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RESEARCH ARTICLE OPEN ACCESS

Analysis and Design of Irregular Building with Re-entrant Corner using Pushover Analysis

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ABSTRACT:
The study of Irregular structures becomes essential when they are situated in higher seismic zones. Since regular structures accordingly (IS Code) designed are safe for gravity load. But, when seismic loads act on Irregular structures, some seismic effective parameters such as maximum story drift, maximum story displacement, stiffness, etc. need to be acknowledged, so the effect of seismic forces on the structure can be assumed for further design. The results are helpful in understanding the behavior of horizontal irregularity such as the "Re-entrant" corner of the building. The study is carried out on L shape geometry (in the plan) RC framed structures. In this study, the comparison is carried out between building "with and without Shear Wall" as Stiff Resisting Element. The Study is considered for Zone III and Zone IV. The Pushover Analysis is used to analyze the G+5 RC framed structure. The analysis and design of all four structures are carried out in ETABS software.
***Keywords*: Re-entrant Corner, Seismic effective parameter, Shear Wall, Pushover Analysis, ETABS**

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I. INTRODUCTION

The Irregular structure is common nowadays and is mostly being practiced in perspective for their architecture uniqueness and esthetical purpose which brings challenges for structural engineers in designing such complex structures in shape and size which are design for the resistance of seismic forces. To fulfill this requirement of irregularities in structure sometimes prevention methods are taken into account. Much research has been done for such prevention of this irregular structure before and used to study the seismic effective parameters such as maximum story drift, displacement, and stiffness, etc. As per IS 1893(Part 1):2016 [04] the irregularity in the building structures may be due to irregular distributions in their mass, strength, and stiffness along with the height of the building. Irregularities are categorized into two types vertical and horizontal. In this study horizontal irregularity is concentrated as re-entrant corner and L shaped model is used in plan geometry. The model results are compared for two different zones III and IV. Prevention method is different for re-entrant corner such separation of building, strengthening the notch by using curved beam and providing stiff elements as shear wall or bracings. The study is focused on the behavior of providing stiff elements at the re-entrant corner on the same plan in a different zone and comparing performance value obtained by pushover analysis. The building is modeled and analyzed in ETABS software.

STRUCTURESDETAILS

The irregular structures proposed for pushover analysis are of L-shaped geometry in plan, which consists of an equal base area of (528 m2) and having a height of 18 meters from the base. The four structures are used in which two structures consist of shear walls. For comparison of seismic effective parameter, the columns and beam at the re-entrant corner in the structure are replaced with shear wall located as per required dimension in structure.

The designing of structures is done in ETABS software as per criteria of IS 456:2000 [06]. Also, the structures are proposed to be designed in seismic zone III and zone IV, the criteria of seismic design of RC framed structure is followed as per IS 1893:2016 [04]. The loads so applied to the structures are slab self-weight, floor finish load, and live load. Where the live load on the roof level and other floor levels are 2KN and 3KN as per co dal provision. Other details of structures are given in Table 1.

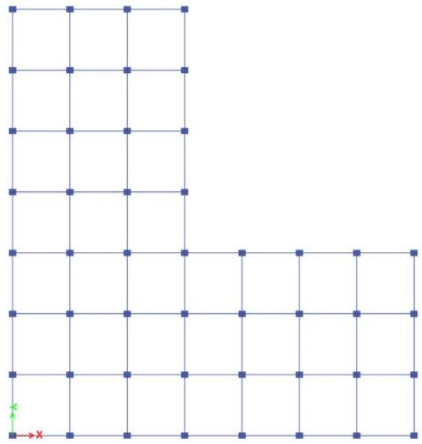

Figure 1: Plan- RC Framed Structures having L Shape Geometry Shape

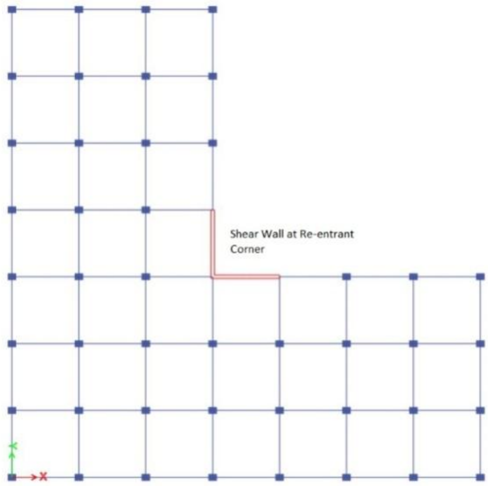

Figure 2: Plan- RC Framed Structures having L Shape Geometry Shape with Shear Wall

Table 1: Detail of RC Structure with Shear Wall

S.No.	Parameter	Details
1	Plan Dimension	28m X 28m
2	Story	G+5
3	Height of Building	18.0 meter
4	Story Height	3.0 meter
5	Beam Size	300mm X 500mm
6	Column Size	400mm X 500mm
7	Shear Wall	200mm
11	Slab Thickness	150 mm
12	Seismic Zone	III and IV

Framed and without

13	Soil Type B	Medium & Stiff Soil
14	Importance factor	1.2
15	Response Reduction Factor	5
16	Density of RCC	25 kN/m^3
17	Density of Masonry Wall	20 kN/m^3

NON-LINEAR STATIC ANALYSIS (PUSHOVERANALYSIS)

The non-linear static analysis (pushover analysis) is a method used to define how far into inelastic range can a structure resist before its total or partial collapse. Lateral horizontal forces on the structure during seismic activity for the particular seismic zone can be determined by linear static analysis. But the Pushover Analysis is generally used to determine the seismic capacity of the structure to build and considered for retrofitting as per seismic design. In the procedure, a small set of lateral forces is applied and deformation is calculated. These forces are increased in steps to achieve the capacity curve or pushover curve. The curve is used to study base shear and base motion/deformation. Retrofitting approach is permitted by analysis where effectiveness for strengthening the building and their ductility can be observing.

II. RESULTS &DISCUSSION

The Pushover analysis is implemented on four L-shaped RC framed structures in plan with/without the shear wall. The structures are analyzed for two different zones by having the same structural configuration. The results so obtained for RC framed structures with & without shear walls are compared to understand the effects on various seismic parameters of structures and their performance.

Maximum Storey Drift

The story drifts in x & y direction for RC framed structure of L shaped (in the plan) are shown in Fig. 3, 4, 5

& Fig. 6 respectively. Figure 3 & Figure 4 shows the graph of story drift in RC framed structure with and without the shear wall in zone III and IV due to lateral non-linear static force (PX) in X and Y direction respectively. The curves show that the story drift of RC framed structure with the shear wall in both directions and also the story drift of RC framed structure without the shear wall in both directions are vary from each other. Figure 5 & Figure 6 shows the graph of story drift in the x & y direction of RC framed structure having PY as a lateral non-linear static force. Similarly, the graph of story drifts in the x & y direction of RC framed structure having L-shaped geometry (in the plan) with shear wall and without a shear wall in both zone III and IV are also different.

It shows that the story drifts of L-shaped geometry (in the plan) RC framed structure with a shear wall in both zones is more in the y-direction is more in x-direction due to PX. Similarly, the story drifts of L-shaped geometry (in the plan) RC framed structure with the shear wall in both zone is more in x-direction than in y-direction due to PY.

But, the comparison of story drifts of structures with the shear wall in both zone is similar in x & y direction for respective PX & PY. The story drifts increased in opposite direction having shear wall as a stiff element.

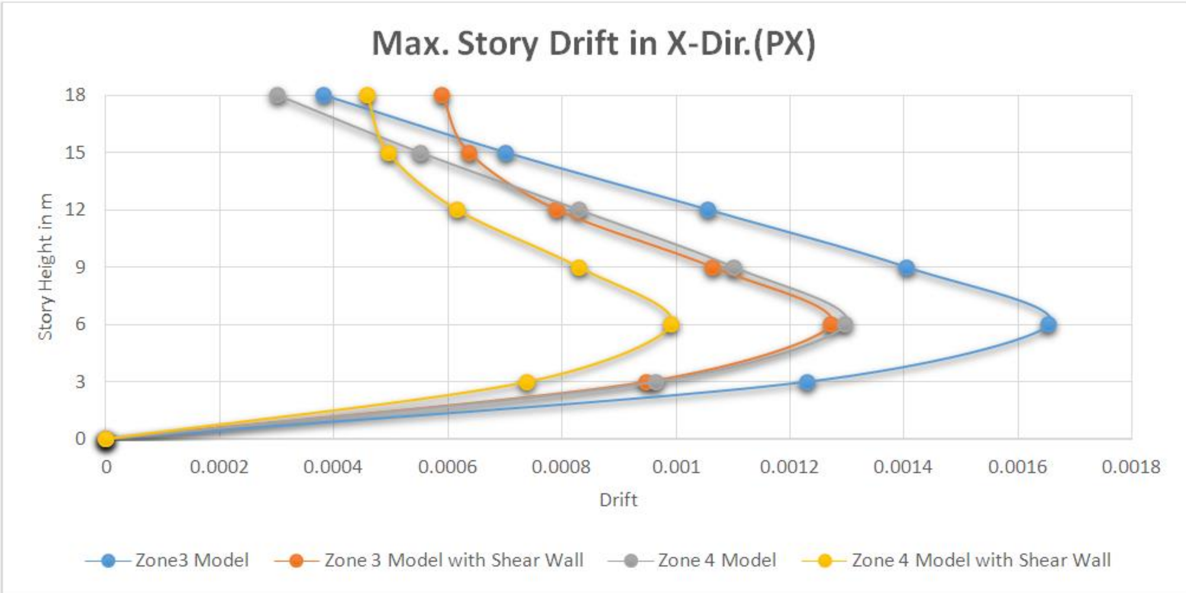

Figure 3: Comparison of Max. Story Drift in X- Dir. for PX in both zone III and zone IV with & without shear wall

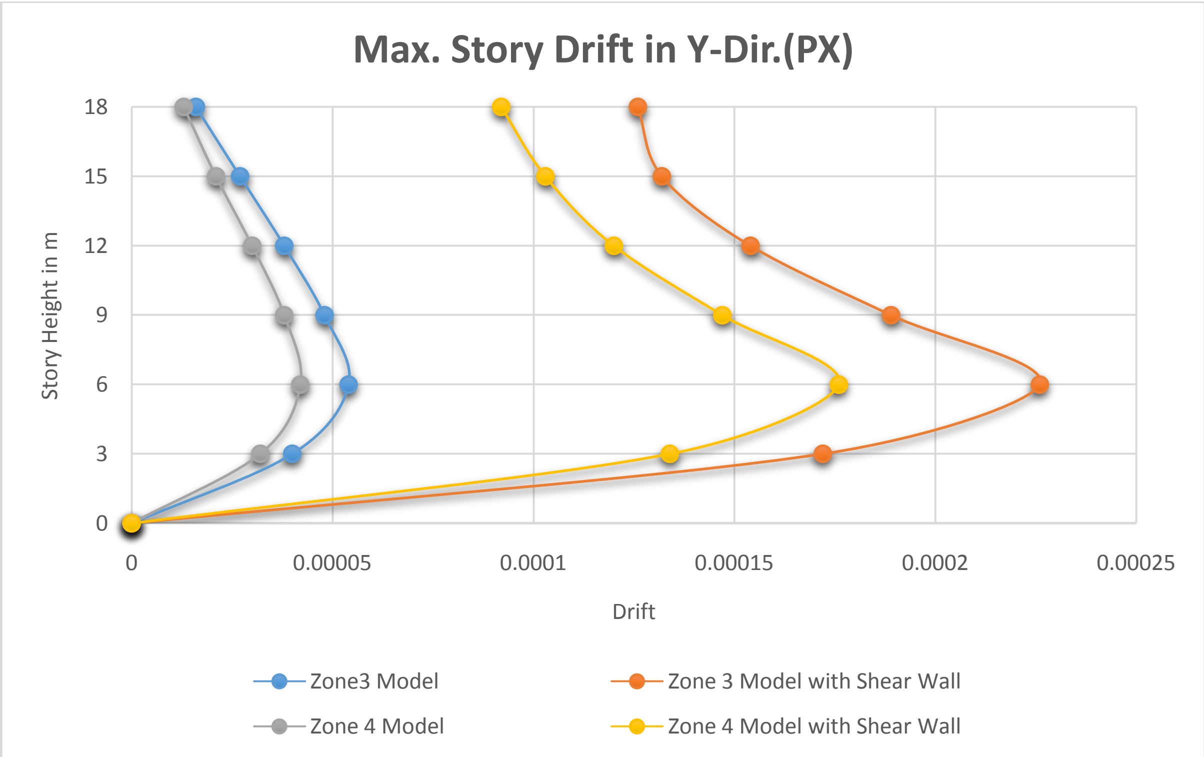

Figure 4: Comparison of Max. Story Drift in Y- Dir. for PX in both zone III and zone IV with & without shear wall

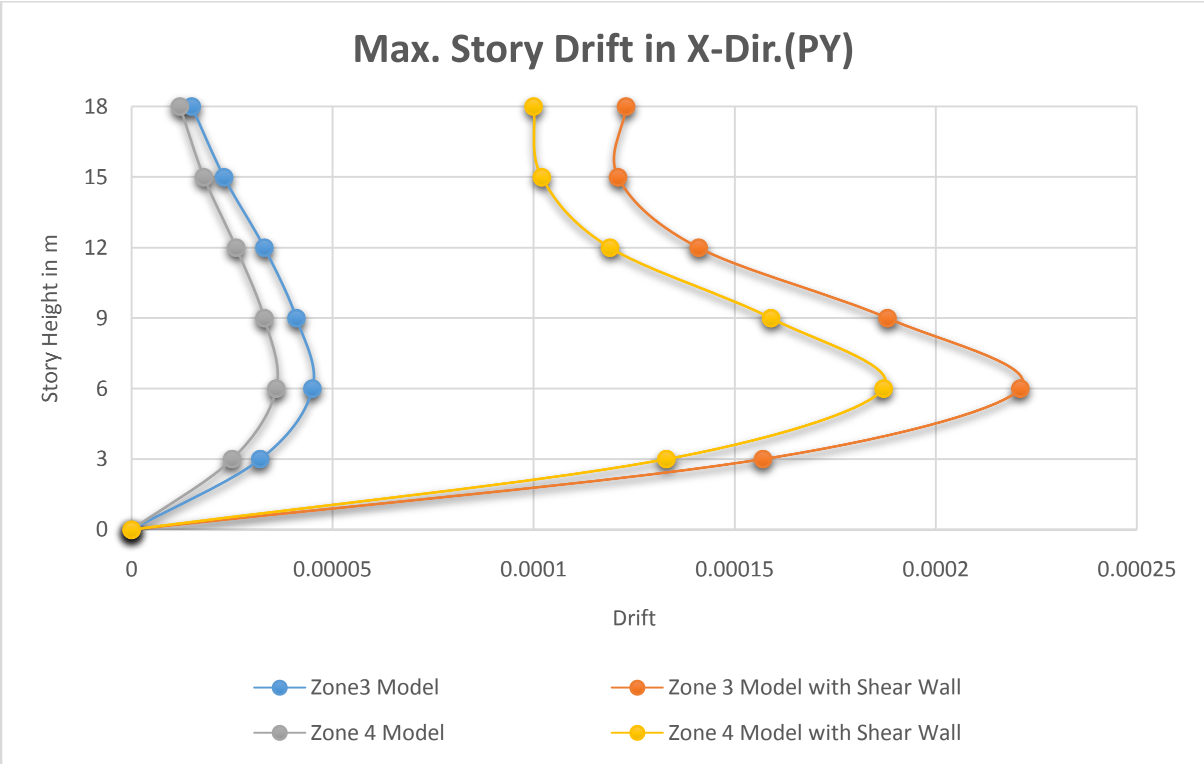

Figure 5: Comparison of Max. Story Drift in X- Dir. for PY in both zone III and zone IV with & without shear wall

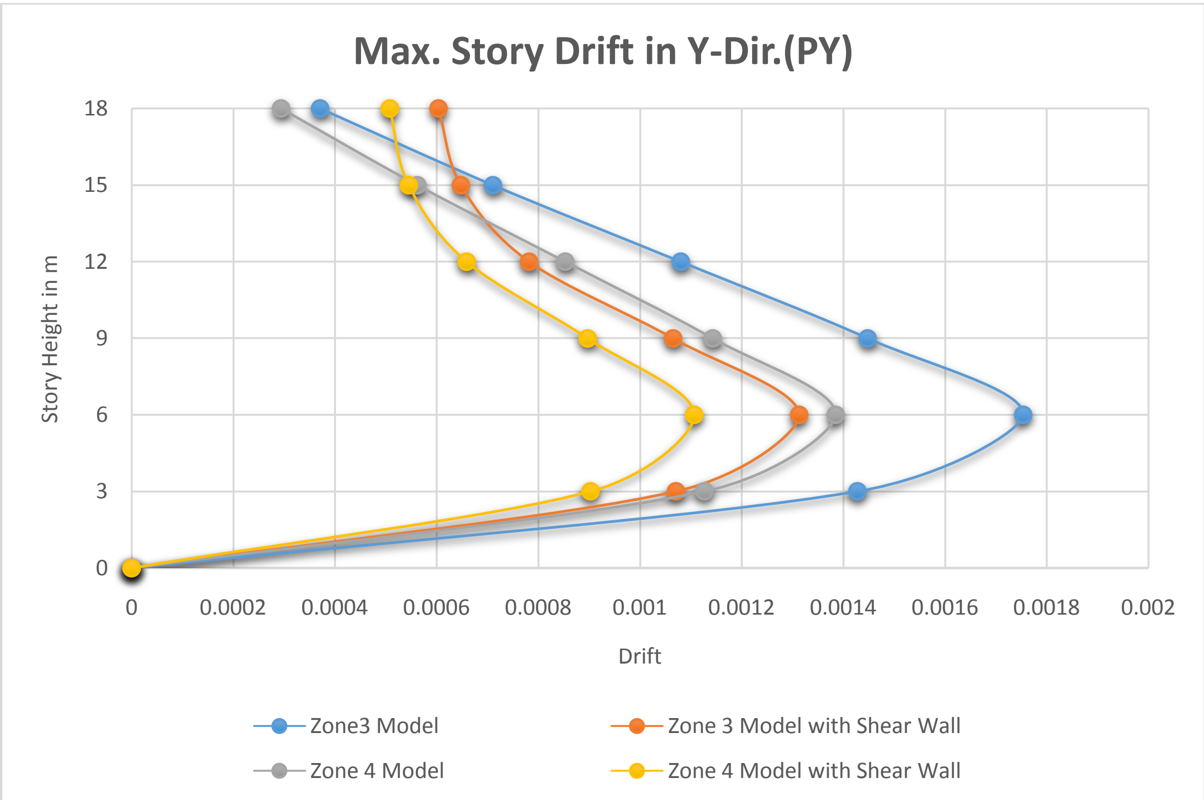

Figure 6: Comparison of Max. Story Drift in Y- Dir. for PY in both zone III and zone IV with & without shear wall

Maximum Storey Displacement

The comparison of maximum story displacement of structures with and without the shear wall in both zone shows in Fig. 7, 8, 9 & Fig. 10 respectively.

The graph showing the displacement curve for structures is decreasing as the shear wall is applied on a re-entrant corner. But for the opposite direction i.e., x-direction for PY and y-direction for PX the displacement is increased for a structure having a shear wall element.

The comparison shown in the graph indicates that the shear walls element works for the same direction forces and displacement. Hence, the shear walls as stiff elements suitable for retrofitting and be used as a preventive design technique for such corner strengthening cases.

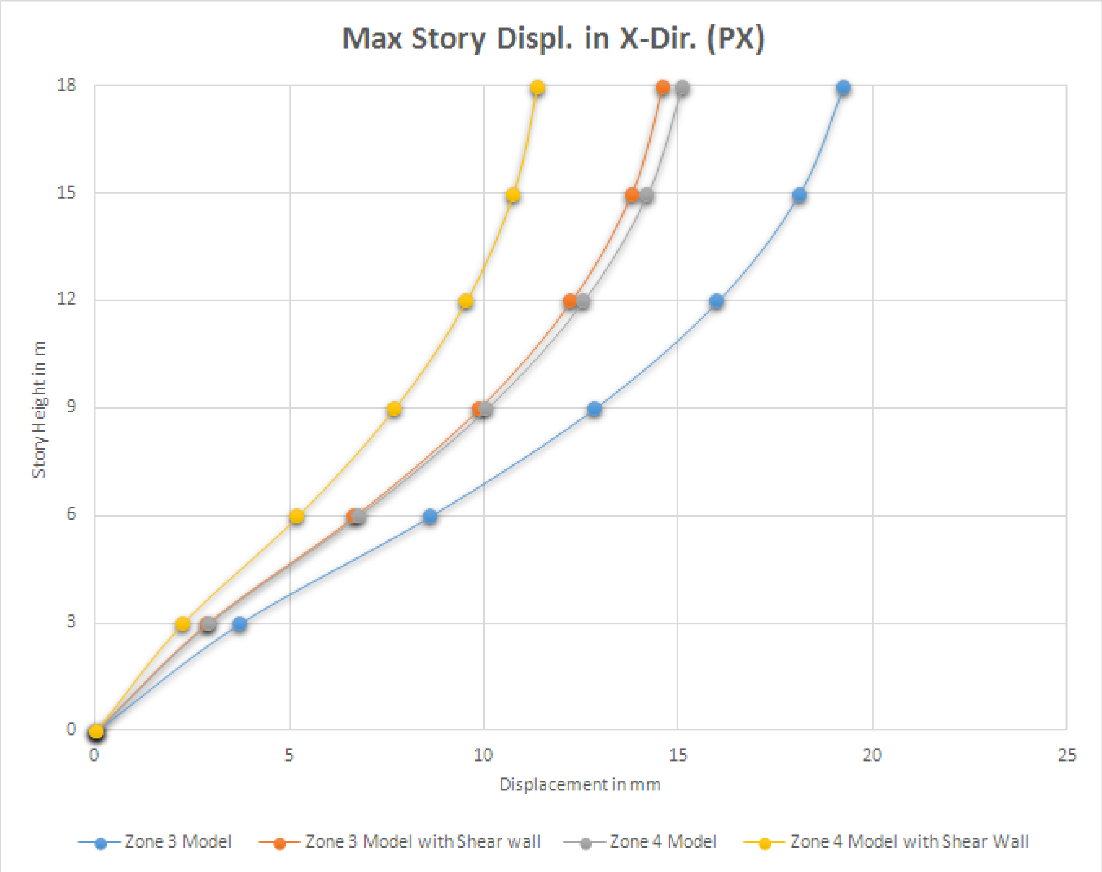

Figure 7: Comparison of Max. Story Displacement in X- Dir. for PX in both zone III and zone IV with & without shear wall

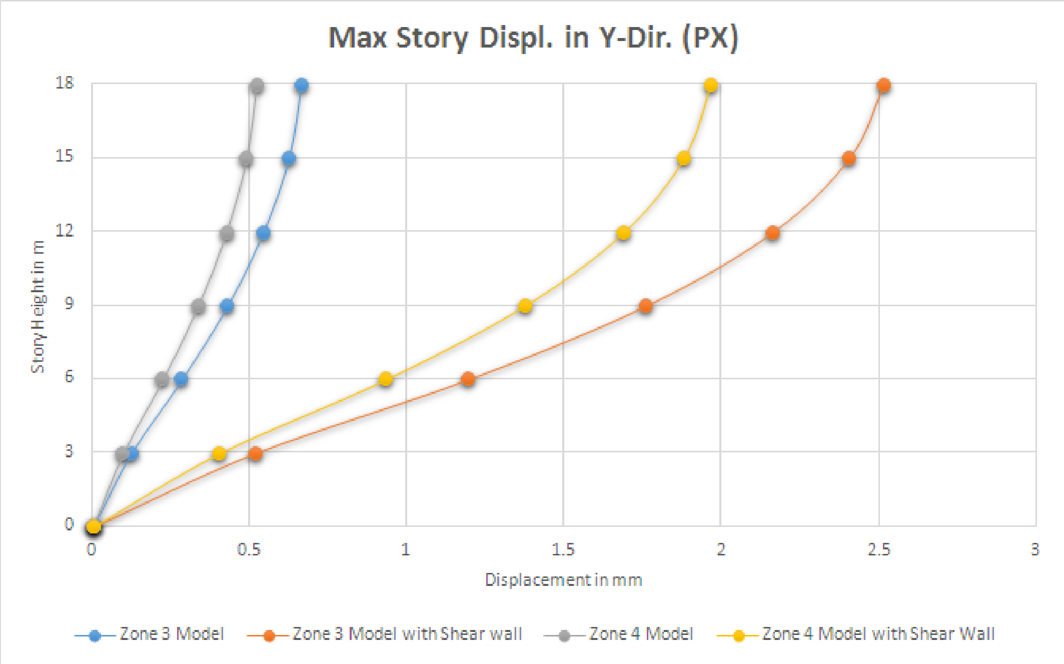

Figure 8: Comparison of Max. Story Displacement in Y- Dir. for PX in both zone III and zone IV with & without shear wall

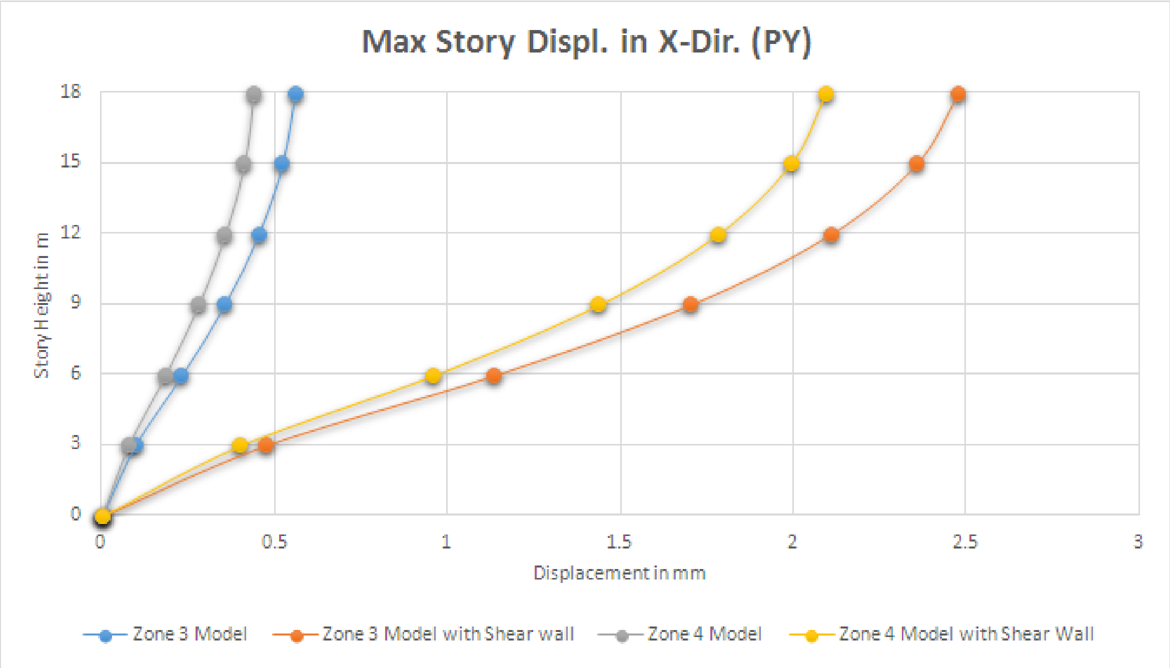

Figure 9: Comparison of Max. Story Displacement in X- Dir. for PY in both zone III and zone IV with & without shear wall

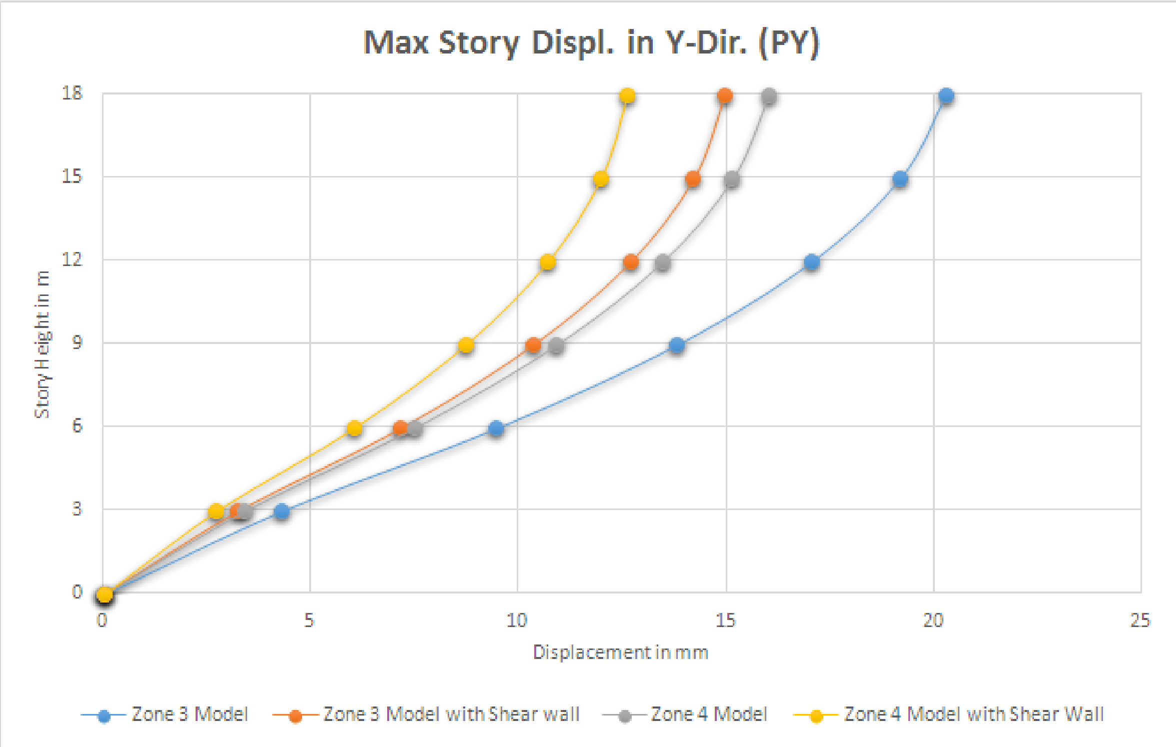

Figure 10: Comparison of Max. Story Displacement in Y- Dir. for PY in both zone III and zone IV with & without shear wall

Pushover Curves for RC framed structures

The pushover curves in x & y-direction for four structures are showninFig 11 to Fig18 respectively. The yield point & performance point found are shown in Table 2 to Table5.

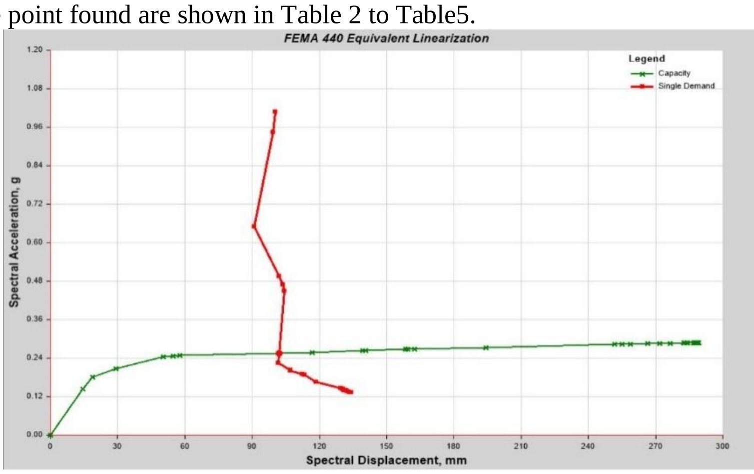

Figure 11: Pushover Curve (in X-Direction) showing performance point for L Shape Model in Zone III.

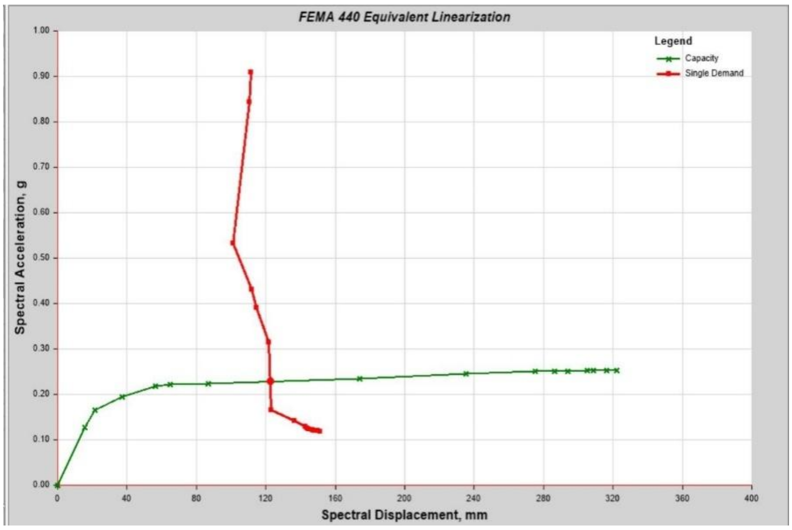

Figure 12: Pushover Curve (in Y-Direction) showing performance point for L Shape Model in Zone III.

Table 2:
Response of L Shaped Model in Zone III

Pushover Analysis	Yield point		Performance point		Performance point	
	Vy (kN)	Dy (mm)	V (kN)	D (mm)	Sa (g)	Sd (mm)
In X-Direction	6299.96	26.7	7195.7	117.9	0.255	102.13
In Y-Direction	5694.88	29.6	6522.7	140.7	0.228	122.48

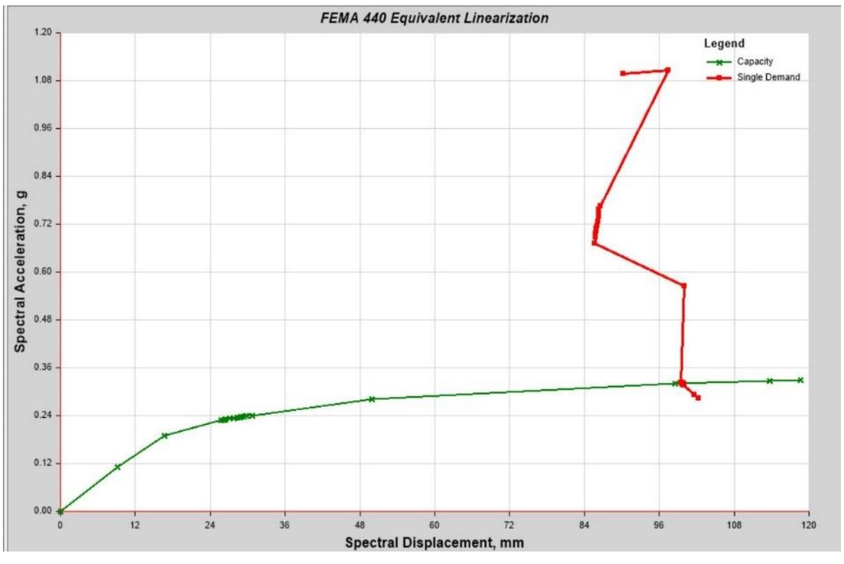

Figure 13: Pushover Curve (in X-Direction) showing performance point for L Shape Model with Shear Wall in Zone III.

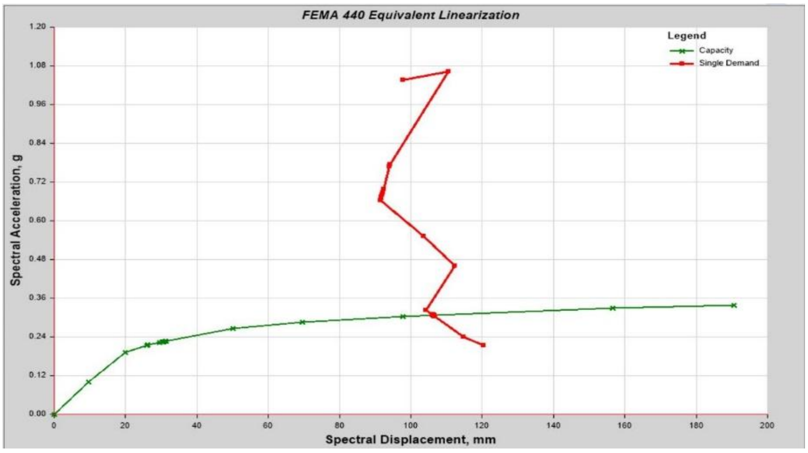

Figure 14: Pushover Curve (in Y-Direction) showing performance point for L Shape Model with shear Wall in Zone III.

Table 3:
Response of L Shaped Model with shear wall in Zone III

Pushover Analysis	**Yield point**		**Performance point**		**Performance point**	
	Vy (kN)	Dy (mm)	V (kN)	D (mm)	Sa (g)	Sd (mm)
In X-Direction	8089.17	30.74	9805.8	129.6	0.320	99.69
In Y-Direction	7708.97	34.76	9189.45	135.4	0.307	106.36

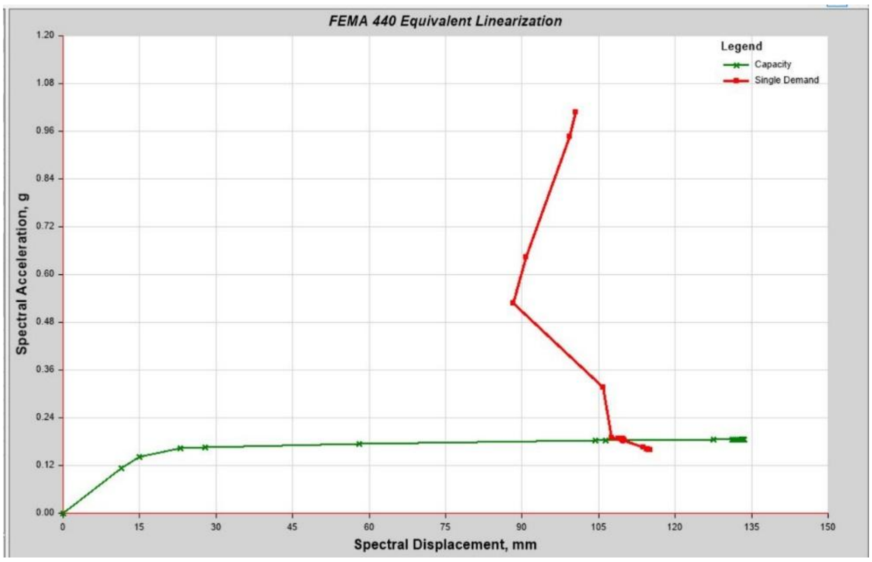

Figure 15: Pushover Curve (in X-Direction) showing performance point for L Shape Model in Zone IV.

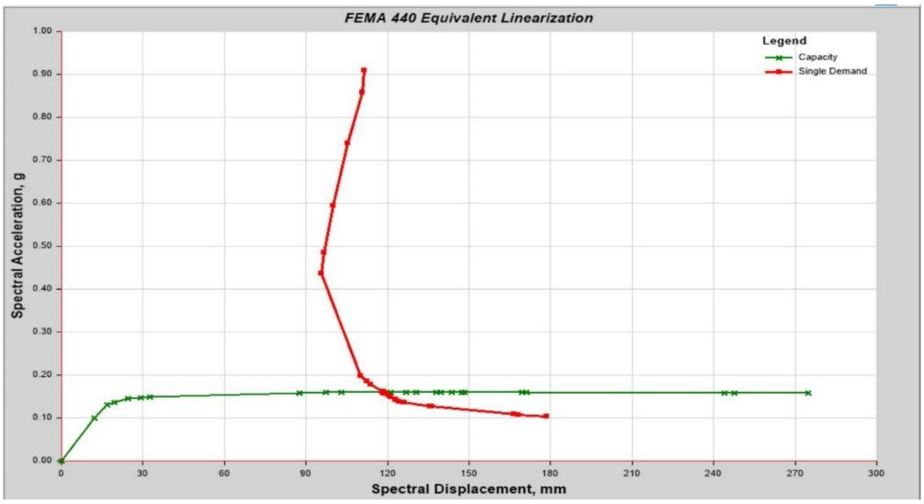

Figure 16: Pushover Curve (in Y-Direction) showing performance point for L Shape Model in Zone IV.

Table 4:
Response of L Shaped Model in Zone IV

Pushover Analysis	Yield point		Performance point		Performance point	
	Vy (kN)	Dy (mm)	V (kN)	D (mm)	Sa (g)	Sd (mm)
In X-Direction	4766.7	20.22	5327.03	126.9	0.184	109.8
In Y-Direction	4300.6	22.36	4721.41	134.6	0.160	118.4

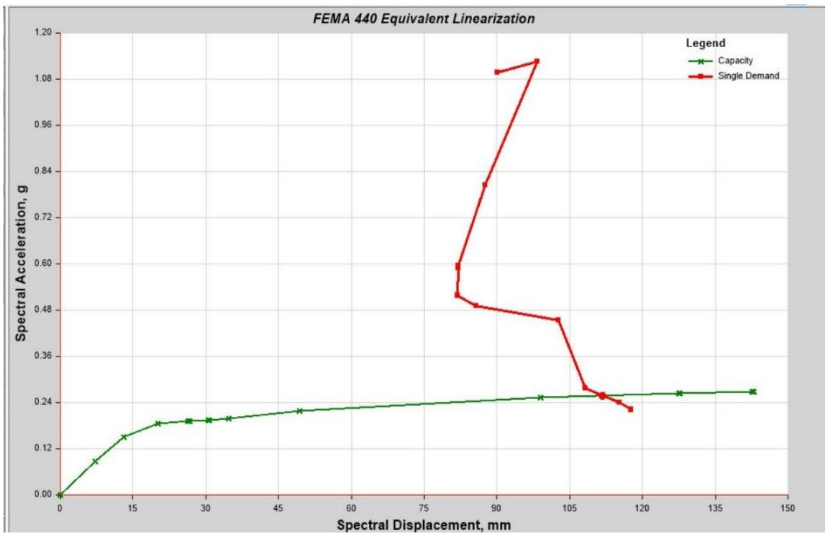

Figure 17: Pushover Curve (in X-Direction) showing performance point for L Shape Model with Shear Wall in Zone IV.

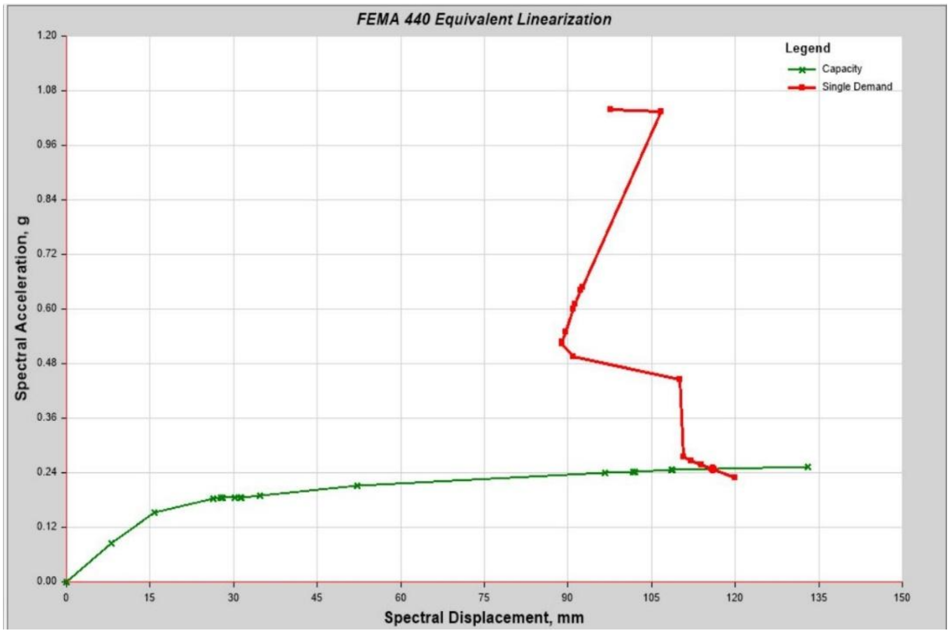

Figure 18: Pushover Curve (in Y-Direction) showing performance point for L Shape Model with Shear Wall in Zone IV.

Table 5:
Response of L Shaped Model with shear wall in Zone IV

Pushover Analysis	Yield point		Performance point		Performance point	
	Vy (kN)	Dy (mm)	V (kN)	D (mm)	Sa (g)	Sd (mm)
In X-Direction	6569.25	24.97	7943.33	145.3	0.258	111.75
In Y-Direction	6227.75	27.99	7496.29	147.4	0.247	115.94

III. DISCUSSION ON PUSHOVER GRAPHS

The capacity curves in the x & y direction for L-Shaped structures with the shear wall in both zone show less ductile behavior in both the x and y direction as the structure deflects very later representing the structure was subjected to more base shear. The ductile behavior was more in x-direction & in y-direction for L-Shaped structures without a shear wall. The curves deflect early indicating the large ductile nature of structures.

The Base Shear is improved by 30% in zone III and 35% in zone IV when the shear wall is used as a stiff resisting element.

IV. CONCLUSION

The conclusion achieved by analysis and comparison of results for four structures with and without shear wall are as follows:

1. The nonlinear static method shows the structural performance at immediate occupancy (IO), life safety (LS) & collapse prevention (CP) category. The hinge result determines the performance level of the structure with different conditions.
2. The story drifts of a framed structure with the shear wall as a stiff element at the re-entrant corner are less than structures without a shear wall in both zones. The curves show that the story drift of structure with a shear wall in both directions and also the story drift of structure without a shear wall in both directions differ from each other in x and y directions for the same load condition.
3. The story displacement graphs of four structures with and without a shear wall in both the zone indicate the displacement in direction with load condition i.e., x-direction for PX is less for stiff element (shear wall at the re-entrant corner) but for direction in different load conditions i.e., y-direction for PX shows that stiff element (shear wall at the re-

entrant corner) displacement is more than a regular model.

4. The stiffness of structure in both zones is the same for a model with shear wall and without shear wall respectively and lateral loads are the same for respective zones for both models compared.

5. The Pushover Curve in the above study shows that a structure with a shear wall as a stiff element in the re-entrant corner provides more rigidity at the joints.

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