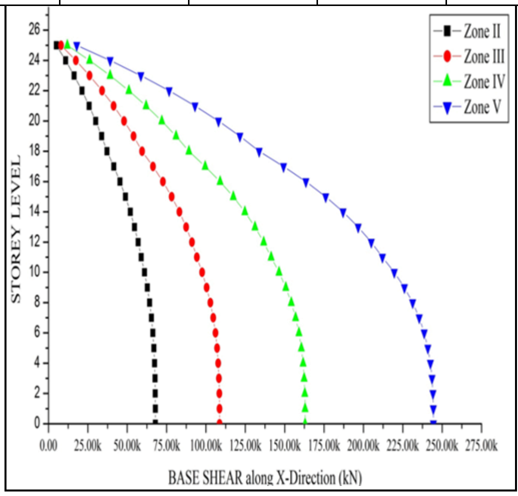


D. Base Shear:

Base shear values along X – axis for the Load case Ex 3

Storey	Zone 2 XII.	Zone 3	Zone 4	Zone 5
Plinth	67903.78	108646	162969.1	244453.6
Story1	67891.66	108626.7	162940	244410
Story2	67819.83	108511.7	162767.6	244151.4
Story3	67658.22	108253.2	162379.7	243569.6
Story4	67370.92	107793.5	161690.2	242535.3
Story5	66922	107075.2	160612.8	240919.2
Story6	66275.58	106040.9	159061.4	238592.1
Story7	65395.72	104633.2	156949.7	235424.6
Story8	64246.52	102794.4	154191.7	231287.5
Story9	62792.07	100467.3	150701	226051.5
Story10	60996.46	97594.33	146391.5	219587.2
Story11	58905.73	94249.18	141373.8	212060.6
Story12	56942.27	91107.64	136661.5	204992.2
Story13	54637.93	87420.69	131131	196696.6
Story14	51965.44	83144.71	124717.1	187075.6
Story15	48897.53	78236.05	117354.1	176031.1

tory16	45406.94	72651.1	108976.6	163465
Story17	41466.38	66346.21	99519.31	149279
Story18	37160.32	59456.51	89184.77	133777.2
Story19	33760.53	54016.85	81025.27	121537.9
Story20	29993.45	47989.51	71984.27	107976.4
Story21	25840.24	41344.38	62016.57	93024.85
Story22	21282.07	34051.31	51076.96	76615.44
Story23	16300.1	26080.16	39120.24	58680.35
Story24	10875.5	17400.8	26101.2	39151.8
Story25	4990.818	7985.309	11977.96	17966.94



CONCLUSIONS

From the results obtained by the analysis of Irregular G+25 model, following conclusions are drawn.

1) The plan configuration of the structure has major impact on the seismic response of the structure in terms of displacement, story drift, story shear etc...
2) The structural performance of the building model is better in zone II when compared to the other three zones. That too, in soil Type I (i.e., Hard Soil) it performs well.
3) It has been concluded that the Storey Overturning moment decreases with increase in the storey height.
4) Greater the height of the structure (building), higher will be the Storey Displacement.
5) The Drift values increases along with the storey height to some extent and then decreases. In this case, The Storey Drift value of the building is more at storey 19 in all the zones. With the help of graph, we can also conclude that, as the plan configuration changes, the drift curve also changes its fashion even in the same structure.
6) The Torsion and Base shear values of the building decreases with increase in height of the structure.
7) The above stated Structural properties (i.e., Displacement, Storey Drift, Base shear, Over- turning Moment…) of the building differs more by about 72% in Zone V when compared to Zone II.
8) Whereas, the Axial shear force values are same in all the zones.

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