

Effect of Variable Storey Height in RC Space Frames Subjected to Seismic Load

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ABSTRACT: In present scenario many buildings have irregular configuration both in plan and elevation. This in future may subject to devastating earthquakes. In case, it is necessary to identify the performance of the structures to withstand against disaster. Structures experience lateral deflections under earthquake loads. In the present study, an attempt is made to understand the influence of stiffness irregularity on response of a G+14 storeyed reinforced concrete framed structure subjected to seismic loading in accordance to IS-1893:2002(part-1). Linear seismic analysis is done for the building by static method (seismic coefficient method) and dynamic method (response spectrum method) using STAAD Pro. Three RC frame structures are considered in the analysis, two structures having stiffness irregularity in different storeys i.e, 4th and 8th storeys of the structure. The results of the deflection, shear force, bending moment and axial forces are observed, compared and summarized for beams, columns of the structure. From results obtained from STAAD Pro it is concluded that, presence of storey with increased storey height at lower storey's levels leads to more damage under seismic load.

KEYWORDS: Bending moment, Shear force, Deflection, Stiffness irregularity, seismic analysis.

I. INTRODUCTION

Earthquake is one of the dangerous and life threatening natural disaster which can come anytime and anywhere on the earth. It has been found that regular shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. The destructive effects of an earthquake can be classified into primary and secondary effects.

Primary effects are the immediate damage caused by the quake, such as collapsing buildings, roads and bridges, which may kill many people. The inertia of the building can cause shearing of the structure which can concentrate stresses on the weak walls or joints in the structure resulting in failure or perhaps total collapse.

Secondary effects are the after-effects of the earthquake, such as fires, tsunamis, landslides and disease. The two most important elements of concern to structural engineer are calculation of seismic design forces and the means of providing sufficient ductility. The seismic analysis and design procedures to be used in the design of building structures. Earthquake loads are inertia forces related to the mass, stiffness, and energy absorbing (damping and ductility) characteristics of the structure. The design ground motions shall be assumed to occur along any horizontal direction of a building structure. There have been several studies on the irregularities, viz., (Jack P. Moehle, A. M. ASCE 2002), Seismic behaviour of Vertically Irregular Structures, seismic response of vertically irregular frames with pushover analysis (Chintanapadke and Chopra 2004) and Effect of vertical Irregularity in RC Framed Buildings in Severe Seismic Zone (S Monish and S Karuna 2015),

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II.SCOPE AND OBJECTIVES

1. The main objective of the thesis is to study the response of multi-storey building with stiffness irregularity subjected to seismic load.
2. To calculate the design lateral forces of regular and irregular buildings using seismic coefficient method and response spectrum analysis and to compare the results of different structures.
3. To analyse the building as per code IS-1893-2002-(part-1) criteria for earthquake resistant structure .
4. Static analysis of building using Seismic coefficient method and Dynamic analysis of building using Response Spectrum method is used.
5. Bending moment, shear force and deflection of stiffness irregular structure are compared with the regular structure.

III. METHODOLOGY

Seismic analysis is a part of structural analysis and a part of structural design where earthquake is prevalent. There are different types of earthquake analysis methods to analyse structure for dynamic loading conditions. This includes following:

- 1) Seismic coefficient method,
- 2) Response spectrum method,
- 3) Pushover analysis method,
- 4) Time history analysis method

For the Present study seismic coefficient method Response spectrum method describes in IS 1893(Part 1): 2002 is adopted.

Seismic Coefficient Method

All design against seismic loads must consider the dynamic nature of the load . However, for simple regular structures analysis by equivalent linear static methods is often sufficient .This is permitted in most codes of practice for regular , low-to medium rise buildings .it begins with the estimation of base shear load and in distribution on each story calculated by using formulas given in the code.

Response Spectrum Method

The representation of the maximum response of idealized single degree freedom system having certain period and damping , during earthquake ground motions. The method is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. The maximum response plotted against un-damped natural period and for various damping values and can be expressed in terms of maximum absolute acceleration , maximum relative velocity or maximum relative displacement.

IV. MODELLING

Three models have been analyzed using Seismic coefficient method and Response spectrum method of IS 1893-part 1: 2002 assuming Preliminary data as Location of Structure in seismic zone IV, with soil type medium soil , effective damping 5% and importance factor 1.0. Analysis has been carried out using STAADPro software. Configuration of models is as given below and typical layout is shown in Fig.1.

MODEL-1: This is the base model of structure having G+14 storeys, with a storey height of 3.0m.

MODEL-2: This frame consists of increase in height of the column on fourth floor introduced in model-1.

MODEL-3: This frame consists of increase in height of the column on eighth floor introduced in model-1.

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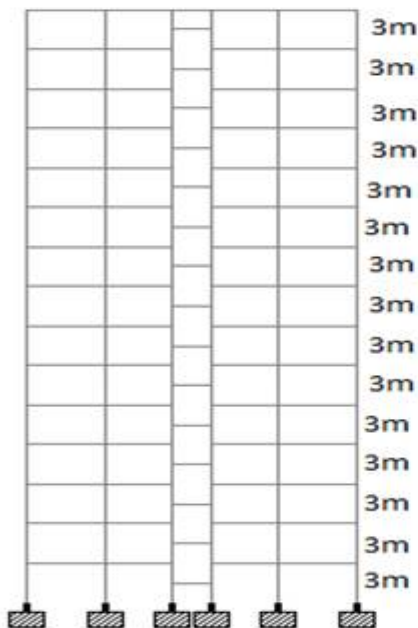
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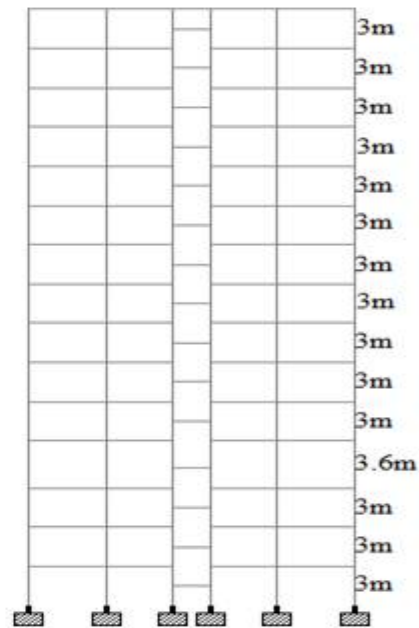
Table 1: Design data of RCC frame structure

S.NO	PARTICULARS	DIMENSION/SIZE/VALUE
1	Model	G+14
2	Seismic zone	IV
3	Zone factor	0.24
4	Importance factor	1.0
5	Response reduction factor	3.0
6	Floor height	3 m
7	Plan size	17m x 28 m
8	Size of columns	0.23mx 0.60m
9	Size of beams	0.23m x 0.45m
10	Walls	1) External wall =0.23 m 2) Internal wall =0.115 m 3)Parapet wall=0.15m
11	Thickness of slab	150 mm
12	Ttype of soil	Type-II, medium soil as per IS-1893:2002
13	Material used	Concrete M-20
14	Static analysis Dynamic analysis	<ul style="list-style-type: none"> • Seismic coefficient method • Response spectrum method
15	Software used	STAADPro for static analysis and dynamic analysis

REGULAR AND STIFFNESS IRREGULAR STRUCTURES



Model-1 : Regular Building

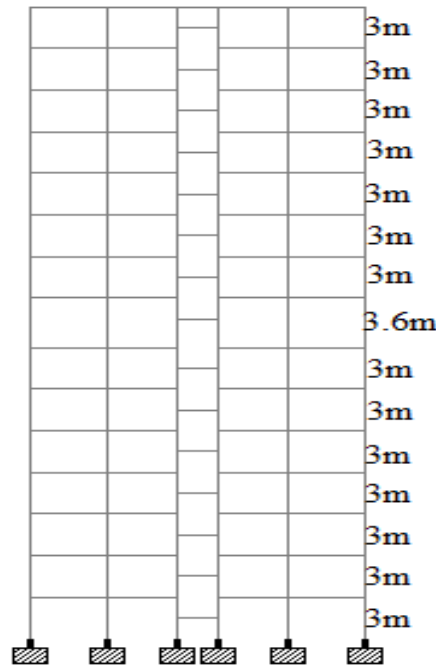


Model-2: Stiffness irregularity at 4th floor

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Model-3:Stiffness irregularity at 8th floor

Fig 1 Elevation of buildings

V. ANALYSIS RESULTS

Three RC frame structures have been analyzed and responses like bending moment, shear force and deflection have been computed to study the effects of stiffness irregularity on the regular frame structure . The results are presented and discussed hereafter.

TABLE 2: MAXIMUM BENDING MOMENT OF A COLUMN AT DIFFERENT FLOORS BY STATIC ANALYSIS

To understand the Maximum bending moment behaviour of a column at different floors in regular and vertically irregular building is studied by static analysis.From Fig 2, it is observed that, bending moment of a column in 4th storey of model-2 is more by 41.7% when compared to model-1 and bending moment of a column in 8th storey of model-3 is more by 37.81% when compared to model-1 .

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Storey No	Column No	Model 1 (kN-m)	Model 2 (kN-m)	Model 3 (kN-m)
15	774	60.904	60.34	60.266
14	732	102.223	101.099	101.45
13	690	116.302	114.99	115.462
12	648	127.837	126.445	127.021
11	606	136.772	135.364	136.064
10	564	143.795	142.411	143.656
9	522	149.133	147.823	152.93
8	480	152.999	151.808	210.853
7	438	155.475	154.472	145.23
6	396	156.982	156.702	153.423
5	354	157.373	161.802	155.722
4	312	156.199	221.399	154.909
3	270	158.665	163.171	157.71
2	228	150.016	150.907	150.113
1	186	165.675	164.111	162.883

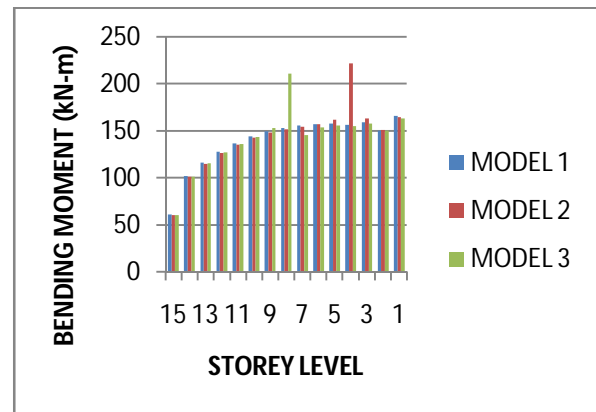


Fig 2:Bending moment of a column by static analysis

TABLE 3: MAXIMUM BENDING MOMENT OF A COLUMN AT DIFFERENT FLOORS BY DYNAMIC ANALYSIS

To understand the Maximum bending moment behaviour of a column at different floors in regular and vertically irregular building is studied by static analysis. From Fig 3, it is observed that, bending moment of a column in 4th storey of model-2 is more by 43.26% when compared to model-1 and bending moment of a column in 8th storey of model-3 is more by 39.5% when compared to model-1.

Storey No	Column No	Model 1 (kN-m)	Model 2 (kN-m)	Model 3 (kN-m)
15	774	61.298	60.486	60.412
14	732	119.365	117.878	118.329
13	690	137.026	135.315	135.915
12	648	151.458	149.651	150.381
11	606	162.762	160.931	161.813
10	564	171.689	169.894	171.448
9	522	178.539	176.837	183.35
8	480	183.58	182.027	256.079
7	438	186.917	185.596	186.88
6	396	189.076	188.651	177.657
5	354	189.875	195.42	187.812
4	312	188.753	270.4	187.142
3	270	192.427	198.138	191.234
2	228	182.676	182.536	181.548
1	186	193.942	191.988	191.708

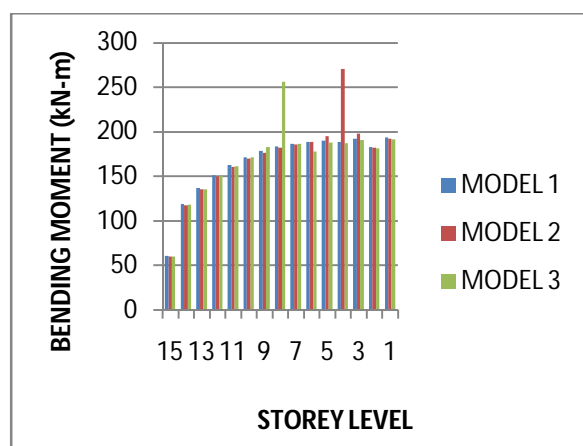


Fig 3:Bending moment of a column by dynamic analysis

TABLE 4 MAXIMUM SHEAR FORCE OF A COLUMN AT DIFFERENT FLOORS BY STATIC ANALYSIS

To understand the Maximum shear force behaviour of a column at different floors in regular and vertically irregular building is studied by static analysis. From Fig4, it is observed that, shear force of a column in 4th storey of model-2 is

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more by 18.35% when compared to model-1 and shear force of a column in 8th storey of model-3 is more by 17.808% when compared to model-1 .

Storey No	Column No	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)
15	774	24.459	24.324	24.206
14	732	46.174	45.736	45.811
13	690	58.163	57.538	57.704
12	648	68.592	67.837	68.073
11	606	77.281	76.438	76.649
10	564	84.51	83.617	83.431
9	522	90.441	89.531	79.519
8	480	95.148	94.245	112.092
7	438	98.806	97.836	87.532
6	396	101.602	100.150	100.434
5	354	103.684	91.315	102.913
4	312	103.797	122.850	103.084
3	270	103.365	90.997	102.645
2	228	99.512	98.239	98.858
1	186	114.843	113.265	113.681

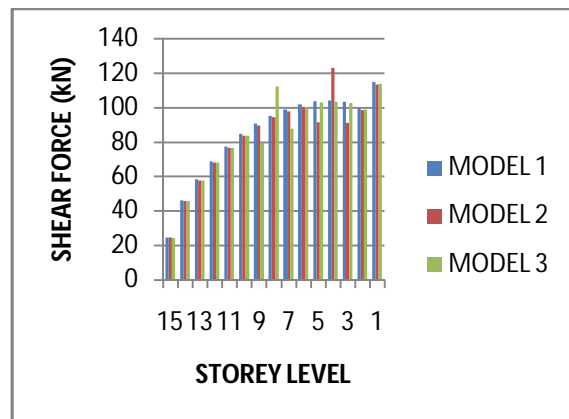


Fig 4: Shear force of a column by static analysis

TABLE 5: MAXIMUM SHEAR FORCE IN A COLUMN AT DIFFERENT FLOORS BY DYNAMIC ANALYSIS

To understand the Maximum shear force behaviour of a column at different floors in regular and vertically irregular building is studied by dynamic analysis. From Fig 5, it is observed that, shear force of a column in 4th storey of model-2 is more by 19.61% when compared to model-1 and shear force of a column in 8th storey of model-3 is more by 18.43% when compared to model-1.

Storey No	Column No	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)
15	774	22.62	22.393	22.255
14	732	51.988	51.385	51.487
13	690	67.1	66.269	66.483
12	648	80.187	79.197	79.499
11	606	91.144	90.045	90.315
10	564	100.296	99.13	98.877
9	522	107.831	106.651	94.147
8	480	113.862	112.69	135.988
7	438	118.603	117.346	104.518
6	396	122.288	120.409	120.8
5	354	125.105	109.587	124.14
4	312	125.487	150.102	124.596
3	270	125.197	109.737	124.297
2	228	120.509	118.875	119.666
1	186	129.322	127.354	127.874

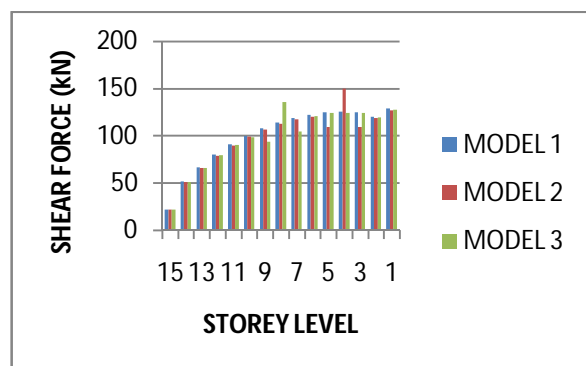


Fig 5: Shear force of a column by dynamic analysis

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TABLE 6: MAXIMUM DEFLECTION OF A COLUMN AT DIFFERENT FLOORS BY STATIC ANALYSIS

To understand the Maximum deflection behaviour of a column at different floors in regular and vertically irregular building is studied by static analysis. From Fig 6, it is observed that, deflection of a column 4th storey of model-2 is more by 10.23% when compared to model-1 and deflection of a column in 8th storey of model-3 is more by 4.587% when compared to model-1.

Storey No	Column No	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)
15	774	368.062	380.785	380.611
14	732	360.837	373.558	373.356
13	690	348.894	361.672	361.42
12	648	332.752	345.632	345.314
11	606	313.106	326.127	325.735
10	564	290.576	303.763	303.303
9	522	265.726	279.1	278.602
8	480	239.079	252.649	251.794
7	438	211.109	224.886	209.815
6	396	182.258	196.251	180.847
5	354	152.928	167.167	151.748
4	312	123.5	137.628	122.536
3	270	94.337	93.612	93.59
2	228	65.828	65.069	65.293
1	186	38.25	37.815	37.937

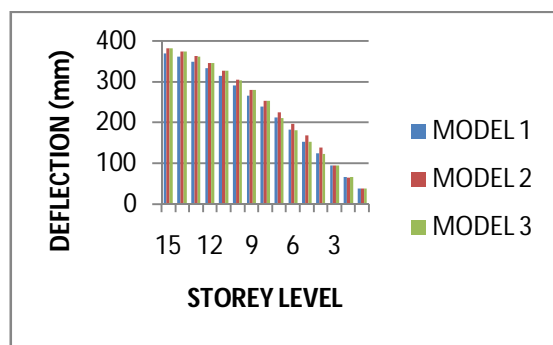


Fig 6 :Maximum deflection of a column by static analysis

TABLE 7: MAXIMUM DEFLECTION OF A COLUMN AT DIFFERENT FLOORS BY DYNAMIC ANALYSIS

To understand the Maximum deflection behaviour of a column at different floors in regular and vertically irregular building is studied by dynamic analysis. From Fig 7, it is observed that, deflection of column in 4th storey of model-2 is more by 11.44% when compared to model-1 and deflection of column in 8th storey of model-3 is more by 5.736% when compared to model-1.

Storey No	Column No	Model 1 (mm)	Model 2 (mm)	Model 3 (mm)
15	774	381.382	394.333	393.987
14	732	374.26	387.241	386.842
13	690	362.973	376.047	375.568
12	648	347.364	360.595	360.002
11	606	328.008	341.435	340.701
10	564	305.479	319.13	318.218
9	522	280.325	294.215	293.017
8	480	253.053	267.183	274.663
7	438	224.129	238.519	224.147
6	396	193.979	208.519	193.908
5	354	162.984	177.578	161.931
4	312	131.506	144.966	130.601
3	270	99.875	100.656	99.758
2	228	68.452	68.130	67.948
1	186	37.443	37.201	37.161

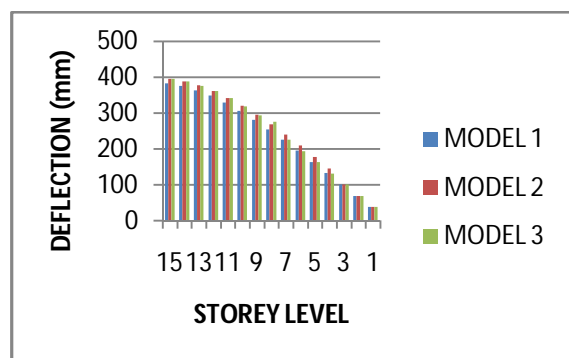


Fig7:Maximum deflection of a column by dynamic analysis

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TABLE 8: MAXIMUM BENDING MOMENT OF A BEAM AT DIFFERENT FLOORS BY DYNAMIC ANALYSIS

To understand the Maximum bending moment behaviour of a beam at different floors in regular and vertically irregular building is studied by dynamic analysis. From Fig, it is observed that, bending moment of beam in 4th storey of model-2 is more by 7.69% when compared to model-1 and bending moment of beam in 8th storey of model-3 is more by 7.89% when compared to model-1.

Storey No	Beam No	Model 1 (kN-m)	Model 2 (kN-m)	Model 3 (kN-m)
15	1814	63.063	62.32	62.25
14	1778	127.5	126.171	126.301
13	1742	174.135	172.124	172.589
12	1706	215.864	213.29	214.079
11	1670	251.829	248.844	249.966
10	1634	282.235	278.988	280.672
9	1598	307.553	304.178	308.88
8	1562	328.271	324.901	354.191
7	1526	344.882	341.67	371.979
6	1490	357.855	355.2	359.285
5	1454	367.578	368.458	365.755
4	1418	374.187	402.974	371.808
3	1382	371.017	400.406	368.464
2	1346	371.586	373.053	368.992
1	1310	370.829	368.923	368.259

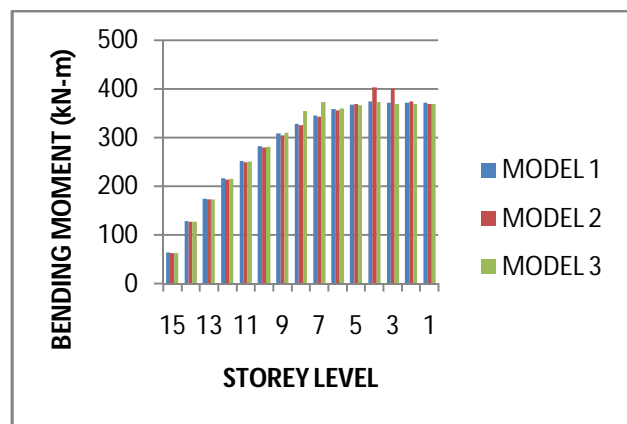


Fig 8: Maximum bending moment of a beam by dynamic analysis

TABLE 9: MAXIMUM SHEAR FORCE OF A BEAM AT DIFFERENT FLOORS BY DYNAMIC ANALYSIS

To understand the Maximum shear force behaviour of a beam at different floors in regular and vertically irregular building is studied by dynamic analysis. From Fig, it is observed that, shear force of beam in 4th storey of model-2 is more by 4.65% when compared to model-1 and shear force of beam in 8th storey of model-3 is more by 4.78% when compared to model-1.

Storey No	Beam No	Model 1 (kN)	Model 2 (kN)	Model 3 (kN)
15	1814	51.769	51.476	51.426
14	1778	99.962	99.472	99.491
13	1742	115.601	114.88	115.011
12	1706	129.783	128.87	129.111
11	1670	142.018	140.963	141.32
10	1634	152.382	151.235	151.786
9	1598	161.033	159.841	161.626
8	1562	168.149	166.956	175.891
7	1526	173.872	172.731	181.991
6	1490	178.403	177.45	179.066
5	1454	181.847	182.327	181.194
4	1418	184.295	192.879	183.46
3	1382	176.651	185.469	175.761
2	1346	177.207	177.931	176.308
1	1310	175.956	175.312	175.083

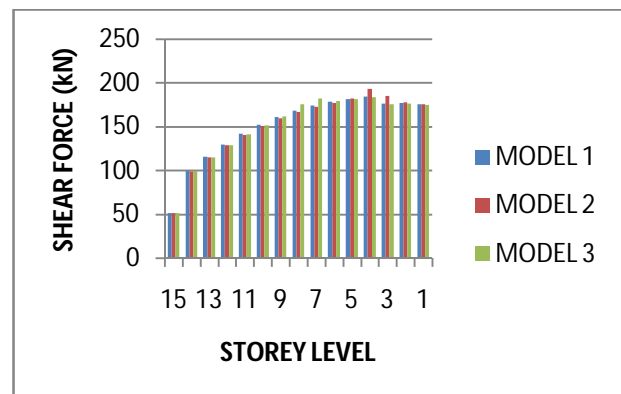


Fig 9: Maximum shear force of a beam by dynamic analysis

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VI. CONCLUSIONS

Studied the behaviour of R.C framed structures with and without stiffness irregularities subjected to seismic loading. Structures are analysed by linear static and dynamic method. The following conclusions are drawn from the study.

1. For columns in considered R.C frames, it is observed that there is an increase in bending moment 43.26% in 4th storey of model-2 and 39.5% in 8th storey of model-3 when compared to model-1.
2. For columns in considered R.C frames, it is observed that there is an increase in shear force of 19.61% in 4th storey of model-2 and 18.43% in 8th storey of model-3 when compared to model-1.
3. For columns in considered R.C frames, it is observed that there is an increase in deflection of 11.44% in 4th storey of model-2 and 5.76% in 8th storey of model-3 when compared to model-1.
4. For beams in considered R.C frames, it is observed that there is an increase in bending moment of 7.69% in 4th storey of model-2 and 7.89% in 8th storey of model-3 when compared to model-1.
5. For beams in considered R.C frames, it is observed that there is an increase in shear force of 4.65% in 4th storey of model-2 and 4.78% in 4th storey of model-3 when compared to model-1.
6. When regular building is compared with other stiffness irregular buildings the bending moment, shear force and deflection is less in regular building.
7. Values obtained for dynamic analysis is higher than the values obtained for static analysis.
8. Based on the results of shear force, bending moment and deflection of columns, model-2 is most vulnerable condition than model-3.
9. From this study, it is concluded that presence of storey with increased storey height at lower storey's levels leads to more damage under seismic load.

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