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Behavior Of Vertical Irregular Building In Different Seismic Zones

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Abstract

When rocks are deformed, enormous amount of energy is released, the resulting vibrations spread out in all directions. An earthquake is the passage of such vibrations resulting vibrations spread out in all directions. An earthquake is the passage of such vibrations. The seismic force can be resolved into 3 perpendicular directions that is 2 in horizontal directions (x and y) and the remaining 1 in vertical direction (z) The main objectives of this work are to know the behaviouraof a multi-storey vertical irregular residential building under lateral loads. The project is carried out by FEM software E-Tabs. The building model used in this work has 15 stories each storey has a height of 3m. Five different models are used in 4 different zones and their effects are tabulated in Results.

Keywords: earthquake, seismic force, multi storey, residential, FEM, E-Tabs

1. INTRODUCTION

India is one of the country where most of the structures are low rise, but due to movements towards city side's results in population increment in most of the cities. In order to fulfil these people in a limited space the height of the building should be increases from medium to high. Improper design and construction of all types of residential buildings results in great destruction of structure in the world. Hence we have to consider the structure safety rather than economy. The structure should be designed in such a way that it must be safe as well as it must be economical from both design and safety point of view. Both wind and earthquake causes dynamic actions on buildings but design for wind force and design for earthquake force are totally different phenomena. Lateral forces are the main forces which act on the building due to greater height hence in order to avoid the effect of these forces and in order to reduce its effect measures have to be taken. Similarly the soil conditions in which the building is present also has a greater effect on the structure which has been discussed in detailed below.

Earthquake :

Earthquake can be simply understood as sudden shaking of ground due to the sudden release of energy from rock deformation. These rocks are called Tectonic plates. The crust of the earth is surrounded by large number of very big size rocks called plates they are in continuous motion with one another, due to their collision with one another leads to release of energy which comes to the earth surface in the form of waves.

Seismic zones:

India is divided into four seismic zones as mentioned below

Zone 2: Zone 2is having low seismic intensity since the zone factor is very low and it attracts very less seismic
forces.

Zone 3: Zone 3is having medium seismic intensity since the zone factor is medium and it attracts medium
seismic forces.
Zone 4: Zone 4 is having moderate intensity since the zone factor is moderate and it attracts moderate seismic
forces.
Zone 5: Zone 5 is having severe seismic intensity since the zone factor is high and it attracts very severe seismic
forces.

Vertical Irregularities:
Structures having significant physical dis-continuities in their vertical configuration or in their lateral force resisting systems or bracing system then such structures are termed as vertically irregular structure.In tall structures perfect regularity of a structure is an idealisation but in real the structures are almost irregular. Original forces which act on structures are always more than design forces. Due to seismic forces, extra shear, displacement and torsion is induced on an irregular structure that leads to decrease in overall seismic performance of the structure significantly. In order to get a safe structure and the modelling of the structure should pass all the design checks.

METHODS OF ANALYSIS USED IN SEISMIC DESIGN

- **Equivalent static analysis:**
Design of structures against lateral forces must consider the dynamic effect of forces. But, for simple structures, analysis by linear methods that is (Static) equivalent linear static methods is satisfied. Equivalent linear static method is allowed in most codes of practice for regular, irregular low- to medium-rise and other buildings. It Static equivalent method first step is the estimation of base shear load and the base shear distribution on each story is calculated by using formulas given in IS codes . This method is not suitable for tall structures as it is not convenient to use because in tall structures number of mode shapes are more and this method should not be used.

- **Response spectrum analysis:**
This analysis is suitable for the structures, whose modes other than the fundamental one affect significantly the behaviour of the structure. In response spectrum method the response of multi degree of freedom system is expressed as the superposition of modal response. Here each modal response being determined from the spectral analysis of Single degree of freedom system and then it is combined to compute the total response.

- **Push over analysis:**
In Push over analysis vertical load and lateral load gradually increase on a structure to be considered to study the displacement and damage of the structure. Cyclic behavior and reversal of load is also observed in this method.

  As the name indicates Push – over, the structure is pushed until it achieves its most extreme ability to twist. This method very much helpful in understanding the miss happening and splitting of a structure, if there should arises an occurrence of earthquake and gives a reasonable comprehension of the distortion of structure and arrangement of plastic hinges in the structure.

Pushover analysis is of two types:
- Force controlled
- Displacement controlled.

Model super position method:
The basic stages involved in modal superposition method are as follows:

- Choosing a suitable Design Spectrum selection
- Determine time period and mode shapes.
- After determining the time period, determine the response from the design spectrum for the period of each of the modes considered .
- Calculate the participation of each and every mode corresponding to the single degree of freedom Response.
- Addition of the effects of modes in order obtains combined maximum response.
- Converting combined maximum response obtained into shears and moments.

Objectives of Study:
- To know the behaviour of a Multi-storey RCC residential building subjected to lateral loads (Seismic loading and wind loading).
- To know the effect of Seismic Zone factor on a RCC Residential building by using two types of analysis.
  - Linear Analysis
  - Non-Linear Analysis
- To know the effect of vertical irregularities in building.

Scope of Study:
- In this work study has undertaken to determine the damage of a RCC Residential building under the action of lateral loads.
- The work is done by using Symmetrical bay frame and the analysis has been carried out by using two methods:
  - Static Analysis
  - Dynamic Analysis
- In this study five different models are used having vertical irregularity and their behaviour is studied in different seismic zones.
- The main scope of this study is to determine the behaviour of a tall irregular building in four different zones that is in zone 2 Zone 3, Zone 4 and Zone 5 all these zones are considered in the seismic behaviour of a building.

2. LITERATURE SURVEY

Mohammed Affan, Md. Imtiyaz Qureshi, Syed Farooq Anwar (Nov 2018):
"Comparative study of Static and dynamic analysis of high rise building in different seismic zones and different soil types by E-Tabs" In this paper static and dynamic analysis of multi-storey building in different seismic zones of India with different soil types starting from medium or soft soil to hard or rocky soils is studied. They used E-Tabs software for their analysis. The seismic and wind loading on the building is as per IS codes. After analyzing the building design parameters such as Storey drift, Storey torsion are compared for different zones. It has been concluded that Static analysis gives higher value of all the parameters such as displacement, torsion, drift than dynamic analysis.

RaviKumar, P Raghava, Dr.T.Suresh Babu (April 2017):
"Seismic analysis of tall buildings for different earthquake zones" In this paper Response They analyzed G+20 Building in FEM Software that is E-Tabs. The method of analysis they used is the dynamic method that is Response Spectrum analysis has been carried out on a 90m tall building in various seismic zones and with different wind speed and varying the value of zone factor for each zone. After the analysis of the structure it has been concluded that the behaviour

of the building in Zone 2 is good when compared to other zones. Stability indices value of zone 3 is 170% more than zone 5.

Siva Naveen E, Nimmy Mariam Abraham et al (2018):
"Analysisc f irregular structures under earthquake loads" In this paper the structural behaviour of a multi-storey frame with single irregularity and with multiple irregularities has been studied. The irregularities considered are

- Mass irregularity
- Vertical irregularity
- Tensional Irregularity

It has been observed that frames with single irregularity or with multiple irregularities change their response. The combination of stiffness and vertical irregularity has shown maximum displacement response and the combination of Re-entrant corners and vertical irregularity has shown maximum displacement.

Rakshith G.M, Panender Naik G, et al (2019):
"Analysis of G+20 RCC tall building uses E-Tabs" In this paper the action of lateral loads on a tall building has been studies in different zones. The wind loads on the structure is considered as per IS 1875 Part 3 and seismic loads considered as per IS 1893-2016. Software used for modelling of the structure is E-Tabs. After the analysis of the building the following results have been concluded.

- Base shear of the building increases with increase in Zone factor.
- Storey displacement increases with increase in Zone factor.
- Storey drift increases with increase in Zone.

MV Naveen, KJ Brahma Chari (2016):
"Study on Static and Dynamic analysis of multi-storey building" This paper presents the behaviour of a multi-storey RCC residential building (G+10) in seismic zone 2. In the seismic zone 2 they used importance factor as 0.10, 0.16, 0.21, 0.36 and response reduction factor as 3. The analysis is carried out by using two methods that is equivalent Static and Dynamic methods using E-Tabs. The analysis is done for different zones and the design parameters are studied. It has been concluded that

- Static analysis gives higher displacement values than dynamic analysis
- As the storeys increases, base shear also increases.
- For tall buildings Static analysis is not enough Dynamic analysis also required.

3. Methodology

In this project study has been carried out in four different zones by using different models having vertical irregularity as follows:

- Modelling of High Rise building by using FEM Software E-Tabs.
- Five different models are used having different irregularity.

Model 1: Building is modelled as a symmetrical frame having an offset of 8.35% in X-Direction on each side.
Model 2: Building is modelled as a symmetrical having an offset of 33% in X-Direction on both sides.
Model 3: Building is modelled as a symmetrical having an offset of 66.7% in X-Direction on one side.
Model 4: Building is modelled as a symmetrical having an offset of 16.7% in X-Direction on each side.
Model 5: Building is modelled as a regular symmetrical frame without any offset.

- After modelling the frames, These frames are analyzed by using two different methods,

- Equivalent Static Analysis.
- Pushover Analysis.

- After analysis, behaviour of all the five different models are then studied in different zones by varying the seismic zone factor as per IS 1893-2016.
- Comparison, Interpretation and validation of the results obtained from different types of analysis and for different zones.

Model description

Table 1: Building configuration data

Number of Stories	G+15
Type of Plan	Asymmetrical
Storey Height	3m
Height of Plinth above	1.5m
Concrete Grade	M30
Steel Grade	Fe 500
Beam Sizes	250mm*450mm
Column Sizes	500mm*750mm
Slab Thickness	150mm
Live Load	$2Kn/m^2$
Floor Finish	$1.5Kn/m^2$

Table 2: Wind Load Data

Wind Speed	Zone 2: 33m/s Zone 3: 44m/s Zone 4: 50m/s Zone 5: 55m/s
Terrain Category	*1*
Class of Structure	*B*
Wind Angle	0^0
Windward Co-efficient	*0.80*
Leeward Co-efficient	*0.25*

Table 3: Data for developing the Model in E-Tabs

Importance Factor	1
Response Reduction Factor	5
Seismic Zone Factor	Zone 2: 0.10 Zone 3: 0.16 Zone 4: 0.24 Zone 5: 0.36
Type of Soil	Medium

Table 4: Earthquake load data

Type of Building	Residential

Height of building	45m
Base Dimension	36m
Number of Bays in X-Direction	6
Number of Bays in y-Direction	6

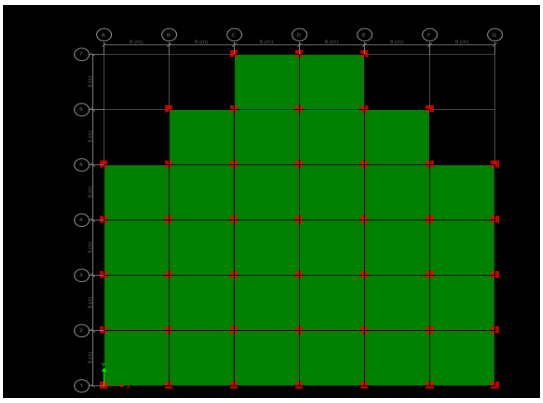


Figure1. Model-1 having an offset of 8.35% in X-Direction

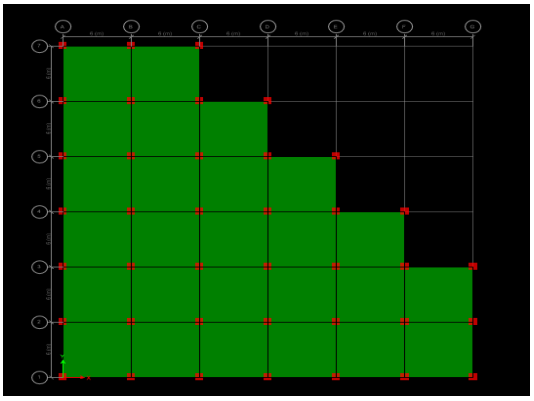


Figure.2. Model-2 having an offset of 33% in X-Direction on both side

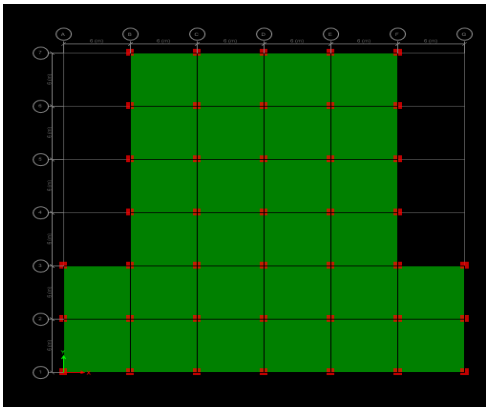


Figure 3. Model-3 having an offset of 66.70% in X-Direction in only one side

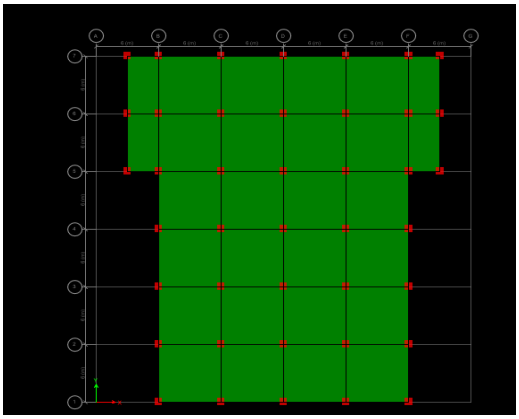


Figure 4. Model-4 having an offset of 16.70% in X-Direction on each side

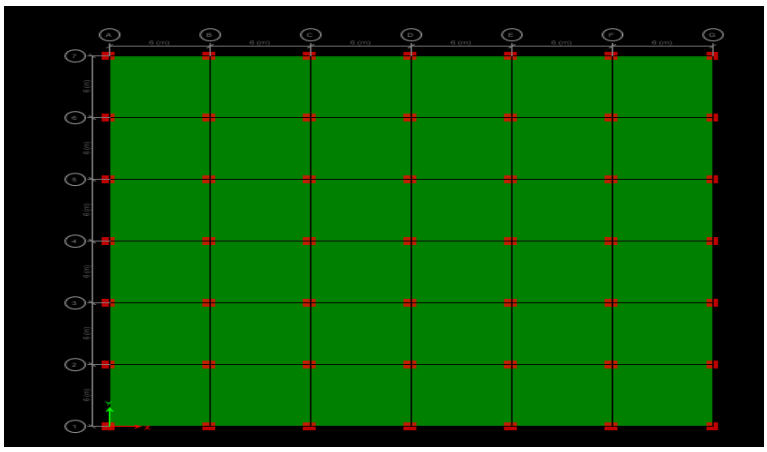


Fig.5. Model-5 Regular Symmetrical Model

Table 5: Displacement for Model-1

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	1.70	2.80	4.100	6.200
Story2	5.60	8.90	13.30	20.00
Story3	10.4	16.7	25.00	37.50
Story4	15.8	16.7	37.80	56.70
Story5	21.3	34.0	51.10	76.60
Story6	26.8	42.9	64.30	96.50
Story7	32.2	51.5	77.30	116.0
Story8	37.4	59.9	89.80	134.7
Story9	42.3	67.7	101.5	152.3
Story10	46.8	74.9	112.4	168.6
Story11	50.9	81.4	122.1	183.1
Story12	54.4	87.0	130.5	195.7
Story13	57.3	91.6	137.4	206.2
Story14	59.5	95.3	142.9	214.3
Story15	61.3	98.0	147.0	220.5

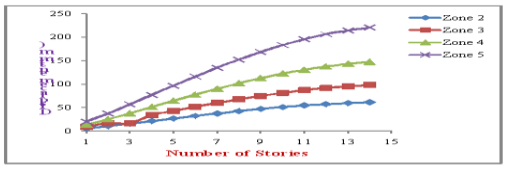


Table 6: Displacement for Model-2

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2.30	3.700	5.500	8.200
Story2	6.40	10.30	15.40	23.10
Story3	11.5	18.40	27.50	41.30
Story4	16.9	18.40	40.70	61.00
Story5	22.5	36.10	54.10	81.20
Story6	28.1	45.00	67.50	101.3
Story7	33.6	53.80	80.60	120.9
Story8	38.8	62.10	93.20	139.8
Story9	43.8	70.00	105.0	157.6
Story10	48.3	77.30	115.9	173.9
Story11	52.4	83.80	125.7	188.5
Story12	55.9	89.40	134.1	201.1
Story13	58.8	94.00	141.0	211.5
Story14	61.0	97.60	146.4	219.6
Story15	62.7	100.4	150.5	225.8

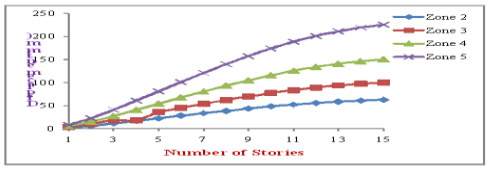


Table 7: Displacement for Model-3

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone4	Zone5
Story1	1.70	2.70	4.100	6.100
Story2	5.60	8.90	13.40	20.00
Story3	10.5	16.8	25.20	37.80
Story4	15.9	16.8	38.20	57.30
Story5	21.6	34.5	51.70	77.60
Story6	27.2	43.5	65.30	97.90
Story7	32.7	52.4	78.60	117.8
Story8	38.0	60.9	91.30	137.0
Story9	43.1	68.9	103.3	155.0
Story10	47.7	76.3	114.4	171.6
Story11	51.8	82.9	124.3	186.5
Story12	55.4	88.6	132.9	199.4
Story13	58.3	93.4	140.0	210.0
Story14	60.7	97.1	145.6	218.4
Story15	62.5	99.9	149.9	224.9

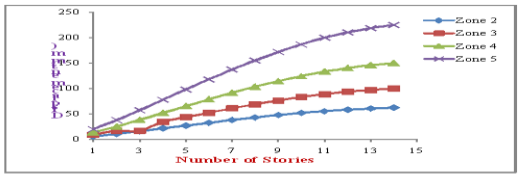


Table 8: Displacement for Model-4

Displacement for Model-4				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2.50	4.00	6.000	9.000
Story2	6.60	10.6	15.80	23.80
Story3	11.6	18.6	27.90	41.90
Story4	17.1	18.6	40.90	61.40
Story5	22.6	36.2	54.30	81.40
Story6	28.1	45.0	67.60	101.3
Story7	33.6	53.7	80.50	120.8
Story8	38.7	62.0	93.00	139.5
Story9	43.6	69.8	104.7	157.1
Story10	48.1	77.0	115.5	173.3
Story11	52.2	83.5	125.2	187.8
Story12	55.6	89.0	133.5	200.3
Story13	58.5	93.6	140.4	210.7
Story14	60.8	97.2	145.9	218.8
Story15	62.5	100	150.0	225.0

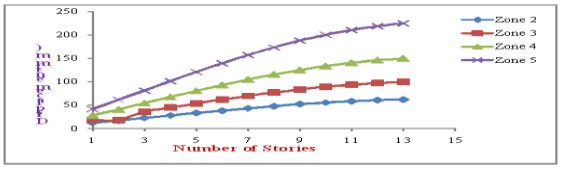


Table 8: Displacement for Model-5

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.1	2.80	4.20	6.300
Story2	0.3	9.00	13.5	20.30
Story3	0.7	16.9	25.4	38.10
Story4	1.1	16.9	38.4	57.60
Story5	1.6	34.6	51.9	77.80
Story6	2.2	43.5	65.3	97.90
Story7	2.7	52.3	78.4	117.6
Story8	3.2	60.7	91.0	136.5
Story9	3.6	68.6	102.9	154.3
Story10	4.0	75.9	113.8	170.7
Story11	4.4	82.4	123.6	185.4
Story12	4.7	88.0	132.0	198.1
Story13	5.0	92.7	139.0	208.5
Story14	5.2	96.3	144.4	216.6
Story15	5.3	99.0	148.5	222.7

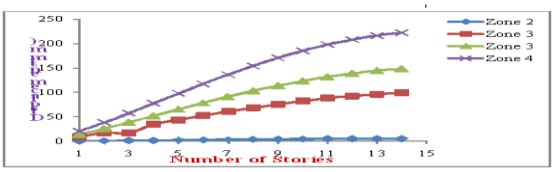


Table 9: Base Shear for all Zones

Base Shear in kN					
Particulars	Model 1	Model 2	Model 3	Model 4	Model 5
Zone 2	3009.1558	3370.4337	2970.7342	3136.42580	3966.3614
Zone 3	4814.6493	5392.6939	4753.1748	5018.28130	6346.1782
Zone 4	7221.9740	8089.0409	7129.7622	7527.42200	8314.2200
Zone 5	10832.961	12133.5613	10694.643	11291.1330	14278.901

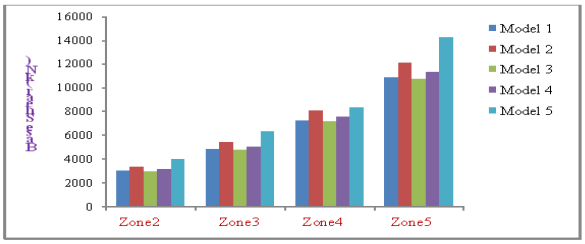


Table 10: Storey Shear of Model-1 for different Zones

Storey Shear in kN				
Particulars	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3009.1558	4814.6493	7221.9740	10832.9610
Story2	3006.6989	4810.7182	7216.0773	10824.1159
Story3	2996.8709	4794.9935	7192.4902	10788.7353
Story4	2974.758	4759.6129	7139.4193	10709.1289
Story5	2935.4463	4696.7140	7045.0710	10567.6065
Story6	2874.0216	4598.4346	6897.6518	10346.4778
Story7	2785.5701	4456.9122	6685.3682	10028.0524
Story8	2665.1778	4264.2844	6396.4267	9594.64000
Story9	2507.9307	4012.6891	6019.0336	9028.55040
Story10	2308.9148	3694.2636	5541.3955	8312.09320
Story11	2063.2162	3301.1458	4951.7188	7427.57820
Story12	1765.9208	2825.4733	4238.2100	6357.31500
Story13	1412.1148	2259.3837	3389.0756	5083.61330
Story14	996.88410	1595.0146	2392.5219	3588.78290
Story15	515.31490	824.50380	1236.7556	1855.13350

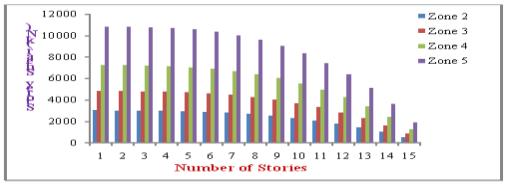


Table 11: Storey Shear of Model-2 for different Zones

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3370.4337	5392.6939	8089.0409	12133.5613
Story2	3367.6839	5388.2942	8082.4413	12123.6620
Story3	3356.6847	5370.6955	8056.0433	12084.0649
Story4	3331.9365	5331.0984	7996.6476	11994.9714
Story5	3287.9397	5260.7036	7891.0553	11836.5830
Story6	3219.1948	5150.7116	7726.0674	11589.1011
Story7	3120.202	4992.3232	7488.4848	11232.7272
Story8	2985.4618	4776.7390	7165.1084	10747.6626
Story9	2809.4747	4495.1595	6742.7393	10114.1090
Story10	2586.7410	4138.7856	6208.1784	9312.26760
Story11	2311.7611	3698.8178	5548.2267	8322.34000
Story12	1979.0355	3166.4567	4749.6851	7124.52760
Story13	1583.0644	2532.9031	3799.3546	5699.03190
Story14	1118.3484	1789.3574	2684.0362	4026.05430
Story15	579.38780	927.0205	1390.5308	2085.79620

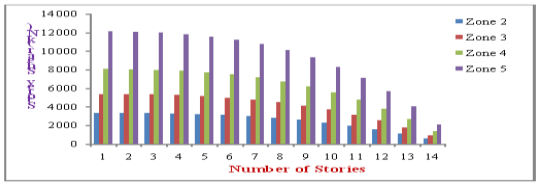


Table 12: Storey Shear of Model-3 for different Zones

Storey Shear in kN				
Number of Stories	Zone 2	Zone 2	Zone 3	Zone 4
Story1	2970.7342	4753.1748	7129.7622	10694.6433
Story2	2968.3097	4749.2956	7123.9433	10685.9150
Story3	2958.6117	4733.7786	7100.6680	10651.0020
Story4	2936.7910	4698.8656	7048.2984	10572.4476
Story5	2897.9987	4636.7980	6955.1969	10432.7954
Story6	2837.3858	4539.8173	6809.7259	10190.0000
Story7	2750.1032	4400.1651	6600.2476	9900.37140
Story8	2631.3018	4210.0829	6315.1244	9472.68660
Story9	2476.1327	3961.8123	5942.7185	8914.07780
Story10	2279.7468	3647.5949	5471.3924	8207.08850
Story11	2037.2951	3259.6721	4889.5082	7334.26230
Story12	1743.9285	2790.2856	4185.4284	6278.14260
Story13	1394.7980	2231.6768	3347.5152	5021.27290
Story14	985.05460	1576.0874	2364.1310	3546.19650
Story15	509.84920	815.75870	1223.6381	1835.45720

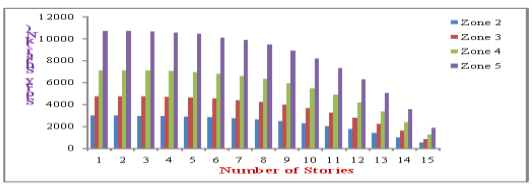


Table 13: Storey Shear of Model-4 for different Zones

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3136.4258	5018.2813	7527.4220	11291.1330
Story2	3133.8662	5014.1859	7521.2789	11281.9184
Story3	3123.6278	4997.8044	7496.7066	11245.0599
Story4	3100.5912	4960.9460	7441.4190	11162.1284
Story5	3059.6374	4895.4199	7343.1298	11014.6947
Story6	2995.6471	4793.0353	7189.5530	10784.3295
Story7	2903.5010	4645.6016	6968.4024	10452.6036
Story8	2778.0799	4444.9279	6667.3918	10001.0877
Story9	2614.2646	4182.8234	6274.2352	9411.35270
Story10	2406.9359	3851.0975	5776.6463	8664.96940
Story11	2150.9746	3441.5593	5162.3390	7743.50850
Story12	1841.2613	2946.0181	4419.0272	6628.54080
Story13	1472.6770	2356.2832	3534.4248	5301.63710
Story14	1040.1023	1664.1636	2496.2455	3744.36820
Story15	538.41800	861.46880	1292.2032	1938.30480

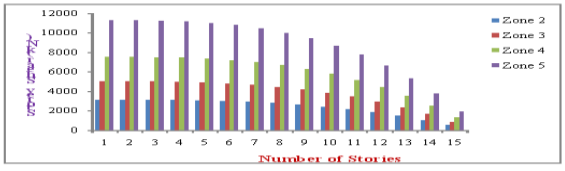


Table 14: Storey Shear of Model-5 for different Zones

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3966.3614	6346.1782	10832.9610	14278.9010
Story2	3963.1293	6341.0070	10824.1159	14267.2656
Story3	3950.1901	6320.3042	10788.7353	14220.6845
Story4	3921.0769	6273.7231	10709.1289	14115.8769
Story5	3869.3201	6190.9122	10567.6065	13929.5523
Story6	3788.4501	6061.5201	10346.4778	13638.4202
Story7	3671.9972	5875.1955	10028.0524	13219.1899
Story8	3513.4919	5621.5870	9594.64000	12648.5709
Story9	3306.4646	5290.3433	9028.55040	11903.2725
Story10	3044.4457	4871.1130	8312.09320	10960.0044
Story11	2720.9655	4353.5448	7427.57820	9795.47570
Story12	2329.5545	3727.2872	6357.31500	8386.39610
Story13	1863.7430	2981.9888	5083.61330	6709.47490
Story14	1317.0615	2107.2984	3588.78290	4741.42150
Story15	683.04040	1092.8646	1855.13350	2458.94540

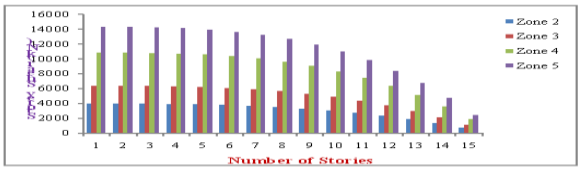


Table 15: Storey Drift of Model-1 for different Zones

Storey Drift				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story2	0.000756	0.001210	0.001815	0.002723
Story3	0.000964	0.001543	0.002314	0.003471
Story4	0.001167	0.001867	0.002800	0.004200
Story5	0.001349	0.002158	0.003238	0.004856
Story6	0.001505	0.002408	0.003612	0.005419
Story7	0.001633	0.002613	0.003920	0.005879
Story8	0.001733	0.002772	0.004158	0.006238
Story9	0.001803	0.002885	0.004327	0.006491
Story10	0.001842	0.002947	0.004420	0.006630
Story11	0.001840	0.002945	0.004417	0.006625
Story12	0.001780	0.002849	0.004273	0.006409
Story13	0.001621	0.002594	0.003891	0.005836
Story14	0.001277	0.002043	0.003065	0.004597
Story15	0.000574	0.000918	0.001377	0.002066

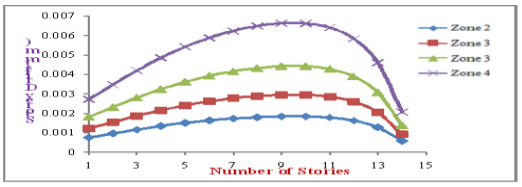


Table 16: Storey drift of Model-2 for different Zones

	Storey Drift in mm			
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.000857	0009130	0.013690	0.002053
Story2	0.000752	0.001203	0.001805	0.002708
Story3	0.000963	0.001540	0.002310	0.003465
Story4	0.001168	0.001869	0.002803	0.004205
Story5	0.001353	0.002165	0.003248	0.004872
Story6	0.001513	0.002420	0.003630	0.005445
Story7	0.001644	0.002630	0.003945	0.005917
Story8	0.001746	0.002794	0.004191	0.006286
Story9	0.001820	0.002912	0.004369	0.006553
Story10	0.001863	0.002981	0.004472	0.006708
Story11	0.001869	0.002990	0.004485	0.006728
Story12	0.001821	0.002913	0.004369	0.006554
Story13	0.001683	0.002692	0.004038	0.006058
Story14	0.001380	0.002209	0.003313	0.004969
Story15	0.000763	0.001220	0.001831	0.002746

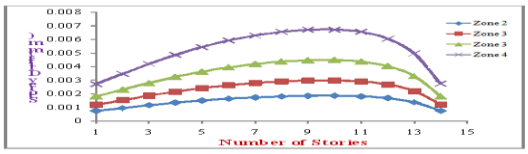


Table 18: Storey drift of Model-4 for different Zones

Storey Drift in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.000574	0.001400	0.001379	0.002068
Story2	0.000751	0.001202	0.001802	0.002703
Story3	0.000958	0.001533	0.002300	0.003450
Story4	0.001161	0.001857	0.002786	0.004179
Story5	0.001343	0.002150	0.003224	0.004836
Story6	0.001500	0.002400	0.003600	0.005401
Story7	0.001629	0.002607	0.003901	0.005865
Story8	0.001730	0.002768	0.004152	0.006228
Story9	0.001803	0.002885	0.004327	0.006490
Story10	0.001846	0.002953	0.004430	0.006644
Story11	0.001852	0.002963	0.004445	0.006668
Story12	0.001808	0.002892	0.004338	0.006508
Story13	0.001680	0.002687	0.004031	0.006046
Story14	0.001396	0.002234	0.003350	0.005026
Story15	0.000832	0.001331	0.001997	0.002995

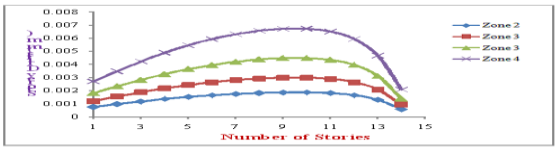


Table 17: Storey Drift of Model-3 for different Zones

Storey Drift in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.000896	0.000777	0.001432	0.002147
Story2	0.000777	0.001244	0.001865	0.002798
Story3	0.000987	0.001580	0.002369	0.003554
Story4	0.001193	0.001909	0.002863	0.004295
Story5	0.001379	0.002206	0.003309	0.004964
Story6	0.001539	0.002462	0.003693	0.005539
Story7	0.001670	0.002671	0.004007	0.006010
Story8	0.001771	0.002834	0.004251	0.006377
Story9	0.001843	0.002948	0.004423	0.006634
Story10	0.001881	0.003010	0.004514	0.006771
Story11	0.001877	0.003003	0.004505	0.006758
Story12	0.001812	0.002899	0.004348	0.006522
Story13	0.001643	0.002629	0.003943	0.005915
Story14	0.001286	0.002057	0.003086	0.004629
Story15	0.000569	0.000910	0.001365	0.002047

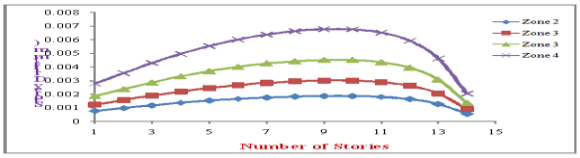


Table 19: Displacement of Model-1

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	1.70	2.80	4.100	6.900
Story2	5.50	8.80	13.10	19.30
Story3	10.2	16.3	24.40	34.20
Story4	15.2	24.4	36.60	50.90
Story5	20.4	32.6	48.90	65.90
Story6	25.4	40.6	60.90	81.40
Story7	30.1	48.2	72.30	96.00
Story8	34.5	55.3	82.90	109.6
Story9	38.6	61.7	92.60	122.0
Story10	42.2	67.4	101.2	132.9
Story11	45.3	72.4	108.6	142.4
Story12	47.8	76.5	114.8	150.2
Story13	49.9	79.8	119.8	156.5
Story14	51.5	82.4	123.5	161.2
Story15	52.7	84.3	126.4	164.8

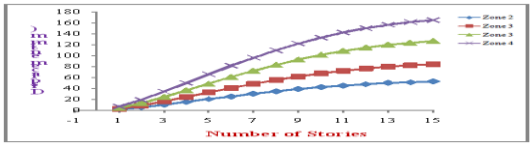


Table 20: Displacement of Model-2

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3.1	3.4	4.6	6.9
Story 2	8.6	8.9	12.9	19.3
Story 3	15.2	15.7	22.8	34.2
Story 4	22.2	22.8	33.4	50
Story 5	29.3	29.9	44	65.9
Story 6	36.2	36.8	54.2	81.4
Story 7	42.7	43.3	64	96
Story 8	48.7	49.4	73.1	109.6
Story 9	54.2	55	81.3	122
Story 10	59.1	59.9	88.6	132.9
Story 11	63.3	64.1	94.9	142.4
Story 12	66.8	67.6	100.2	150.2
Story 13	69.5	70.5	104.3	156.5
Story 14	71.7	72.6	107.5	161.2
Story 15	73.2	74.2	109.9	164.8

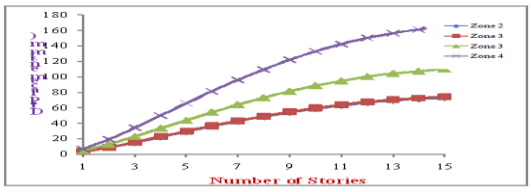


Table 21:Displacement of Model-3

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story 1	1.4	2.3	3.4	5.1
Story 2	4.6	7.4	11	16.6
Story 3	8.6	13.8	20.7	31
Story 4	13	20.8	31.2	46.8
Story 5	17.4	27.9	41.8	62.7
Story 6	21.8	34.8	52.2	78.3
Story 7	25.9	41.4	62.1	93.2
Story 8	29.7	47.5	71.3	107
Story 9	33.2	53.2	79.7	119.6
Story 10	36.3	58.1	87.2	130.8
Story 11	39	62.4	93.7	140.5
Story 12	41.3	66	99.1	148.6
Story 13	43.1	68.9	103.4	155.1
Story 14	44.5	71.2	106.7	160.1
Story 15	45.5	72.8	109.2	163.9

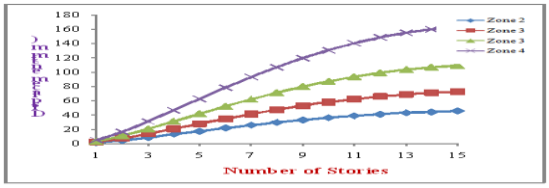


Table 22: Displacement of Model-4

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2.1	3.4	5.1	7.7
Story 2	5.6	8.9	13.4	20.1
Story 3	9.8	15.7	23.5	35.2
Story 4	14.2	22.8	34.1	51.2
Story 5	18.7	29.9	44.8	67.2
Story 6	23	36.8	55.2	82.8
Story 7	27.1	43.3	65	97.5
Story 8	30.9	49.4	74.1	111.2
Story 9	34.3	55	82.4	123.7
Story 10	37.4	59.9	89.8	134.7
Story 11	40.1	64.1	96.2	144.2
Story 12	42.3	67.6	101.5	152.2
Story 13	44	70.5	105.7	158.5
Story 14	45.4	72.6	108.9	163.4
Story 15	46.4	74.2	111.3	167

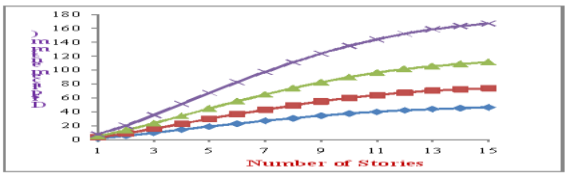


Table 23: Displacement of Model-5

Displacement in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	1.4	2.3	3.4	5.1
Story 2	4.6	7.3	11	16.4
Story 3	8.5	13.6	20.5	30.7
Story 4	12.8	20.5	30.7	46.1
Story 5	17.1	27.4	41.1	61.7
Story 6	21.3	34.1	51.2	76.9
Story 7	25.4	40.6	60.9	91.3
Story 8	29.1	46.5	69.8	104.7
Story 9	32.5	51.9	77.9	116.9
Story 10	35.5	56.7	85.1	127.7
Story 11	38.1	60.9	91.4	137
Story 12	40.2	64.3	96.5	144.8
Story 13	41.9	67.1	100.7	151
Story 14	43.3	69.2	103.8	155.7
Story 15	44.2	70.7	106.1	159.2

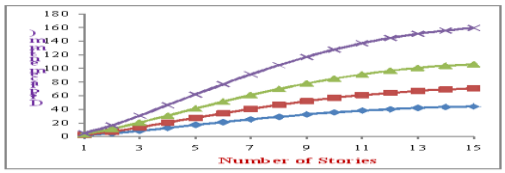


Table 24: Base Shear for all Zones

Base Shear in kN				
Particulars	Model 1	Model 2	Model 3	Model 4
2592.6841	4327.718	2376.585	2525.1022	3177.2876
4148.325	4327.718	3802.5121	4039.8133	5082.0554
6222.4113	6491.7651	5703.7682	6060.4363	7625.4902
6222.4113	9737.5365	8555.727	9091.1321	11438.4359

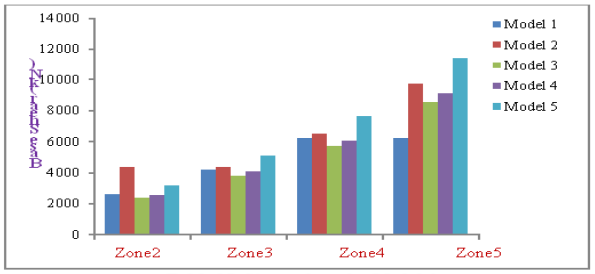


Table 25: Storey shear for Model-1

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2592.684	4148.325	5777.437	6222.411
Story2	2580.013	4128.052	5748.946	6192.002
Story3	2542.878	4068.635	5665.877	6102.878
Story4	2478.95	3966.349	5523.553	5949.45
Story5	2389.174	3822.707	5324.363	5733.99
Story6	2274.339	3638.968	5070.107	5458.386
Story7	2135.28	3416.472	4762.604	5124.646
Story8	1973.691	3157.929	4405.488	4736.836
Story9	1791.258	2866.033	4002.173	4298.998
Story10	1588.683	2541.912	3553.684	3812.821
Story11	1366.531	2186.465	3060.654	3279.658
Story12	1126.255	1802.021	2525.751	2702.998
Story13	868.9607	1390.347	1951.018	2085.495
Story14	593.3918	949.4338	1333.538	1424.133
Story15	296.8776	475.0076	667.6608	712.5027

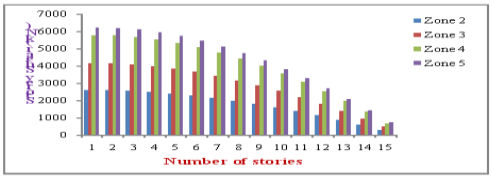


Table 26: Storey shear for Model-2

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	4148.325	4327.718	6491.765	9737.537
Story2	4128.052	4305.756	6458.821	9688.121
Story3	4068.635	4242.718	6364.261	9546.283
Story4	3966.349	4135.017	6202.706	9303.952
Story5	3822.707	3984.316	5976.648	8964.869
Story6	3638.968	3791.964	5688.111	8532.069
Story7	3416.472	3559.408	5339.267	8008.809
Story8	3157.929	3289.491	4934.379	7401.484
Story9	2866.033	2984.993	4477.619	6716.352
Story10	2541.912	2647.083	3970.739	5956.04
Story11	2186.465	2276.725	3415.186	5122.721
Story12	1802.021	1876.347	2814.602	4221.854
Story13	1390.347	1447.769	2171.716	3257.537
Story14	949.4338	988.9517	1483.471	2225.18
Story15	475.0076	495.6367	743.4766	1115.202

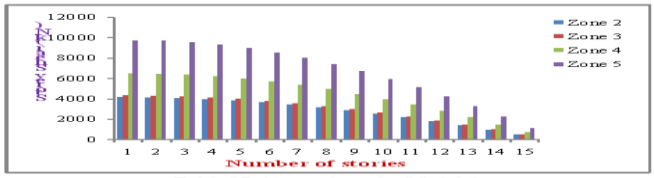


Table 27: Storey shear for Model-3

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2376.585	3802.512	5703.768	8555.727
Story2	2365.863	3785.356	5678.034	8517.126
Story3	2332.872	3732.572	5598.858	8398.360
Story4	2275.190	3640.281	5460.422	8190.704
Story5	2193.655	3509.827	5264.740	7897.179
Story6	2088.999	3342.377	5013.566	7520.415
Story7	1961.955	3139.108	4708.663	7063.056
Story8	1814.068	2902.490	4353.735	6530.659
Story9	1646.915	2635.048	3952.572	5928.909
Story10	1461.157	2337.837	3506.756	5260.180
Story11	1257.286	2011.645	3017.468	4526.241
Story12	1036.634	1658.604	2487.905	3731.891
Story13	800.2434	1280.381	1920.572	2880.883
Story14	546.9353	875.091	1312.637	1968.972
Story15	274.1421	438.6246	657.9368	986.9139

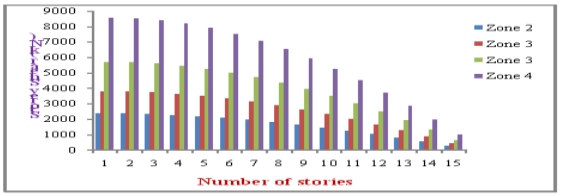


Table 28: Storey shear for Model-4

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	2525.102	4039.813	6060.436	9091.132
Story2	2512.321	4019.366	6029.761	9045.117
Story3	2475.598	3960.614	5941.623	8912.903
Story4	2412.851	3860.226	5791.024	8686.992
Story5	2325.033	3719.73	5580.254	8370.821
Story6	2212.917	3540.36	5311.168	7967.171
Story7	2077.337	3323.451	4985.765	7479.041
Story8	1919.943	3071.642	4608.008	6912.375
Story9	1742.352	2787.521	4181.776	6272.994
Story10	1545.235	2472.161	3708.68	5563.313
Story11	1329.142	2126.443	3190.041	4785.313
Story12	1095.48	1752.615	2629.234	3944.058
Story13	845.3001	1352.363	2028.784	3043.336
Story14	577.3895	923.7432	1385.779	2078.777
Story15	289.213	462.7007	694.1332	1041.255

Table 29: Storey shear for Model-5

Storey Shear in kN				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	3177.288	5082.055	7625.49	11438.44
Story2	3162.921	5059.076	7591.011	11386.72
Story3	3118.744	4988.415	7484.985	11227.68
Story4	3041.511	4864.882	7299.627	10949.63
Story5	2932.343	4690.268	7037.624	10556.62
Story6	2792.235	4466.165	6701.363	10052.22
Story7	2622.193	4194.185	6293.264	9440.062
Story8	2424.298	3877.653	5818.315	8727.626
Story9	2200.672	3519.965	5281.614	7922.56
Story10	1952.228	3122.579	4685.347	7028.144
Story11	1679.657	2686.603	4031.177	6046.872
Story12	1384.766	2214.926	3323.437	4985.243
Story13	1068.976	1709.822	2565.543	3848.382
Story14	730.7851	1168.887	1753.884	2630.873
Story15	366.8768	586.8175	880.5042	1320.78

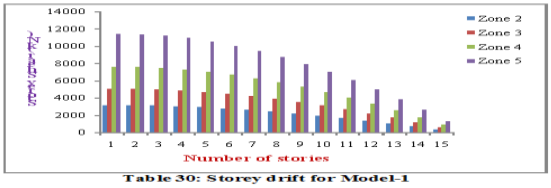


Table 30: Storey drift for Model-1

Storey Drift in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.000574	0.000918	0.001377	0.002309
Story2	0.001250	0.002000	0.003000	0.004126
Story3	0.001565	0.002504	0.003756	0.004967
Story4	0.00169	0.002705	0.004057	0.005283
Story5	0.001711	0.002738	0.004107	0.005309
Story6	0.001671	0.002674	0.004011	0.005162
Story7	0.001592	0.002547	0.00382	0.004901
Story8	0.001484	0.002375	0.003563	0.004560
Story9	0.001356	0.002170	0.003255	0.004157
Story10	0.001211	0.001937	0.002906	0.003703
Story11	0.001051	0.001682	0.002523	0.003208
Story12	0.000882	0.001412	0.002117	0.002685
Story13	0.00071	0.001135	0.001703	0.002152
Story14	0.000545	0.000871	0.001307	0.001645
Story15	0.00041	0.000656	0.000984	0.001231

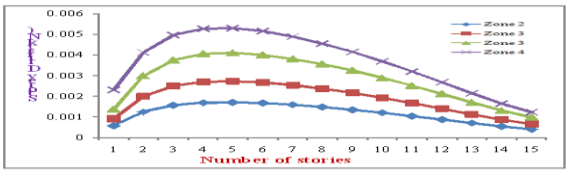


Table 31: Storey drift for Model-2

Storey Drift in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.001026	0.001377	0.00154	0.002309
Story2	0.001834	0.003	0.002751	0.004126
Story3	0.002207	0.003756	0.003311	0.004967
Story4	0.002348	0.004057	0.003522	0.005283
Story5	0.00236	0.004107	0.00354	0.005309
Story6	0.002294	0.004011	0.003441	0.005162
Story7	0.002178	0.00382	0.003268	0.004901
Story8	0.002027	0.003563	0.00304	0.00456
Story9	0.001848	0.003255	0.002771	0.004157
Story10	0.001646	0.002906	0.002469	0.003703
Story11	0.001426	0.002523	0.002139	0.003208
Story12	0.001193	0.002117	0.00179	0.002685
Story13	0.000957	0.001703	0.001435	0.002152
Story14	0.000731	0.001307	0.001096	0.001645
Story15	0.000547	0.000984	0.000821	0.001231

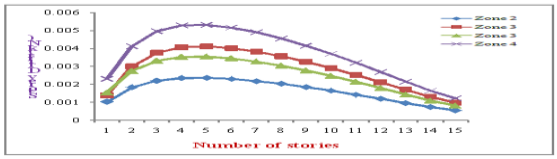
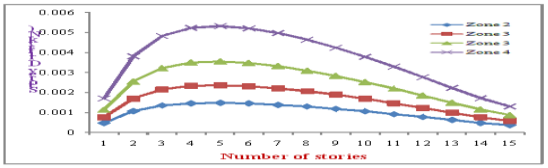


Table 32: Storey drift for Model-3

Storey Drift in mm				
Number of Stories	Zone 2	Zone 3	Zone 4	Zone 5
Story1	0.000472	0.000755	0.001133	0.001699
Story2	0.001061	0.001697	0.002546	0.003819
Story3	0.001341	0.002146	0.003218	0.004828
Story4	0.001456	0.002330	0.003495	0.005242
Story5	0.001479	0.002367	0.003550	0.005325
Story6	0.001447	0.002316	0.003474	0.005210
Story7	0.001380	0.002208	0.003313	0.004969
Story8	0.001288	0.002061	0.003092	0.004638
Story9	0.001178	0.001884	0.002826	0.004240
Story10	0.001052	0.001683	0.002524	0.003786
Story11	0.000914	0.001462	0.002193	0.003290
Story12	0.000768	0.001228	0.001842	0.002763
Story13	0.000619	0.000990	0.001485	0.002227
Story14	0.000477	0.000763	0.001145	0.001717
Story15	0.000362	0.000579	0.000869	0.001303



5. CONCLUSION

Lateral Displacement

- Maximum Lateral displacement occurs at the top storey and minimum at the bottom storey.

- Lateral Displacement increases with increase in Zone. From the analysis it has been found that there is a 40% increase in lateral displacement from zone-2 to zone-5.
- As the height of the structure increases, Lateral displacement also increases.
- The displacement obtained from linear analysis is 70% higher when compared to the displacement obtained from the Non-Linear analysis. Hence we can conclude that for tall buildings Non linear methods of analysis holds good this gives lower value of all the parameters hence the percentage of steel used in construction can be reduced.
- From the analysis it has been noticed that minimum value of displacement is seen in regular model (Model-5) without any irregularity hence it can be concluded the presence of irregularity in a building greatly increases the lateral displacement.

Base Shear

- Base Shear obtained for zone-2 to zone-5 is maximum for Equivalent static Analysis when compared to Pushover analysis. From the analysis it has been observed that static analysis gives 36% more base shear than pushover analysis.
- Base Shear of a building increases as the zone factor increases. For the same building base shear in Zone-2 is 3966.36 KN and in Zone-5 are 14278.9 which show that base shear increases by 30%.
- From the results it has been observed that minimum value of Base Shear is observed in Model-3 having an irregularity of 66.7% and maximum base shear is observed Model-5 in regular model.

Storey Shear

- Storey shear obtained from static analysis is 40% more when compared to the storey shear obtained from pushover analysis.
- Increase in zone factor increases the storey shear. From Zone-2 to Zone-5 there is an increase of 42% in storey shear.
- From the results it has been observed that minimum storey shear is seen in Model-3 and maximum storey shear is seen in Model-5

Storey Drift

- As we compare Zone II and Zone V, storey drift is higher in Zone V when compared to Zone II.
- Storey drift is greatly influenced by the presence of irregularity. It was found that model 3 showed least storey drift, whereas model 5(showed maximum storey drift.
- The results are within the permissible limit as per the Indian standard code IS 1893:2016 (clause 7.11.1).
- The value of storey drift obtained for static analysis was found to be more than thecstorey drift obtained from push over analysis for all the five models.

6. Results

Equivalant Static Analysis

Pushover analysis

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