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Evaluation of Lateral Load Patterns for G+4 Storey R.C.C. Building

Mr. Jigar Zala

Assist. Prof., Civil Engineering Department, Arham Veerayatan Institute of Engineering Technology & Research Haripar, Mandvi-kutch.
jigar.zala@hotmail.com

Abstract

Earthquakes are known to produce one of the most destructive forces on the earth. It can causes loss of life and property and economical loss of the country. Earthquake cannot be prevented, since it is unpredictable, but loss of life of people and damage to the structures can be prevented if later is designed properly. Performance Based Design (PBD) of structure is the modern approach to earthquake resistant design. The performance of a building depends on various parameters out of which lateral load pattern is most critical. FEMA-273 and ATC-40 adopts specific pattern of lateral loading for nonlinear static analysis, widely known as pushover analysis.

For a performance evaluation the load pattern selection is likely to be more critical than the accurate determination of the target displacement. Here, the evaluation of three different loading patterns namely, Rectangular and Triangular (k=1) as per FEMA-273 and ATC-40 and Parabolic (k=2) as per IS: 1893(Part 1)-2002 is applied on G+4 storey R.C.C. building for three different types of building model likely Bare Frame, Infill Wall and Equivalent Strut. Analysis has been carried out using ETABS (version 9.5). The capacity curve (V/W) to displacement for different levels is obtained for three different types of lateral loading patterns.

Keywords- *Different Loading Pattern, Different Analytical Model, Lateral Load Analysis, Capacity Curve.*

I. INTRODUCTION

Each building need to access for its seismic capacity and characteristic performance of building is required to understand. Hence, performance based seismic analysis is essential for the buildings to understand its behavior and response during earthquake.

For a performance evaluation the loading pattern selection is more critical than the accurate determination of the target displacement. The load patterns are intended to represent and bound the distribution of inertia forces in a design earthquake. It is clear that the distribution of inertia forces will vary with the severity of the earthquake and with time within an earthquake. If no invariant loading pattern is used, the basic assumptions are that the distribution of inertia forces will be reasonably constant throughout the earthquake and the maximum deformations obtained from this invariant loading pattern will be comparable to those expected in the design earthquake. These assumptions may be closed to the reality in some cases, but not in others. They are likely to be reasonable if (1) the structure response is not severely affected by higher mode effects or (2) the structure has only a single load yielding mechanism that can be detected by an invariant loading pattern.

In such cases carefully selected invariant load pattern may provide adequate prediction of element deformation demands. Since no single load pattern can capture the variations in the local demands expected in a design earthquake, the use of atleast two loading patterns that are expected to bound inertia forces distribution is recommended. One should be a “uniform” load pattern, which emphasis the demands in lower storey compared to the demands in upper stories and magnifies the relative importance of storey shear forces compared to overturning moments. The other could be the design load pattern used in present codes or, preferably, a load pattern that accounts for elastic higher mode effects, such as a load pattern derived from SRSS method as per IS: 1893 – 2002 (Part I) storey shears.

As IS: 1893-2002(Part I) do not much emphasis on nonlinear static analysis, loading pattern of ATC-40 is widely used across the globle. This paper includes three types of lateral loading patterns namely, uniform and triangular (k=1) as per ATC-40 and parabolic (k=2) as per IS: 1893-2002 (Part I) based on the lateral load distribution across height of structure.

II. BUILDING CONFIGURATION

2.1. A G+4 storey RC building of plan dimension 20 m x 15 m as shown in figure (1), each bay of 5m in length, located in seismic zone III on medium soil is considered. The storey height is 3m and slabs are of 150 mm thickness. Brick wall below all beams are 115 mm thick. Consider concrete grade M 25 and steel grade Fe 415, respectively.

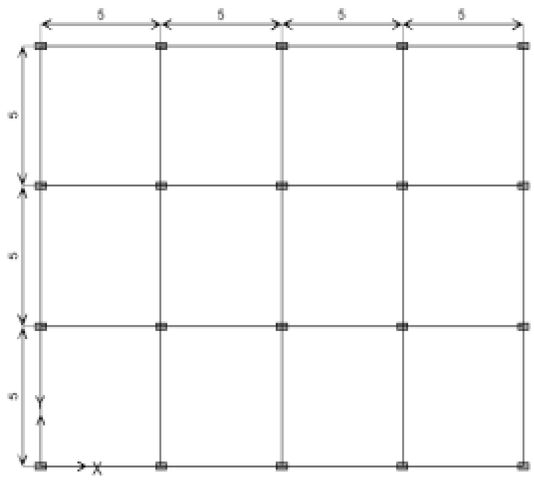

Figure 1: Plan of G+4 storey R.C.C. building

Table 1: Geometric Properties of frame and live loads on slab

Floor	Column size (mm)	Beam size (mm)	Live load on slab (KN/m^2)
G.F.	230x600	230x500	2
1st floor	230x600	230x500	2
2nd floor	230x500	230x450	1.5
3rd floor	230x500	230x450	1.5
4th floor	230x450	230x450	1.5

2.2. Modeling of building

To perform lateral load analysis, it is required to prepare analytical model of G+4 storey building. Structural elements like slabs, beams and columns are modelled as rigid diaphragm. However, modeling of masonry infill wall is typical.

In present study, masonry wall is replaced by membrane element with inplane stiffness and as a strut element of some width and thickness. Thus, three analytical models are considered in present study, namely, Bare Frame (i.e, w/o masonry infill wall), Frame with infill wall as membrane and Frame with infill wall as strut.

2.2.1. Bare Frame without infill wall

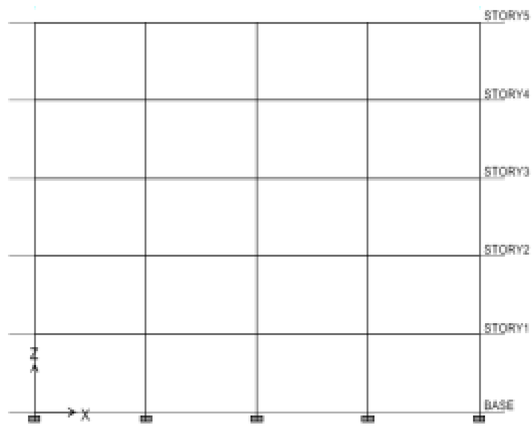

Figure 2: Elevation of G+4 bare frame model

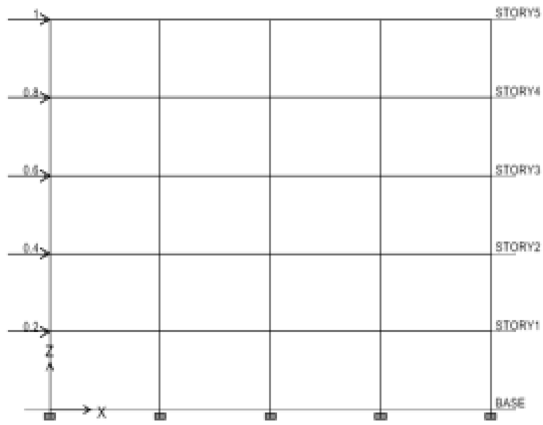

Figure 3: Lateral Loading Pattern

The lateral load is applied in X-direction. The unit load (1kN) is applied at the top of the column and simultaneously reducing by 0.2kN from top to base as shown in figure (4).

2.2.2. Building Frame with infill as membrane wall

This model is prepared as membrane elements to replace with infill wall. To estimate real life problem, the masonry infill walls of thickness 115 mm are provided below all the beams except the first floor beams.

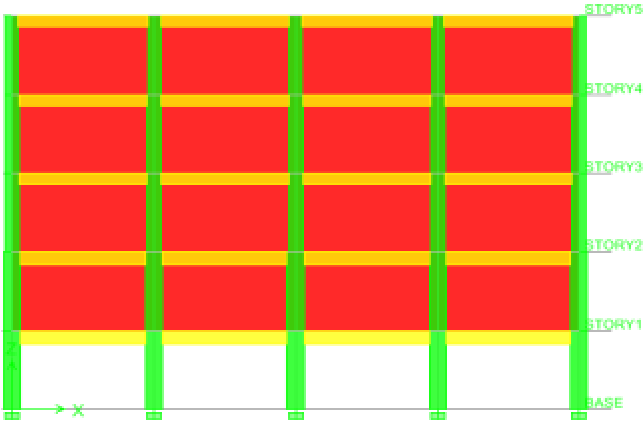

Figure 4: G+4 storey model with infill as membrane wall

2.2.3. Building Frame with infill as equivalent strut

In this model, the diagonal strut is modeled in place of infill wall. Here, the ends of diagonal struts are released for moments and torsion in all the directions, to overcome rigidity effect. We have taken the thickness of the strut is 115 mm and the width of strut is calculated as 1.94 m, for present case.

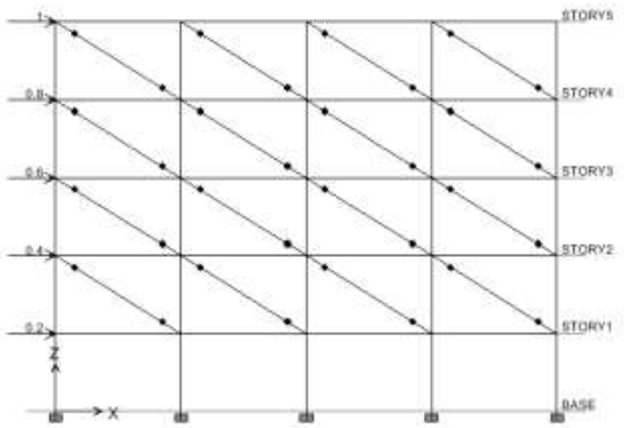

Figure 5: G+4 storey with infill as equivalent strut

III. LATERAL LOAD PATTERN ANALYSIS AND RESULTS

3.1. Bare Frame with Parabolic Loading

The total weight of building for bare frame model was found to be 11255.84 kN. Table 2 indicates the variation of V/W and displacement of each floor level for bare frame with parabolic loading pattern.

Table 2: Lateral Load Pattern Results for Bare Frame with Parabolic Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.1	0.018	0.1	0.015	0.1	0.011	0.1	0.007	0.1	0.0028
0.35	0.094	0.37	0.089	0.41	0.078	0.41	0.044	0.39	0.015
0.58	0.2	0.58	0.18	0.59	0.14	0.59	0.08	0.42	0.017
0.64	**0.24**	**0.64**	**0.21**	**0.64**	**0.17**	**0.64**	**0.11**	**0.64**	**0.055**
0.44	0.17	0.44	0.15	0.44	0.13	0.44	0.09	0.44	0.048

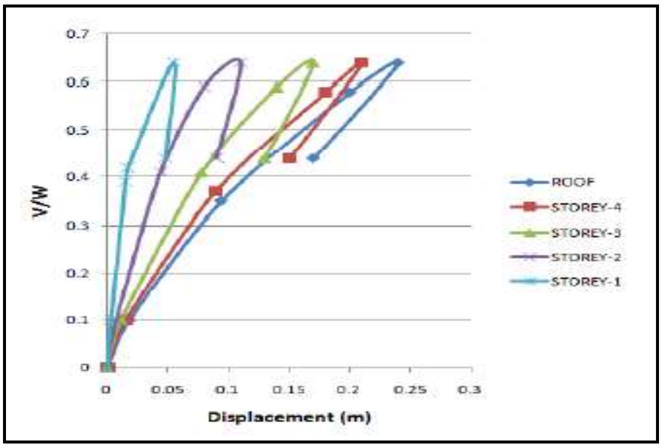

Figure 6: V/W Vs. Displacement Curve for Bare Frame with Parabolic Loading

As shown in Figure (6) the maximum displacement was obtained at roof level only. The displacements were goes on reducing while coming down from roof level to ground level of building. The maximum displacement obtained was about 0.24 m at a base shear of 7203.74 kN at ultimate capacity.

3.2. Bare Frame with Triangular Loading

Table 3: Lateral Load Pattern Results for Bare Frame with Triangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.1	0.018	0.1	0.015	0.1	0.011	0.1	0.007	0.1	0.0028
0.34	0.09	0.37	0.086	0.42	0.077	0.41	0.044	0.4	0.015
0.53	0.17	0.53	0.14	0.59	0.13	0.61	0.11	0.42	0.017
0.64	**0.23**	**0.64**	**0.2**	**0.64**	**0.16**	**0.64**	**0.13**	**0.64**	**0.055**
0.22	0.14	0.22	0.13	0.22	0.1	0.22	0.076	0.22	0.042

Table 3 indicates the variation of V/W and displacement of each floor level for bare frame with triangular loading pattern. As shown in Figure (7) the maximum displacement of building was obtained about 0.23 m with base shear of 7203.74 kN.

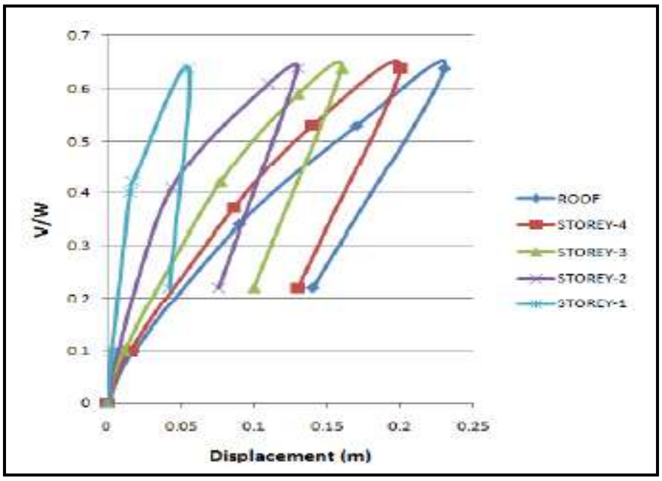

Figure 7: V/W Vs. Displacement Curve for Bare Frame with Triangular Loading

3.3. Bare Frame with Rectangular Loading

Table 4: Lateral Load Pattern Results for Bare Frame with Rectangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.15	0.016	0.15	0.015	0.15	0.012	0.15	0.007	0.15	0.003
0.51	0.087	0.53	0.083	0.51	0.064	0.51	0.04	0.51	0.015
0.71	0.15	0.77	0.16	0.76	0.13	0.76	0.1	0.53	0.016
0.81	**0.19**	**0.81**	**0.18**	**0.81**	**0.15**	**0.81**	**0.13**	**0.81**	**0.055**
0.2	0.11	0.2	0.1	0.2	0.088	0.2	0.067	0.2	0.038

Table 4 indicates the variation of V/W and displacement of each floor level for bare frame with rectangular loading pattern. It was observed from Figure (8) that, the displacement of roof level was maximum. Also, it was evident that, the ultimate capacity of building estimated by rectangular loading pattern is more among all the loading pattern considered. The value of maximum displacement was about 0.19 m for the base shear value of 9117.23 kN.

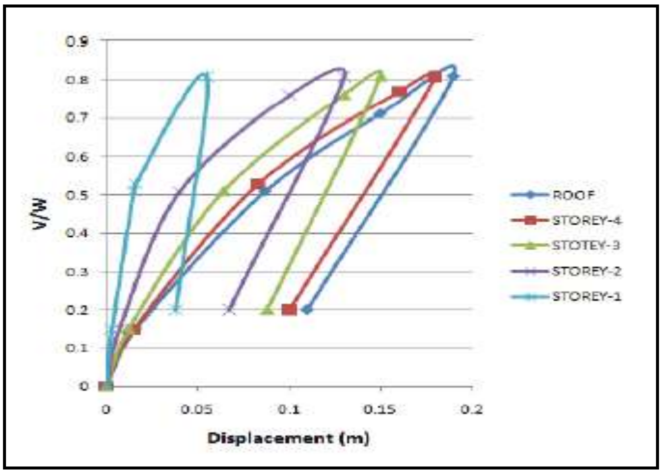

Figure 8: V/W Vs. Displacement Curve for Bare Frame with Rectangular Loading

3.4. Infill Wall with Parabolic Loading

Table 5: Lateral Load Pattern Results for Infill Wall with Parabolic Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.075	0.017	0.075	0.015	0.075	0.017	0.075	0.007	0.075	0.0028
0.26	0.092	0.29	0.092	0.31	0.077	0.3	0.044	0.3	0.016
0.38	0.16	0.4	0.16	0.44	0.15	0.44	0.09	0.31	0.017
0.47	**0.23**	**0.47**	**0.21**	**0.47**	**0.17**	**0.47**	**0.11**	**0.47**	**0.055**
0.34	0.18	0.34	0.16	0.34	0.13	0.34	0.091	0.34	0.048

The total weight of building for infill wall model was found to be 15533.84 kN. Table 5 indicates the variation of V/W and displacement of each floor level for infill frame with parabolic loading pattern. As shown in Figure (9) the maximum displacement was obtained at roof level only. The displacements were goes on reducing while coming down from roof level to ground level of building. The maximum displacement obtained was about 0.23 m at a base shear of 7300.90 kN at ultimate capacity.

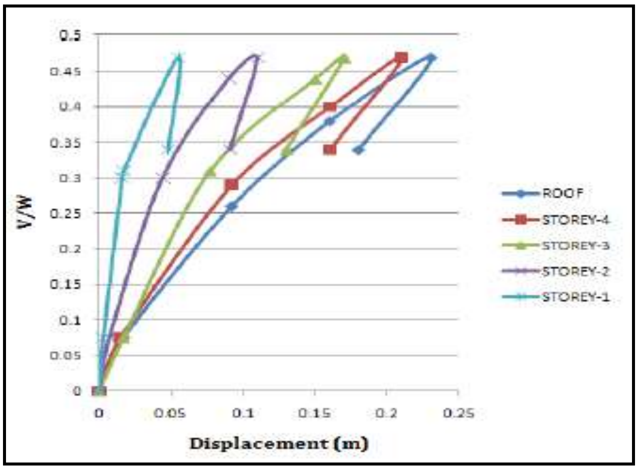

Figure 9: V/W Vs. Displacement Curve for Infill Wall with Parabolic Loading

3.5. Infill Wall with Triangular Loading

Table 6: Lateral Load Pattern Results for Infill Wall with Triangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.075	0.017	0.075	0.015	0.075	0.017	0.07	0.007	0.075	0.0028
0.27	0.095	0.29	0.094	0.31	0.076	0.3	0.044	0.29	0.016
0.38	0.16	0.41	0.16	0.44	0.13	0.43	0.08	0.31	0.017
0.47	**0.21**	**0.47**	**0.21**	**0.47**	**0.17**	**0.47**	**0.11**	**0.47**	**0.056**
0.14	0.13	0.14	0.12	0.13	0.1	0.14	0.074	0.14	0.042

Table 6 indicates the variation of V/W and displacement of each floor level for infill wall with triangular loading pattern. As shown in Figure (10) the maximum displacement of building was obtained about 0.21 m with base shear of 7300.90 kN.

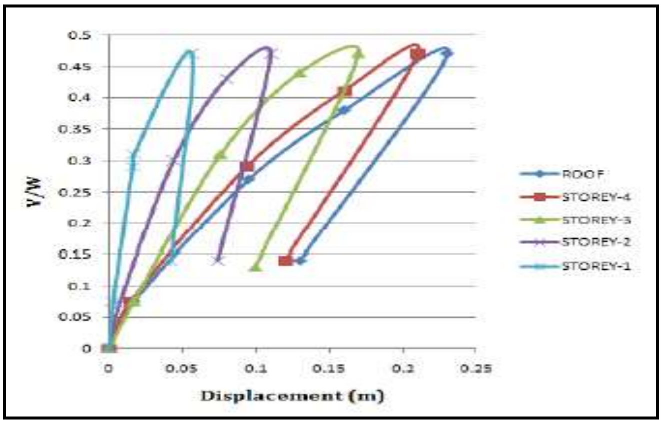

Figure 10: V/W Vs. Displacement Curve for Infill Wall with Triangular Loading

3.6. Infill Wall with Rectangular Loading

Table 7: Lateral Load Pattern Results for Infill Wall with Rectangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.11	0.017	0.11	0.015	0.11	0.012	0.11	0.007	0.11	0.0032
0.37	0.087	0.39	0.083	0.38	0.06	0.38	0.041	0.38	0.015
0.53	0.15	0.54	0.14	0.58	0.13	0.58	0.08	0.39	0.016
0.6	**0.19**	**0.6**	**0.18**	**0.6**	**0.15**	**0.6**	**0.11**	**0.49**	**0.055**
0.19	0.13	0.19	0.11	0.2	0.1	0.2	0.078	0.2	0.046

It was observed from Figure (11) that, the displacement of roof level was maximum. Also, it was evident that, the ultimate capacity of building estimated by rectangular loading pattern is more among all the loading pattern considered. The value of maximum displacement was about 0.19 m for the base shear value of 9320.30 kN.

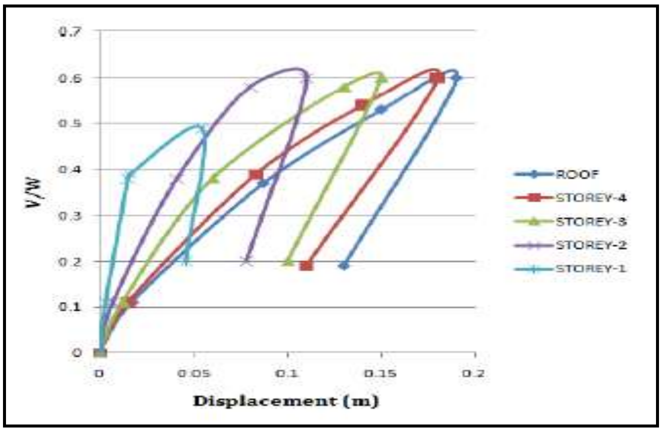

Figure 11: V/W Vs. Displacement Curve for Infill Wall with Rectangular Loading

3.7. Equivalent Strut with Parabolic Loading

Table 8: Lateral Load Pattern Results for Equivalent Strut with Parabolic Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.082	0.018	0.082	0.015	0.082	0.011	0.082	0.007	0.082	0.0028
0.28	0.091	0.3	0.089	0.33	0.078	0.33	0.045	0.32	0.016
0.44	0.18	0.44	0.16	0.48	0.15	0.48	0.09	0.34	0.017
0.51	**0.23**	**0.51**	**0.21**	**0.51**	**0.17**	**0.51**	**0.11**	**0.51**	**0.055**
0.16	0.14	0.16	0.12	0.16	0.1	0.16	0.075	0.16	0.041

The total weight of building for equivalent strut model was found to be 14033.33 kN. Table 8 indicates the variation of V/W and displacement of each floor level for equivalent strut with parabolic loading pattern. As shown in Figure (12) the maximum displacement was obtained at roof level only. The displacements were goes on reducing while coming down from roof level to ground level of building. The maximum displacement obtained was about 0.23 m at a base shear of 7156.99 kN at ultimate capacity.

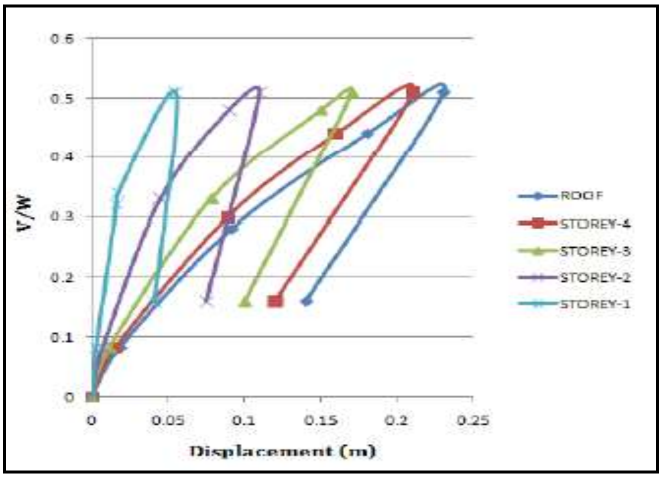

Figure 12: V/W Vs. Displacement Curve for Equivalent Strut with Parabolic Loading

3.8. Equivalent Strut with Triangular Loading

Table 9: Lateral Load Pattern Results for Equivalent Strut with Triangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.08	0.017	0.08	0.015	0.08	0.017	0.08	0.007	0.08	0.0028
0.28	0.094	0.31	0.092	0.33	0.07	0.33	0.044	0.32	0.016
0.41	0.17	0.45	0.17	0.48	0.15	0.45	0.08	0.33	0.016
0.51	**0.22**	**0.51**	**0.2**	**0.51**	**0.17**	**0.51**	**0.11**	**0.51**	**0.03**
0.19	0.15	0.19	0.13	0.19	0.11	0.19	0.07	0.19	0.04

Table 9 indicates the variation of V/W and displacement of each floor level for equivalent strut with triangular loading pattern. As shown in Figure (13) the maximum displacement of building was obtained about 0.22 m with base shear of 7156.99 kN.

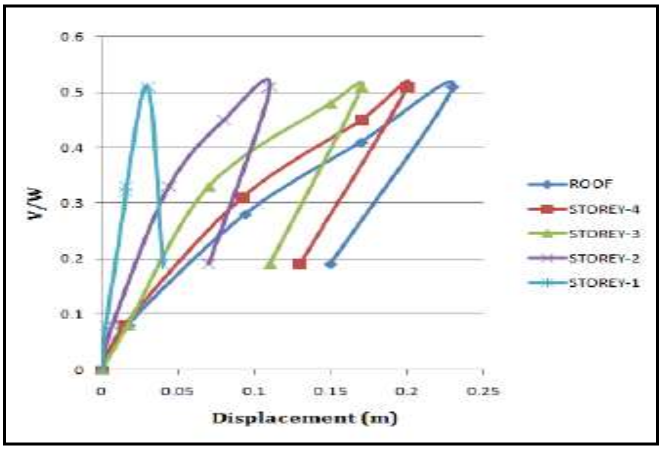

Figure 13: V/W Vs. Displacement Curve for Equivalent Strut with Triangular Loading

3.9. Equivalent Strut with Rectangular Loading

Table 10: Lateral Load Pattern Results for Equivalent Strut with Rectangular Loading

Roof		Storey-4		Storey-3		Storey-2		Storey-1	
V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)	V/W	Displ (m)
0	0	0	0	0	0	0	0	0	0
0.12	0.017	0.12	0.015	0.12	0.017	0.12	0.007	0.12	0.0032
0.41	0.08	0.42	0.084	0.41	0.064	0.41	0.041	0.41	0.015
0.58	0.16	0.63	0.16	0.63	0.14	0.63	0.09	0.43	0.016
0.65	**0.19**	**0.65**	**0.18**	**0.65**	**0.15**	**0.65**	**0.11**	**0.65**	**0.055**
0.15	0.11	0.15	0.1	0.15	0.087	0.15	0.067	0.15	0.04

It was observed from Figure (14) that, the displacement of roof level was maximum. Also, it was evident that, the ultimate capacity of building estimated by rectangular loading pattern is more among all the loading pattern considered. The value of maximum displacement was about 0.19 m for the base shear value of 9121.66 kN.

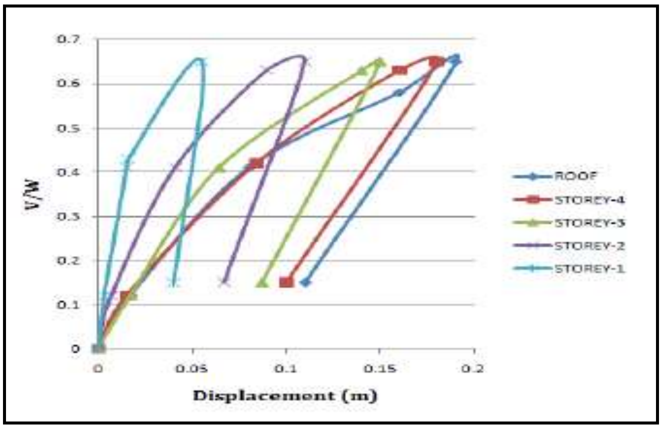

Figure 14: V/W Vs. Displacement Curve for Equivalent Strut with Rectangular Loading

VI. CONCLUSION

Following conclusions are made based on work carried out:

1. Different building model developed based on different modeling aspects showed distinct modeling effect on overall results of the building.

2. A rectangular loading pattern gives higher base shear to weight ratio as compared to other loading patterns.

3. Parabolic loading patterns gives the least base shear to weight ratio as compared to rectangular and triangular loading pattern.

4. It was observed that displacement capacity under bare frame with parabolic loading pattern is maximum compared to triangular and rectangular loading pattern.

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