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Comparative Study for Seismic Analysis of Symmetrical and Asymmetrical Buildings with Heavy Loads

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ABSTRACT

Due to rapid urbanization, there is substantial increase in population in hilly areas. Many urban centers have come up in the hills in last decade attracting lot of peoples thereby increasing the population and business activities. Demand of multi storied RCC framed buildings have grown manifold due to shortage of land in these urban centers. Buildings constructed on sloping hilly areas behave distinctively different than the buildings constructed on plain ground. Buildings constructed on sloping grounds steps back at each floor, thus making it unsymmetrical geometry. Moreover foundations of building on hilly areas are supported at different levels leading to varying heights of columns. Shorter columns are stiffer hence attracts more forces and susceptible to more damages under the action of seismic forces.

Most of the commercial buildings constructed are loaded with 4 to 5 kN/m^2 as the normal imposed loads. But in case of some special types of buildings such as Data Centre the imposed load could be as high as 8 to 15 kN/m.^{2} Data Centre buildings are special type of buildings whose purpose is to provide the dedicated space for storage of data thus it contains various components of I.T & telecommunication systems. In this Study, symmetrical buildings on Plain ground under the action of normal loading as well as heavy loading is compared to the asymmetrical buildings on hilly ground under the action of normal loading and heavy loading. Effect of varying height of columns, infill walls & heavy loading are studied. Seismic analysis is done using linear dynamic (response spectrum method) as well as nonlinear static procedure (pushover) has been performed. 3D analytical models for symmetrical and asymmetrical buildings are generated by keeping the geometrical configuration same for both normal and heavy loads. Symmetrical buildings behave differently than the asymmetrical buildings.

Keywords: Data centre, Heavy Loads, Non Linear Analysis, Pushover Analysis, Seismic design.

I. INTRODUCTION

Hilly regions of India have seen rapid urbanization in recent years, which have created clusters of urban centres and resulted in increase in the business activities on one hand and shortage of space on the other hand. Demand of multi storied RCC framed buildings have grown manifold due to shortage of land in these urban centers.

Buildings constructed on sloping hilly areas behave distinctively different than those constructed on plain ground. Mostly of the buildings which are constructed on the hilly areas step back towards hills at different levels which makes it highly irregular and asymmetrical in nature. At the location of step back, there exists stress concentration under the seismic loading. The foundations of these buildings are supported on different levels of the natural sloping ground which leads to varying heights of columns. Shorter columns are stiffer hence attracts more forces and susceptible to more damages under the action of seismic forces. Buildings Asymmetrical in nature and constructed on sloping ground is also subjected to the lateral earth pressure at different levels in addition to other normal specified loading for the buildings at plain grounds.

Most of the commercial buildings constructed are loaded with 4 to 5 kN/m^2 as the normal imposed loads. But in case of some special types of buildings such as Data Centre the imposed load could be as high as 8 to 15 $kN/m.^2$ Loads on Data Centre is govern by TIA 942 [1] guidelines. In this era of Digitization and Globalization, enormous amount of data is produced and stored, which needs to be secured for future usage and analysis purpose. Earlier companies used to outsource the job of data storage to specialized data firms. Nowadays most of the organisations prefer to setup in-house data storage facility. The facility having complete telecommunication racks, which houses I.T and storage system along with its components in controlled environment at desired level of air conditioning with fully equipped electrical equipments with the highest level of fire protection with redundant power supply is called Data centre building. Structurally data centre buildings are subjected to heavy loading due to loads from equipment and storage systems. The behaviour of normal commercial building differs from that of buildings with heavy loads. Structural planning for data centre is done simultaneously with Architectural space planning from the conceptual stage itself as the location and size of columns have direct impact on the number of equipment/racks that can be accommodated. Large spans of column free space, sunken slabs in server areas (for services to pass underneath) coupled with heavy imposed loading are distinctive structural features of a Data centre building.

This Study seeks to compare the seismic behaviour of symmetrical and asymmetrical buildings when subjected to the normal and heavy loading. ETABS 9.2.0 [2] analytical tool is used for generation of 3D analytical models for buildings with normal loading ($4Kn/m^2$) and with heavy loads ($14.4Kn/m^2$) both for symmetrical buildings on plain areas and asymmetrical buildings on sloping hilly terrains. Plan layout is kept same for all the generated models for comparison. Effect of varying height of column, infill walls & heavy loading are studied. Seismic analysis is done using linear dynamic (response spectrum method) as well as nonlinear static procedure (pushover) has been performed. Linear dynamic analysis (response spectrum method) has the ability to access explicitly for the effects of higher modes of vibration. Furthermore, these results obtain from Linear dynamic analysis can be used to ascertain the existence of significant inelastic behaviour in the structure. Push over analysis is a nonlinear elastic analysis method. This technique is also termed as sequential yielding or simply "Pushover". This technique have gained significant acceptance during last few years after improvement in desktop computing techniques. It is one of the analysis techniques recommended by FEMA 273 [3] and a main component of Capacity Spectrum Analysis method as prescribed by ATC-40 [4].

II. ANALYTICAL MODELLING

Three different types of analytical models are generated in 3D using the analysis tool "ETABS 9.2.0", separately for symmetrical buildings and asymmetrical buildings, first with normal commercial loadings and then with heavy loading of data centre. Symmetrical buildings on plain ground is having equal height of columns on ground storey, whereas Asymmetrical models on sloping hilly terrain have the height of ground storey columns varying from 3m to 13.8m. Seismic design parameters are based on IS.1893 [5]

Model-1: Bare frame without the effect of stiffness of infill walls.

Model-2: Infills of brick masonry walls of 230 mm thickness is modelled by considering both mass and stiffness in upper stories, whereas ground storey is kept open without any infill wall.

Model-3: Infills of brick masonry wall of 230mm thickness is modelled by considering both mass and stiffness in upper floors. In ground storey, walls are considered in all the bays only along the periphery of building in longitudinal direction and in transverse direction it is considered only in the end bays along periphery.

Both stiffness and mass of the walls are taken into account.

Table 1: Design Parameters

Load	**Intensity**
Dead Loads Brick Masonry Concrete	 20.0kN/m3 25.0kN/m3
Imposed Live Loads (Normal Commercial building) Live Load (Data Centre buildings) Roof Load Floor Finishes	$4.0 kN/m^2$ $14.4 kN/m^2$ $2.0 kN/m^2$ $1.5 kN/m^2$
Importance Factor	1
Response reduction factor	5.0

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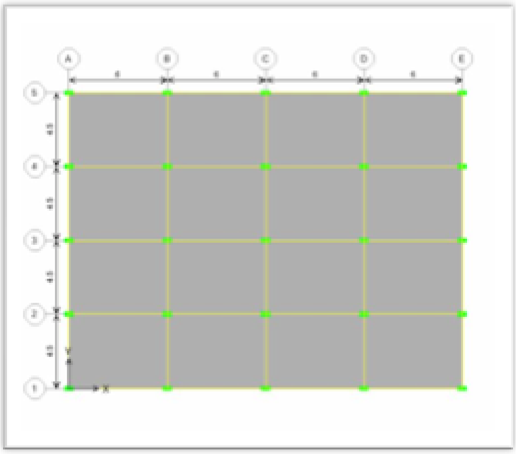

Figure 1. Symmetrical (Plan: Model-1)

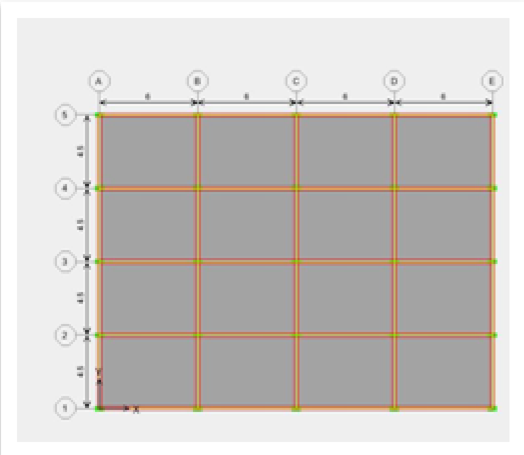

Figure 2. Symmetrical (Plan: Model-2)

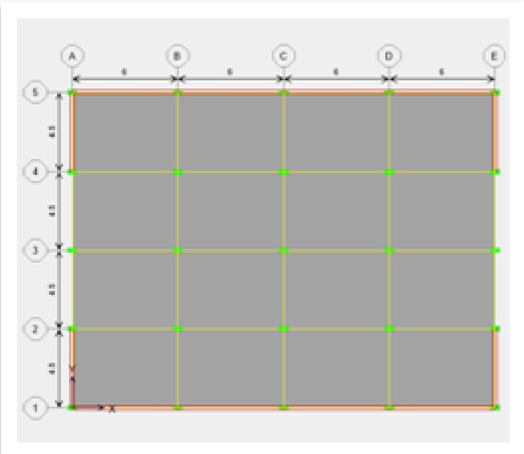

Figure 3. Symmetrical (Plan: Model-3)

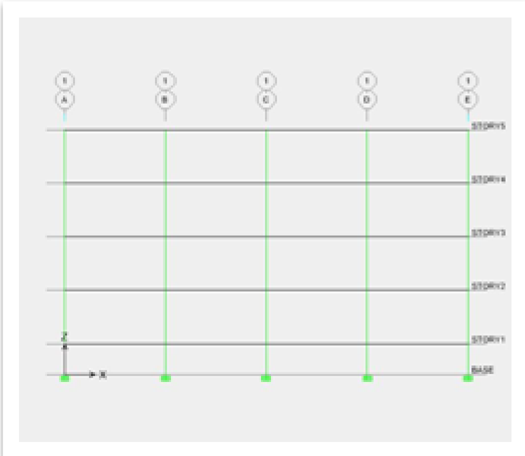

Figure 4. Symmetrical (Elevation: Model -1)

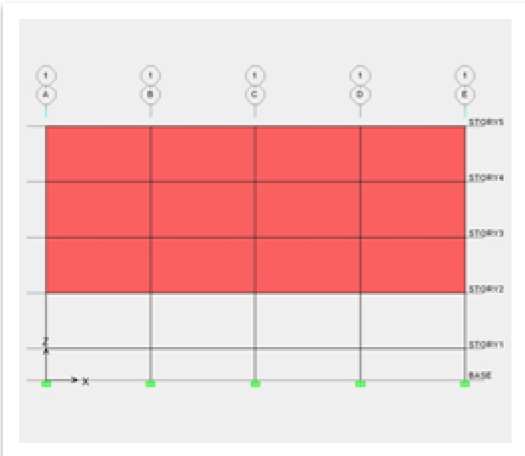

Figure 5. Symmetrical (Elevation: Model-2)

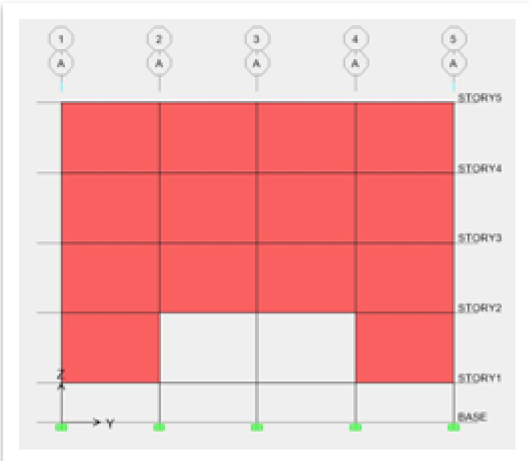

Figure 6. Symmetrical (Elevation: Model-3)

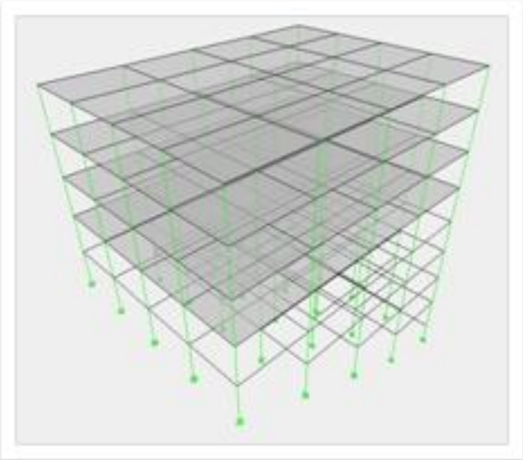

Figure 7. Asymmetrical (3D View Model-1)

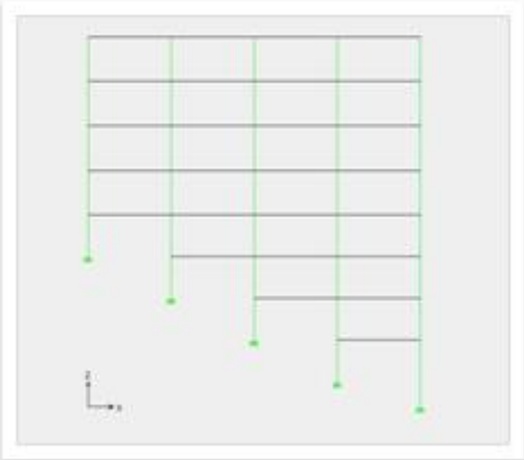

Figure10. Asymmetrical (Elev: Model -1)

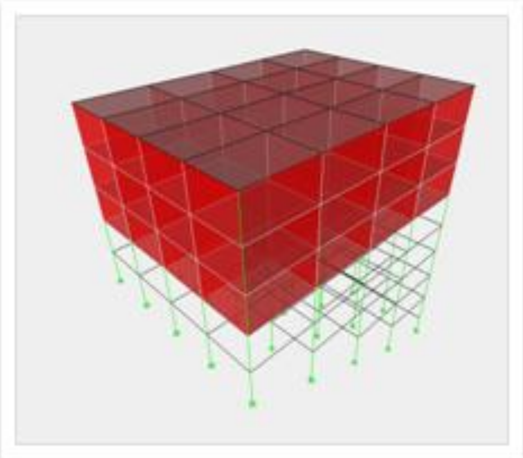

Figure 8. Asymmetrical (3D View Model-2)

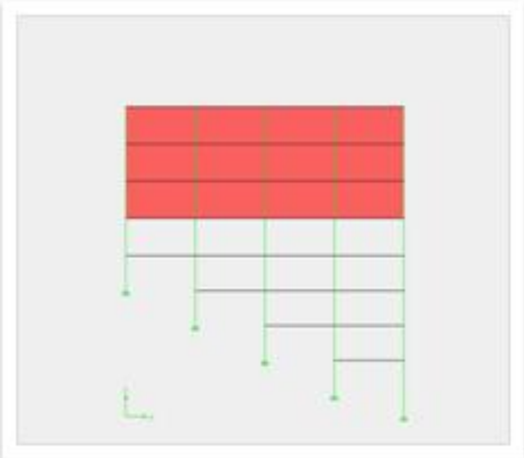

Figure 11. Asymmetrical (Elev: Model -2)

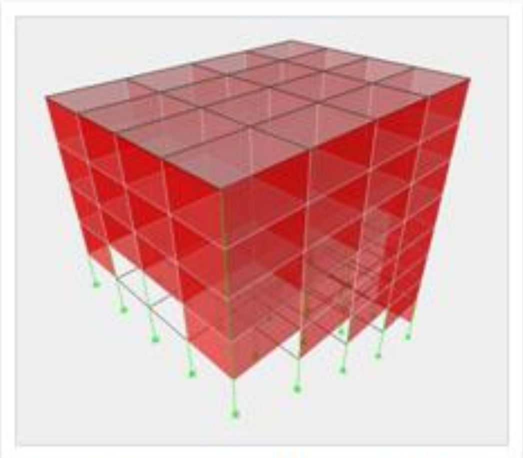

Figure 9. Asymmetrical (3D View Model-3)

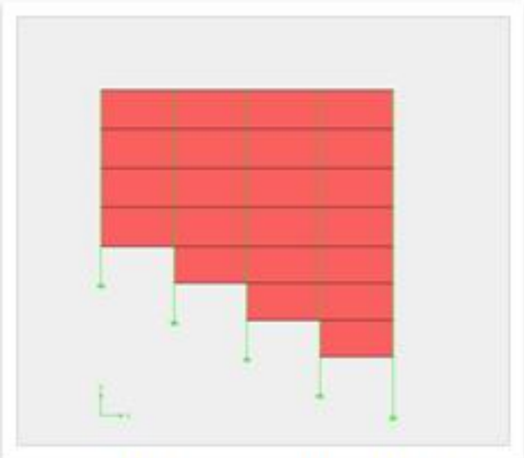

Figure 12. Asymmetrical (Elev: Model -3)

Member Properties of the structural elements used for modeling are tabulated below in Table-2.

International Journal of Advance Research in Science and Engineering
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www.ijarse.com
IJARSE
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Table 2: Member Properties

Member	Dimension mm
Columns	250x500
Beams	250x600
Slab	120
Wall	230

III. RESULTS

Lateral drifts results for response spectrum method and Pushover analysis is compared for Symmetric and Asymmetric building models with normal commercial loading and with heavy data centre loadings.

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-1 with Normal commercial loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 3.

Table 3. Lateral Drifts: X & Y under Normal commercial Loading for Symmetrical and Asymmetrical Buildings for Model-1.

MODEL-1 NORMAL LOADS (COMMERCIAL BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000201	0.000275	0.000242	0.000698	0.000159	0.000174	0.000139	0.000497
4	0.000078	0.000110	0.000444	0.001388	0.000282	0.000315	0.000303	0.000959
3	0.000104	0.000148	0.000662	0.002095	0.000390	0.000431	0.000493	0.001414
2	0.000109	0.000169	0.000766	0.002687	0.000455	0.000772	0.000642	0.002710
1	0.000024	0.000034	0.000307	0.000547	0.000716	0.000619	0.001071	0.002214

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-1 with Heavy loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 4.

Table 4. Lateral Drifts: X & Y under Heavy Loading for Symmetrical and Asymmetrical Buildings for Model-1.

MODEL-1 HEAVY LOADS (DATA CENTRE BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000181	0.000234	0.000046	0.000377	0.000144	0.000153	0.000000	0.000400
4	0.000389	0.000550	0.000133	0.000964	0.000285	0.000319	0.000072	0.000887
3	0.000562	0.000804	0.000208	0.001569	0.000414	0.000457	0.000166	0.001378
2	0.000604	0.000953	0.000185	0.002076	0.000493	0.000835	0.000243	0.002698
1	0.000241	0.000338	0.000086	0.000755	0.001380	0.001190	0.000723	0.003903

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-2 with Normal commercial loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 5.

Table 5. Lateral Drifts: X & Y under Normal commercial Loading for Symmetrical and Asymmetrical Buildings for Model-2.

MODEL-2 NORMAL LOADS (COMMERCIAL BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000008	0.000008	0.000032	0.000025	0.000016	0.000013	-0.000109	0.000040
4	0.000008	0.000008	0.000027	0.000023	0.000018	0.000015	-0.000123	0.000037
3	0.000012	0.000011	0.000043	0.000033	0.000029	0.000021	-0.000089	0.000058
2	0.000812	0.001408	0.001544	0.003248	0.000536	0.001035	0.000625	0.002546
1	0.000443	0.000558	0.000860	0.001275	0.002001	0.001591	0.002727	0.003964

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-2 with Heavy loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 6.

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 11, November 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Table 6. Lateral Drifts: X & Y under Heavy Loading for Symmetrical and Asymmetrical Buildings for Model-2.

MODEL-2 HEAVY LOADS (DATA CENTRE BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000008	0.000008	0.000035	0.000025	0.000016	0.000013	-0.000121	0.000041
4	0.000009	0.000009	0.000030	0.000023	0.000018	0.000016	-0.000136	0.000037
3	0.000013	0.000011	0.000048	0.000036	0.000030	0.000022	-0.000099	0.000053
2	0.000905	0.001568	0.001527	0.003251	0.000561	0.001082	0.000603	-0.000994
1	0.000494	0.000620	0.000850	0.001264	0.002088	0.001661	0.002666	0.010239

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-3 with Normal commercial loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 7.

Table 7. Lateral Drifts: X & Y under Normal commercial Loading for Symmetrical and Asymmetrical Buildings for Model-3.

MODEL-3 NORMAL LOADS (COMMERCIAL BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000006	0.000009	0.000046	0.000034	0.000021	0.000020	-0.000044	0.000075
4	0.000008	0.000011	0.000047	0.000038	0.000026	0.000026	-0.000051	0.000083
3	0.000009	0.000020	0.000058	0.000063	0.000035	0.000037	-0.000022	0.000126
2	0.000020	0.000037	0.000108	0.000091	0.000053	0.000092	0.000029	0.000290
1	0.000501	0.001647	0.002221	0.003711	0.002023	0.003428	0.003873	0.010571

Lateral drifts for X & Y direction of symmetrical as well as asymmetrical building Model-3 with Heavy loading for Response Spectrum Method (Spec-X & Spec-Y) and for Pushover method of analysis (Push-X & Push-Y) are shown in Table 8.

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 11, November 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Table 8. Lateral Drifts: X & Y under Heavy Loading for Symmetrical and Asymmetrical Buildings for Model-3.

MODEL-3 HEAVY LOADS (DATA CENTRE BUILDINGS)								
Storey no	Symmetric				Asymmetric			
	Response Spectrum Method		Pushover Method		Response Spectrum Method		Pushover Method	
	Spec-X	Spec-Y	Push-X	Push-Y	Spec-X	Spec-Y	Push-X	Push-Y
5	0.000007	0.000010	0.000046	0.000037	0.000022	0.000020	-0.000052	0.000074
4	0.000009	0.000012	0.000047	0.000036	0.000027	0.000027	-0.000060	0.000081
3	0.000011	0.000022	0.000058	0.000066	0.000036	0.000039	-0.000030	0.000124
2	0.000024	0.000041	0.000105	0.000088	0.000056	0.000097	0.000023	0.000286
1	0.000609	0.001851	0.002025	0.003514	0.002106	0.003605	0.003781	0.010349

Figure 13.Shows the comparison of Lateral Drift values for Model-1, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

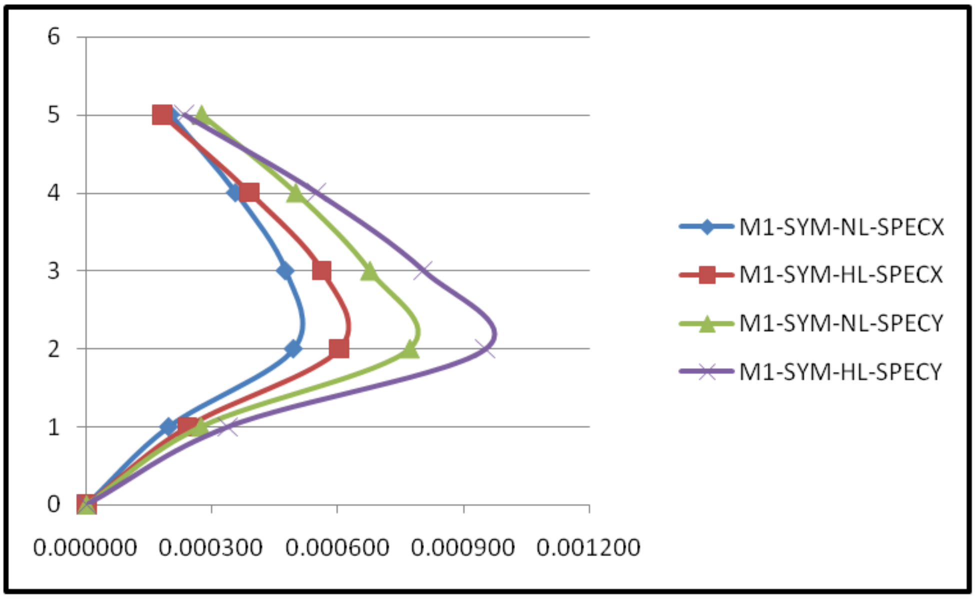

Figure 13. Lateral Drift: X & Y direction for Model-1 symmetrical buildings.

Figure 14. Shows the comparison of Lateral Drift values for Model-1, Asymmetrical **buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

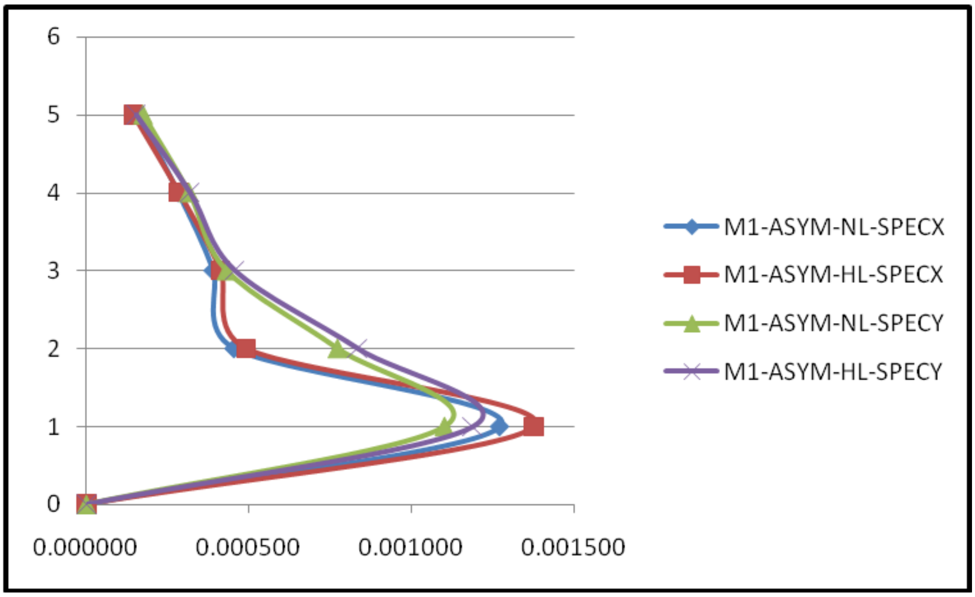

Figure 14. Lateral Drift: X & Y direction for Model-1 Asymmetrical buildings.

Figure 15. Shows the comparison of Lateral Drift values for Model-1, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

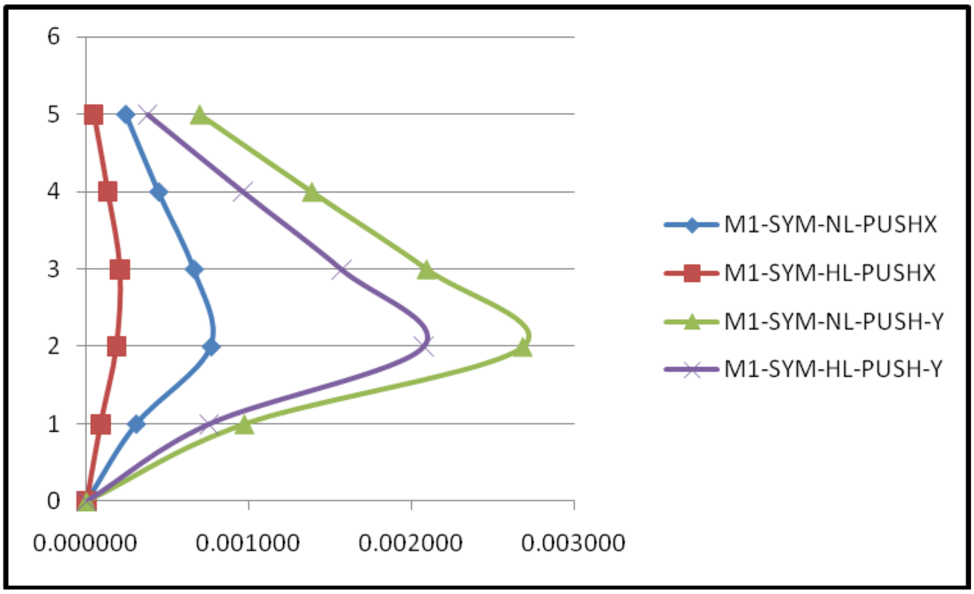

Figure 15. Lateral Drift: X & Y direction for Model-1 symmetrical buildings.

Figure 16. Shows the comparison of Lateral Drift values for Model-1, **Asymmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 11, November 2017
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ISSN: 2319-8354

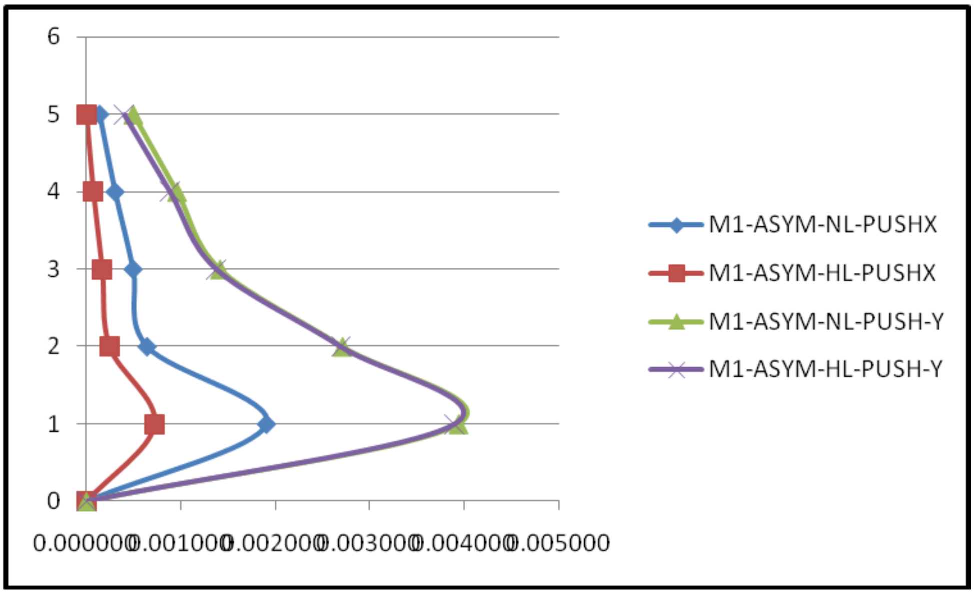

Figure 16. Lateral Drift: X & Y direction for Model-1 Asymmetrical buildings.

Figure 17. Shows the comparison of Lateral Drift values for Model-2, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

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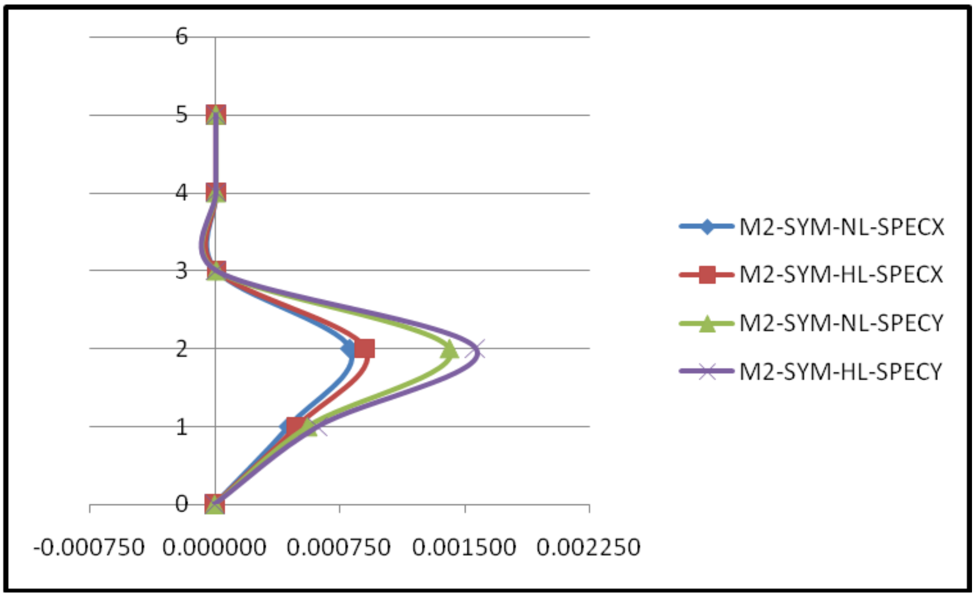

Figure 17. Lateral Drift: X & Y direction for Model-2 symmetrical buildings.

Figure 18. Shows the comparison of Lateral Drift values for Model-2, Asymmetrical **buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

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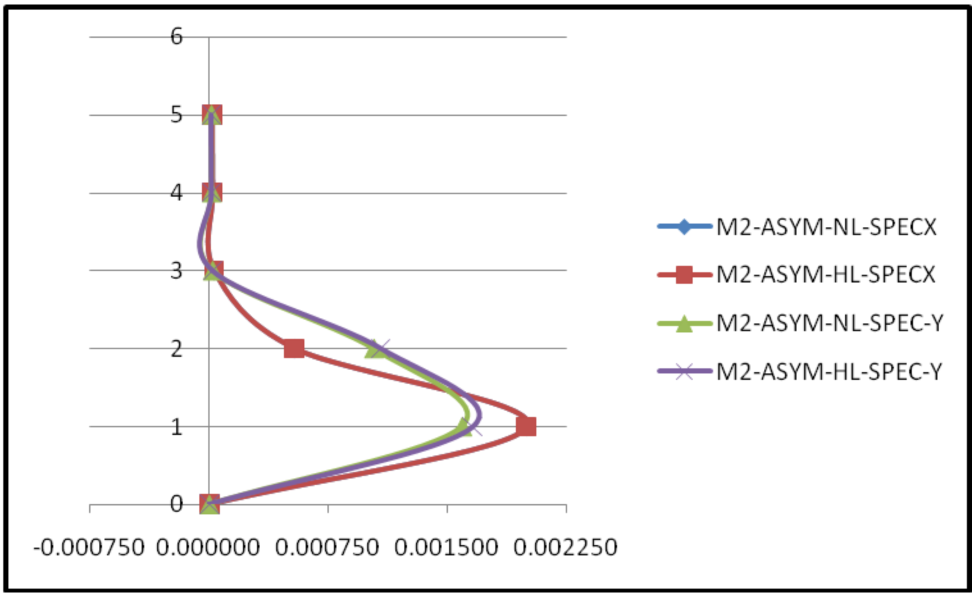

Figure 18. Lateral Drift: X & Y direction for Model-2 Asymmetrical buildings.

Figure 19. Shows the comparison of Lateral Drift values for Model-2, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

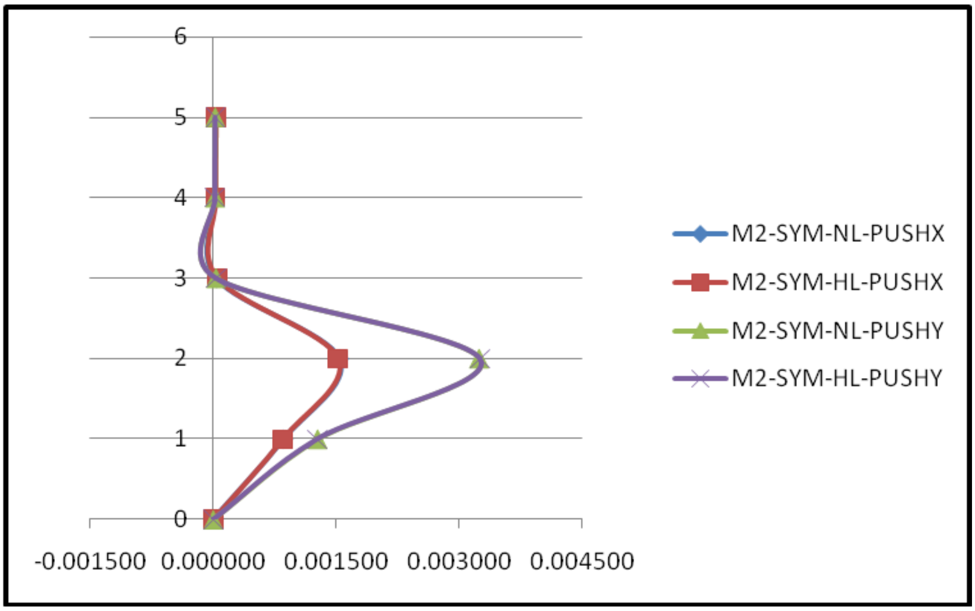

Figure 19. Lateral Drift: X & Y direction for Model-2 symmetrical buildings.

Figure 20. Shows the comparison of Lateral Drift values for Model-2, **Asymmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

IJARSE
ISSN: 2319-8354

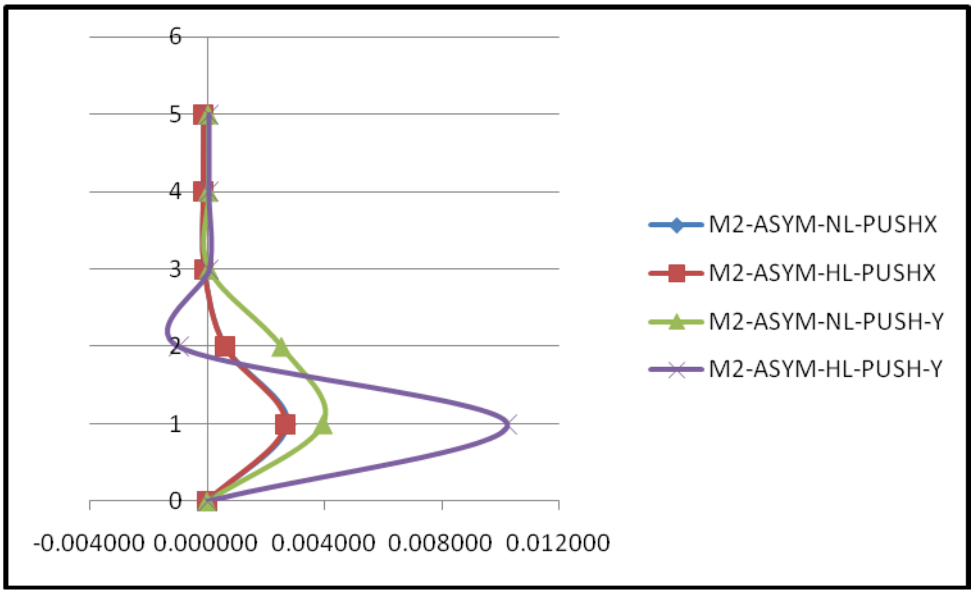

Figure 20. Lateral Drift: X & Y direction for Model-2 Asymmetrical buildings.

Figure 21. Shows the comparison of Lateral Drift values for Model-3, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

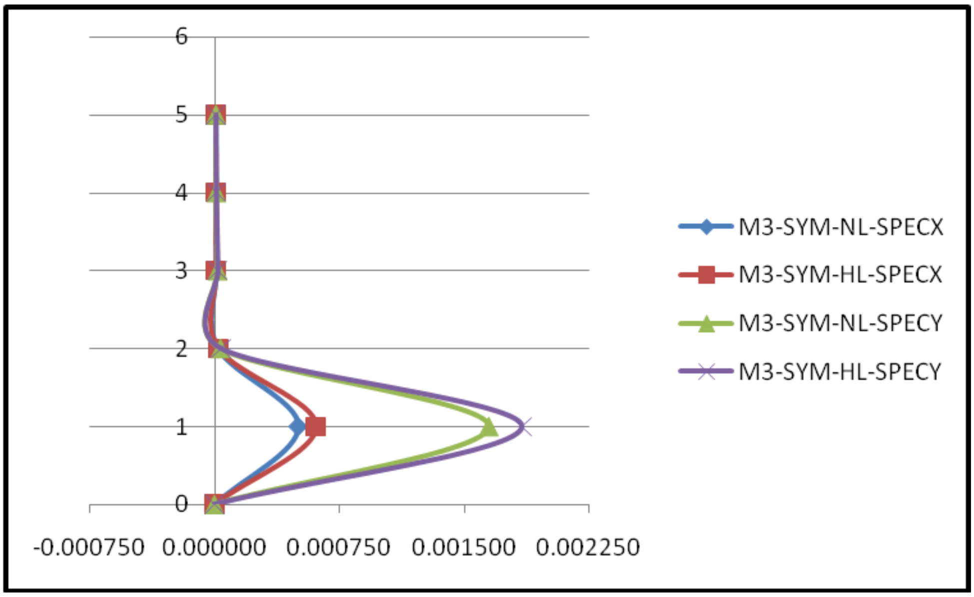

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Figure 21. Lateral Drift: X & Y direction for Model-3 symmetrical buildings.

Figure 22. Shows the comparison of Lateral Drift values for Model-3, Asymmetrical **buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Response spectrum Analysis.

International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 11, November 2017
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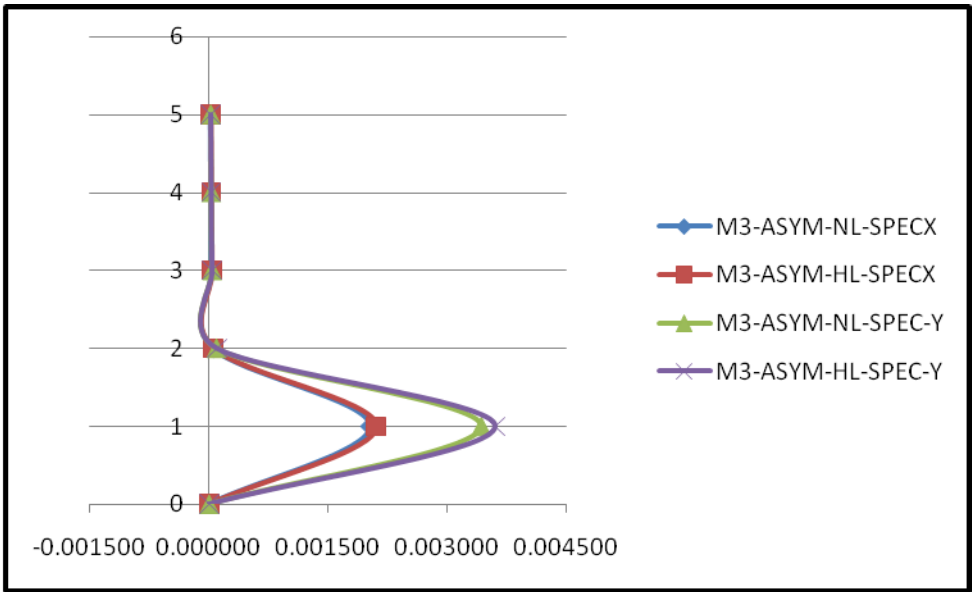

Figure 22. Lateral Drift: X & Y direction for Model-3 Asymmetrical buildings.

Figure 23. Shows the comparison of Lateral Drift values for Model-3, **symmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

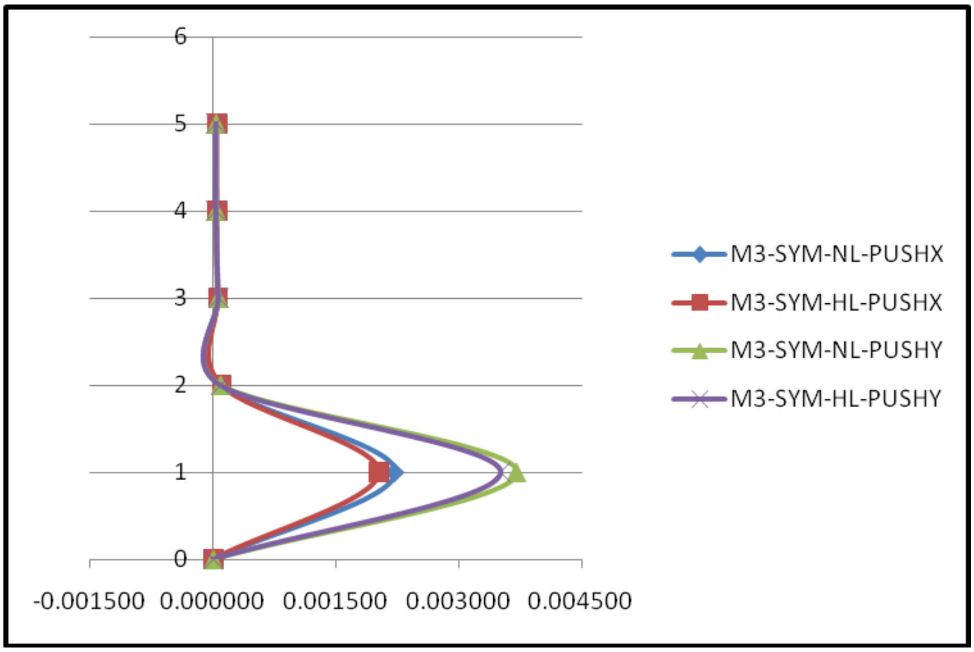

Figure 23. Lateral Drift: X & Y direction for Model-3 Symmetrical buildings.

Figure 24. Shows the comparison of Lateral Drift values for Model-3, **Asymmetrical buildings** subjected to Normal loading and Heavy Loading in both X & Y direction for Pushover analysis.

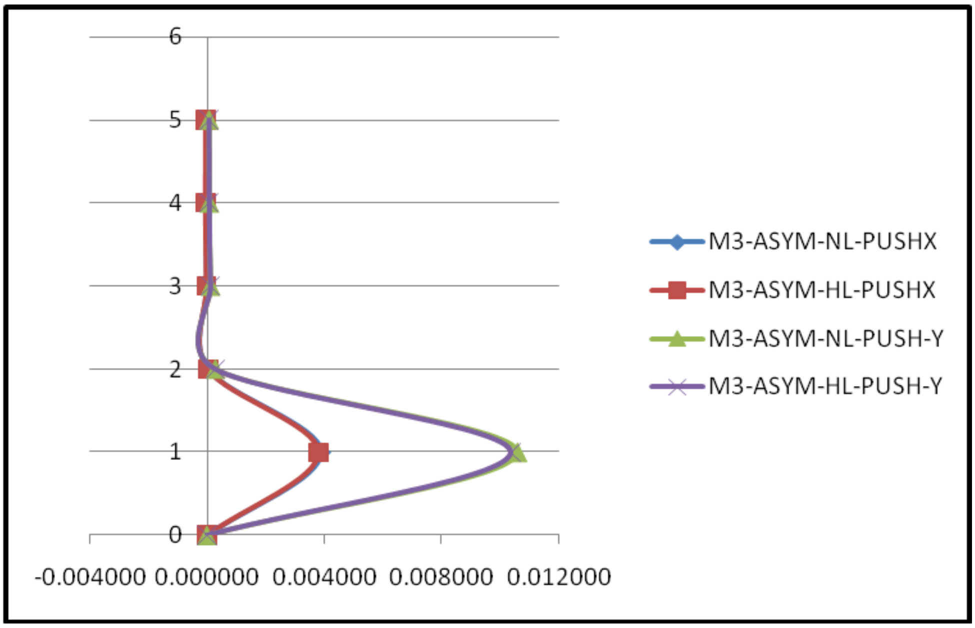

Figure 24. Lateral Drift: X & Y direction for Model-3 Asymmetrical buildings.

IV. CONCLUSIONS

1) Buildings constructed on sloping ground are very irregular in configuration and behaves completely different than those built on plains.
2) Lateral drifts for Asymmetric buildings is more compare to the symmetrical buildings, as they are irregular in nature and are susceptible to the high torsion. Asymmetrical buildings of Model-1, Model-2 & Model-3 have large lateral drifts compare to their respective symmetrical models of same geometrical configuration.
3) Long columns of Asymmetric buildings on sloping terrain undergo large drifts due to varying heights in ground storey as building step backs.
4) Lateral drifts in buildings with heavy loading are higher compare to the buildings with normal loading for both response spectrum and pushover analysis method.
5) Infills affect the overall behavior of buildings when subjected to the seismic forces. Lateral Drifts are considerably reduced in Model-3 because of the effect of infill walls.

REFERENCES

[1] Telecommunications Industry Association. 2010. TIA-942 Telecommunications Infrastructure Standards for Data Centres.

[2] ETABS nonlinear version 9.2.0 Computers and Structures, Inc, CA.

[3] FEMA-273. "NEHRP guidelines for the seismic rehabilitation of buildings." Federal Emergency Management Agency, Washington DC, 1997.

[4] Applied Technology Council, ATC-40, “Seismic evaluation and retrofit of concrete buildings”, Vol. 1 and 2, California 1996.

[5] IS: 1893 (Part 1) 2002- Indian standard- “Criteria for earthquake resistant design of structures”, Bureau of Indian Standards, New Delhi.

[6] Data Centre Projects: Establishing a Floor Plan White Paper #144 By Neil Rasmussen & Wendy Torell (APC American power conversion 2007).

[7] Yee Keen Seng., Wu Xianghua., Lim Hwee Kwang and Wong Marn Chee Ang Choon Keat "Planning and Designing Data Centres"

[8] T.Seshadri Sekhar & Md Jaweed Jilani Khan., “Evalation of Seismic response of Symmetric and asymmetric multistoried buildings” International journal of Research in Engineering and Technology.

[9] Md. Jaweed Jilani Khan, Bellam Sivarama Krishna Prasad “Siesmic Effects on Buildings with Data Centre loads”, International journal of Advanced Reserach in Basic Engineering Sciences and Technology (IJARBEST), VOLUME 3, SPECIAL ISSUE 32-APRIL 2017, pp.73-82