Comparative Analysis of Regular and Irregular Buildings With and Without Shear Wall

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Abstract: **Modern residential structure are going higher and higher these days. The impact of lateral loads in the form of wind/Earthquakes affects the performance of these structures dramatically. It is often a common practice among structural engineers to use shear walls in place of columns. In the present study the comparison of seismic behaviour of G+10 storey buildings having horizontal irregularity with the regular building of similar properties with and without shear wall by using ETAB software was done. For this purpose four multi-storey building plans are considered that are symmetric plan, L shape, T shape, and + shape. For the comparison, parameters taken are lateral displacement, storey drift and model period. All the four buildings were analyzed for zone IV. Modal Period with different configuration of building, Storey Displacement of structure with different configuration of building, Storey Drift with different configuration of building were studied and their comparison was done.**

***Keywords*: Regular and Irregular Buildings, Shear wall, ETABs Software, Seismic and wind forces, Storey Displacement, Storey drift and Modal period.**

I. INTRODUCTION

Tall towers and buildings have fascinated mankind from the beginning of civilization, their construction being initially for defense and subsequently for ecclesiastical purposes. The growth in modern tall building construction, however, which began in the 1880s, has been largely for commercial and residential purposes. Tall commercial buildings are primarily a response to the demand by business activities to be as close to each other and to the city centre, as possible, thereby putting intense pressure on the available land space. Also, because they form distinctive landmarks, tall commercial buildings are frequently developed in city centers as prestige symbols for corporate organizations. The rapid growth of the urban population and the consequent pressure on limited space has considerably influenced city residential development.

Shear walls are structural systems which provide stability to structures from lateral loads like (due to its self-weight and other living / moving loads) but they are also designed for lateral loads of earthquakes / wind. The shear wall structural systems are more stable because their supporting area (total cross sectional area of all shear walls) with reference to total plans area of building is comparatively more unlike in the case of RCC framed structures. Shear walls are quick in construction, as the method adopted to construct is concreting the members using formwork.

Irregularity is different types such as vertical irregularity and horizontal irregularity. Vertical irregularity refers to sudden change of strength, stiffness, geometry and mass result in irregular distribution of forces and /or deformation over the height of building. Horizontal Irregularity refers to asymmetrical plan shapes (e.g.: L-, T-, U-, F-,+-) or discontinuities in the horizontal resisting elements (diaphragms) such as cut-outs, large openings, re-entrant corners and other abrupt changes resulting in torsion, diaphragm deformations and stress concentration. Shear walls are not only designed to resist gravity / vertical loads (due to its self-weight and other living / moving loads) but also designed for lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors (diaphragms) and other lateral walls running across at right angles, thereby giving the three dimensional stability for the building structures.

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS features an intuitive and powerful graphical interface coupled with unmatched modelling, analytical, design, and detailing procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviours, making it the tool of choice for structural engineers in the building industry. Most buildings are of straightforward geometry with horizontal beams and vertical columns. Many of the floor levels in buildings are similar. The commonality of floors in the buildings can dramatically reduce modelling and design time.

II. LITERATURE REVIEW

To analyze high-rise box system structures considering the effects of floor slabs, an efficient method was proposed which reduce computational time and memory in the analysis by using sub structuring technique and matrix condensation. The effects of floor slabs on seismic response of high rise apartment building structures were also investigated [**Guen Lee et al.(2002)].** Two types of irregularities in the building models i.e. plan irregularity with geometric and diaphragm discontinuity and vertical irregularity with setback and sloping ground was analyzed. These irregularities are created as per clause 7.1 of IS 1893 (part1)2002 code. Effect of three different lateral load patterns on the performance of various irregular buildings in pushover analysis was also studied [**Ravikumar C M et.al. (2012)**]. The response spectrum, time history and linking slab in-plan stresses analysis were executed combined with practical project with inclined columns by several programs such as ETABS, SAP2000, MIDAS/gen and SATWE. The results of time history analysis by SAP2000 and ETABS are roughly similar. SAP2000 did not have the concept of storey which made the post-processing much more complicated. For regular structure ETABS is recommended and for gymnasium or space truss structures SAP2000 has irreplaceable advantages [**Hu Kai et al.(2012)].** RCC Building of 10 storeys with and without shear wall was analyzed for seismic behaviour. It was observed that large dimension of shear wall was not effective in 10 storey or below 10 storey buildings and the shear wall was economical and effective in high rise building [**Chandurkar et.al. (2013)]**. They presented the results of a simplified model for the analysis of free-plan buildings based on sub structuring of the structural elements, the shear wall core (WCA), the perimeter frame and the floor slabs (finite element model) [**Encina Javier et al. (2013)].** The response parameters like story drift, story deflection and story shear of structure under seismic force under the linear static & dynamic analysis of G+10 vertically irregular buildings was studied using commercial software CSI-ETABS (version 9.7)[**Abdul Rahman et al.(2013)].** 14 storey building with varying location of shear wall for determining parameters like storey drift, storey shear and storey moment was analyzed using ETABS V9.7.1 software. All necessary load combinations were considered in shear walls analysis and frame analysis. Wind load and seismic load was considered as external lateral load in the dynamic analysis [**Mon (2014)**]. 20 storey buildings with horizontal irregularity were modelled in program STAAD.pro and analyzed for their stability. Irregular plan like L - shape, H – shape and U- shape were considered for study. Buildings are analyzed for Dead loads, Live loads, wind loads as per IS 875 and earthquake load as per IS 1893: 2002. Parameters like internal forces and roof displacement were used for the assessment [**Gaur et.al. (2014)**]. Fundamental periods of eccentrically braced frame (EBF) structures of no. in 12 with varying geometric irregularities were designed and analyzed. From statistical comparison it was concluded that 3-variable power model was better fit to the Rayleigh data than equations which were dependent on height only [**Young Kelly et al. (2016)].**

III. MODELS CONSIDERED FOR ANALYSIS

Nine types of models have been considered for analysis. It was attempted to choose models that are representative of actual building types that are being constructed nowadays. Type 1 is regular framed structure with and without shear wall. Type 2, Type-3, Type-4, Type-5 are L-shape Irregular framed structure with and without shear wall. Type A and Type-B are T-shape Irregular framed structure with and without shear wall. Type-C and Type-D are + shape framed structure with and without shear wall.

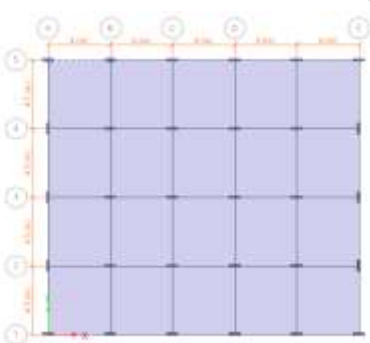


Fig.1: Regular framed structure without shear wall (Type-1)

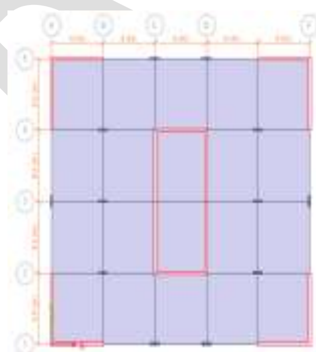


Fig.2: Regular Framed structure with shear wall (Type-1)

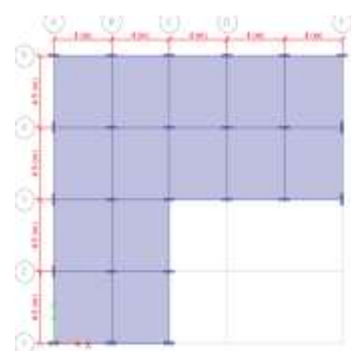


Fig.3: L-shape structure without shear wall (Type-2)

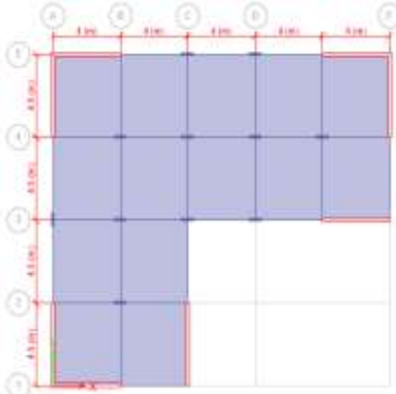


Fig.4: L-shape structure with shear wall (Type-2)

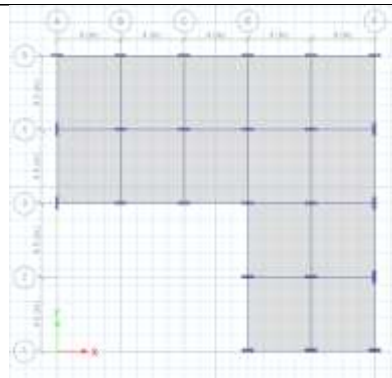


Fig.5: L-shape structure without shear wall (Type-3)

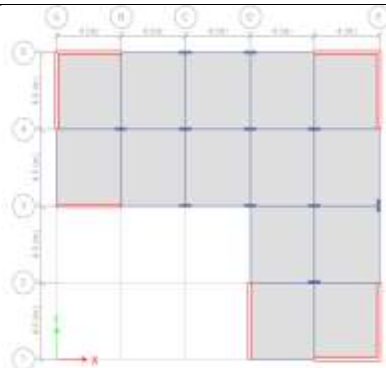


Fig.6: L-shape structure with shear wall (Type-3)

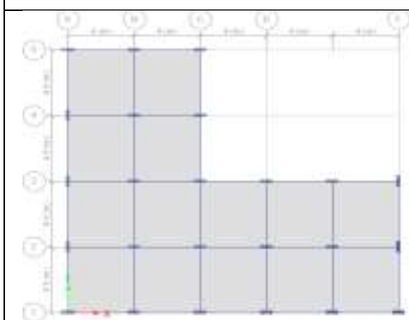


Fig.7: L-shape structure without shear wall (Type-4)

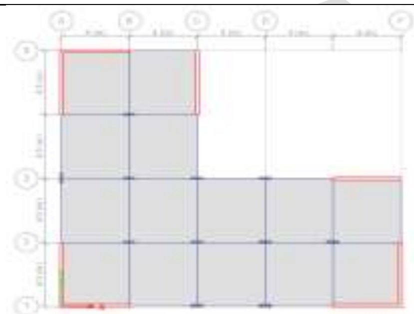


Fig.8: L-shape structure with shear wall (Type-4)

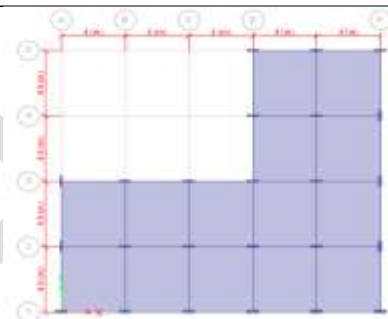


Fig.9: L-shape structure without shear wall (Type-5)

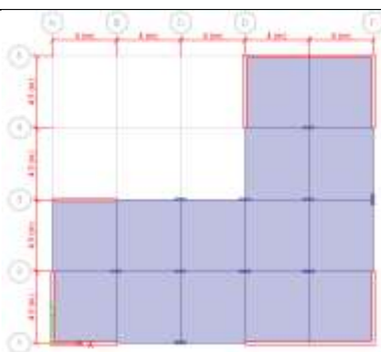


Fig.10: L-shape structure with shear wall (Type-5)

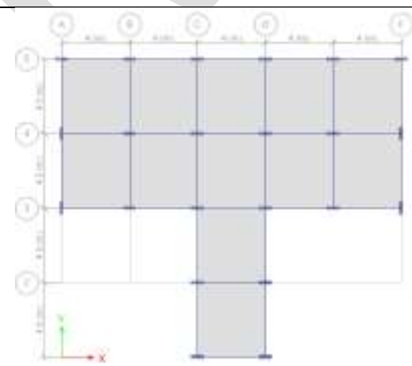


Fig.11: T-shape structure without shear wall (Type-A)

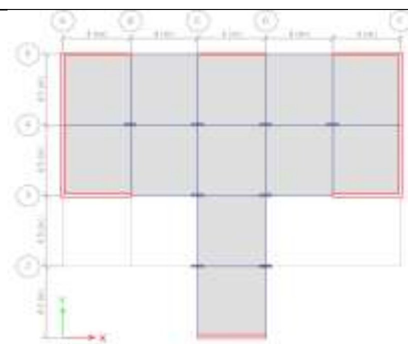


Fig.12: T-shape structure with shear wall (Type-A)

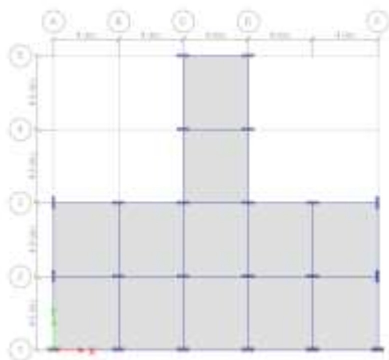


Fig.13: T-shape structure without shear wall (Type-B)

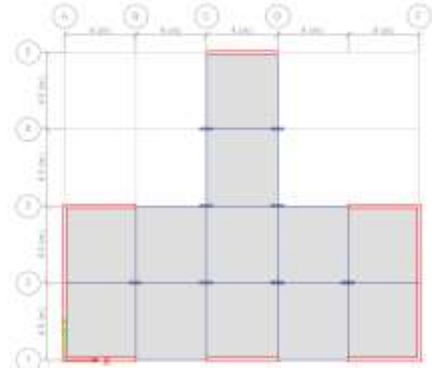


Fig.14: T-shape structure with shear wall (Type-B)

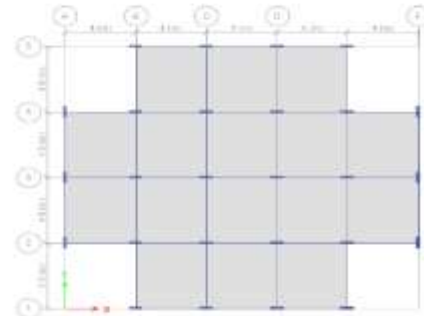


Fig.15: + -shape structure without shear wall (Type-C)

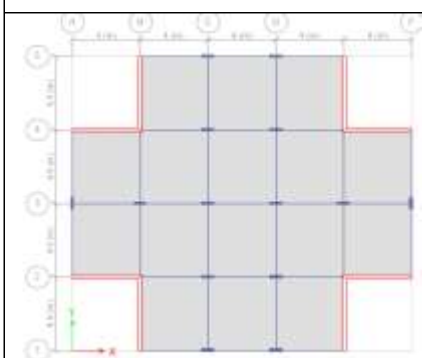


Fig.16: + -shape structure with shear wall (Type-C)

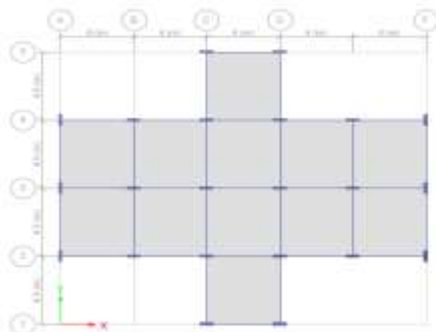


Fig.17: + -shape structure without shear wall (Type-D)

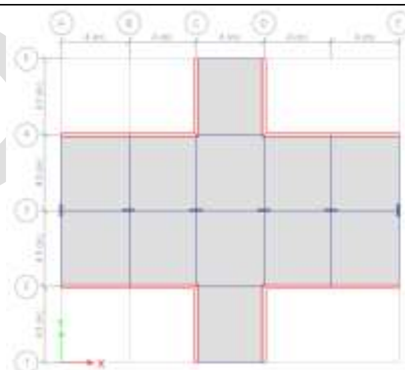


Fig.18: + -shape structure with shear wall (Type-D)

IV. DESIGN BASIS

Table- 1 Design Data of RCC Frame Structures

S.No	Particulars	Dimension/Size/Value
1.	Model	G+10
2.	Seismic Zones	IV
3.	Floor height	3M
4.	Basement	3.5M
5.	Building height	33.5m
6.	Plan size	20mx18m
8.	Size of columns	700mm×300mm (M35)
9.	Size of beams	300mm×600mm (M30) throughout
10	Shear Walls	0.23m
11.	Thickness of slab	150mm
12.	Earthquake load	As per IS-1893-2002
13.	Type of soil	Type -II, Medium soil as per IS-1893
14.	E_c	5000√fck N/ mm2(E_c is short term static modulus of elasticity in N/ mm^2)
15.	F_{ck}	0.7√fc k N/ mm2(F_{ck} is characteristic cube strength of concrete in N/ mm2

16.	Live load	2 kN/ m2
17.	Floor finish	1.00kN/ m2
18.	Services	1.00kN/ m2
19	Specific wt. of RCC	25.00 kN/ m2
20.	Specific wt. of infill	20.00 kN/ m2
21.	Material used	Concrete M-25, M-30 and M35 and Reinforcement Fe-500(HYSD Confirming to IS-1786)
22.	Reinforcement used	High strength deformed steel Confirming to IS-786. It is having modulus of Elasticity as 200 kN/ mm2
23.	Static analysis	Equivalent static lateral force method.
24.	Dynamic analysis	Using Response spectrum method
25.	Software used	ETABS for both static and dynamic analysis
26.	Specified characteristic	compressive strength of 150mm cube at 28 days for M-30 grade concrete - 30N/ mm^2
27.	Fundamental natural period of building	Ta = 0.075 $h^{0.75}$ for moment resisting RC frame building without infill wall. Ta = 0 .09 h /√d for all other building moment resisting RC frame building with brick infill walls ere h = height of building , base dimension of building at plinth level in m along the Considered direction of lateral forces.
28.	Zone factor Z	0.24, As per Is-1893-2002 Part -1 for different. Zone as per clause 6.4.2.

4.1ANALYSIS OF FORCES

4.1.1 Model Parameters

For the analysis of multi storey building nine types of models have been considered for analysis. Type -1 is regular framed structure with and without shear wall. Type-2, Type-3, Type-4 and Type-5 L-shape framed structure with and without shear wall. Type A, Type-B T-shape framed structure with and without shear wall. Type-C and Type- D is + shape framed structure with and without shear wall. In the current study main goal is Dynamic Analysis of different types of building.

4.1.3 Wind Load (WL)

The wind velocity at Delhi is 47m/s. The other parameter of wind load as per IS: 875 (Part-3) is summarized below:

Table-2 Wind parameters

Sl.	Description	Value	Reference
01	Terrain category.	2	IS-875
02	Class of structure.	B	IS-875
03	Probability factor, k1.	1.0	IS-875
04	Terrain, height and structure size factor, k2.	As/Height	IS-875
05	Topography factor, k3.	1.0	IS-875

4.1.4 Seismic Load (EQ)

Seismic loads to be applied for structures were in accordance with the applicable provision of the IS 1893, 2002 and noted below:

Table-3 Seismic parameters

Sl.	Description	Value	Reference
01	Seismic Factor for Zone : IV	0.24	IS-1893
02	Structure importance	1.0	IS-1893
	coefficient, I.		
03	Response reduction factor, R	5.00	IS-1893
04	Damping	5%	IS-1893
05	Time period	Variable	IS-1893

4.1.5 Load Combinations

For the design of superstructure the loads combinations shall be as follows:

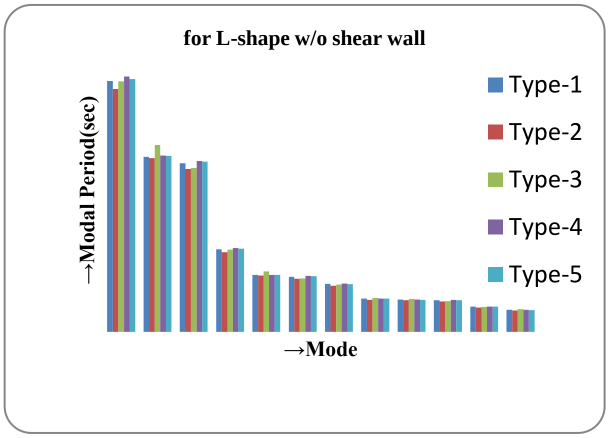
Table -4 Load combinations

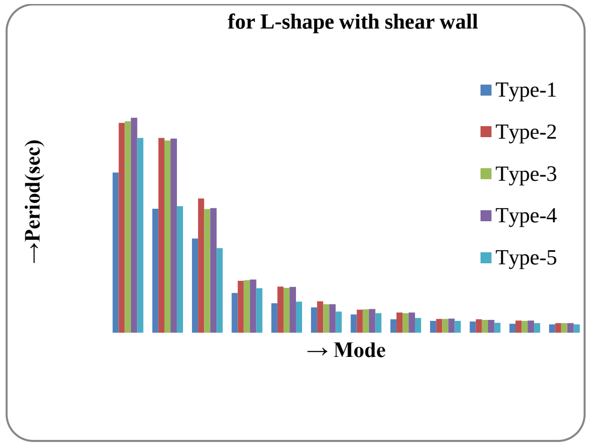
Sr. No.	Load combination
1	1.5 (DL + LL)
2	1.2 (DL + LL ±EQX)
3	1.2 (DL + LL ± EQY)
4	1.5 (DL ± EQX)
5	1.5 (DL ±EQY)
6	1.2 (DL + LL ± WLX)
7	1.2 (DL + LL±WLY)

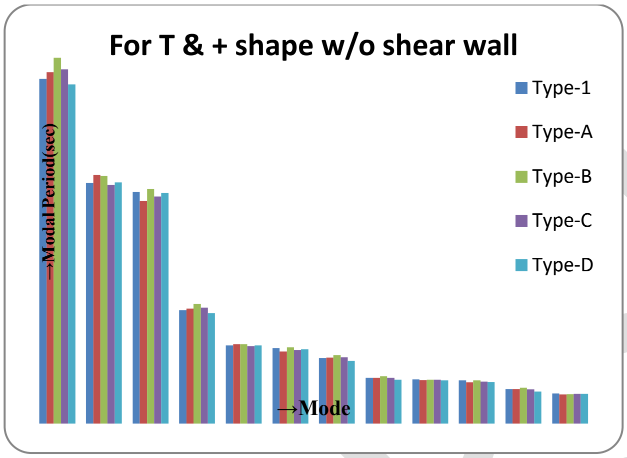
V. RESULTS AND DISCUSSIONS

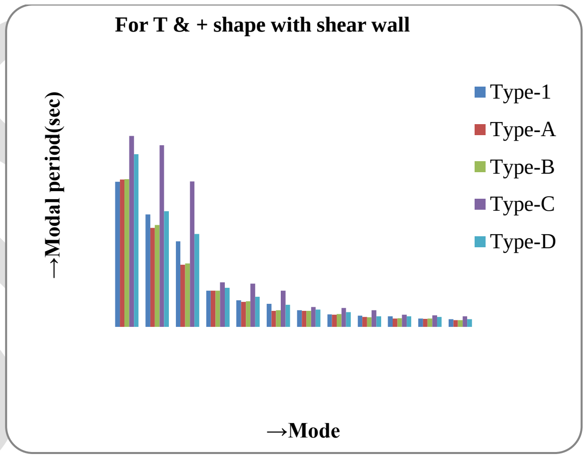
The analysis of different models produced a large set of data. Microsoft excel was used for tabulation, plotting and analysis of results obtained by ETABS analysis. The first objective was to figure out the key parameters that affected the building. Tabulation was done for different key parameters for all the models.

5.1.1 Modal period

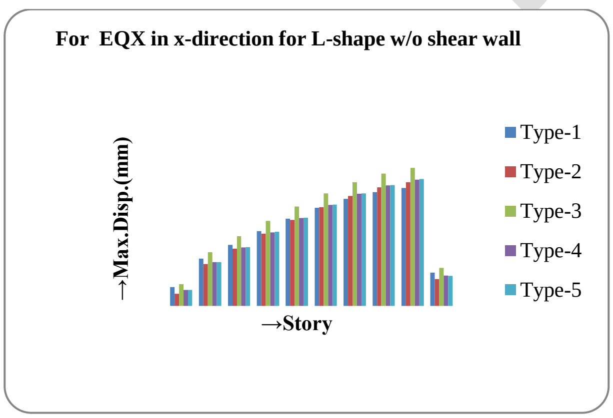


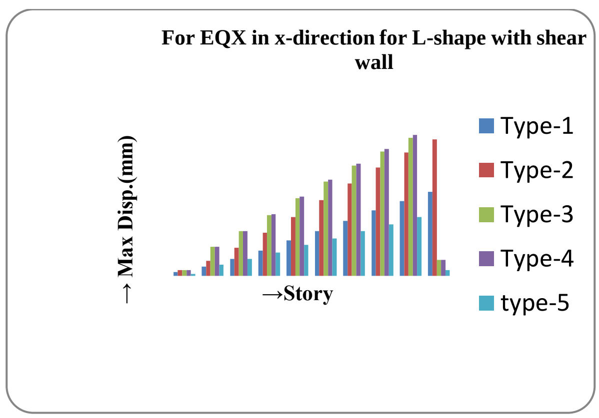


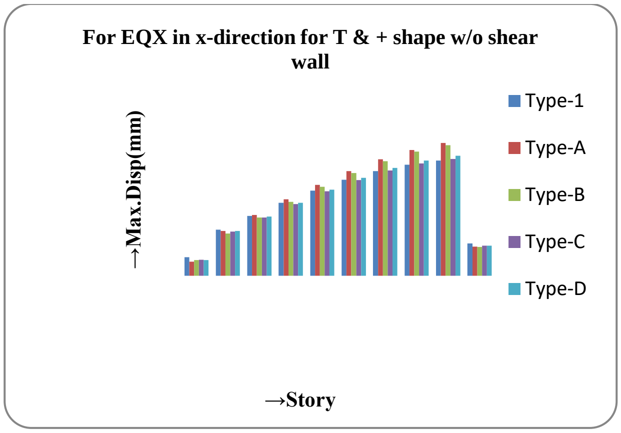




5.1.2 Storey Displacement in x-direction



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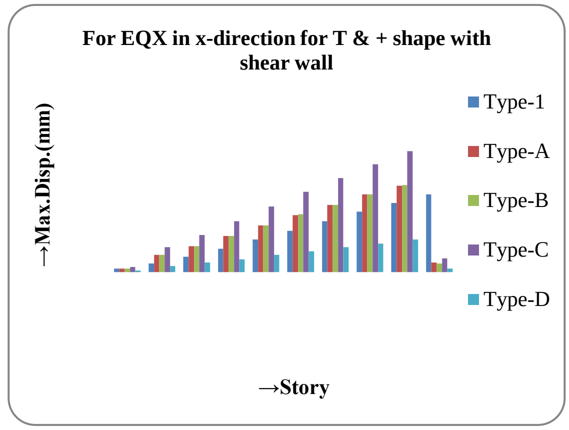
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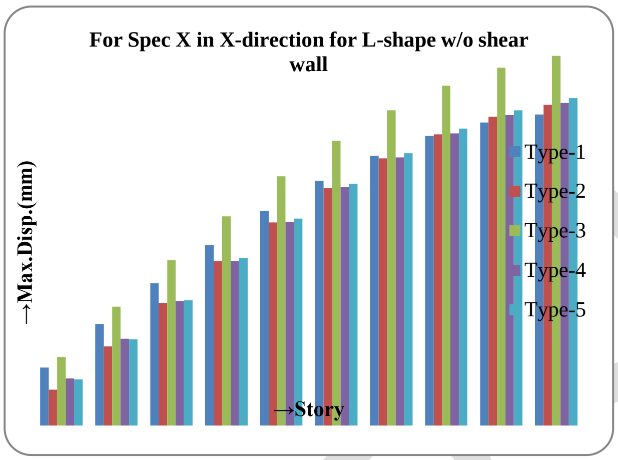
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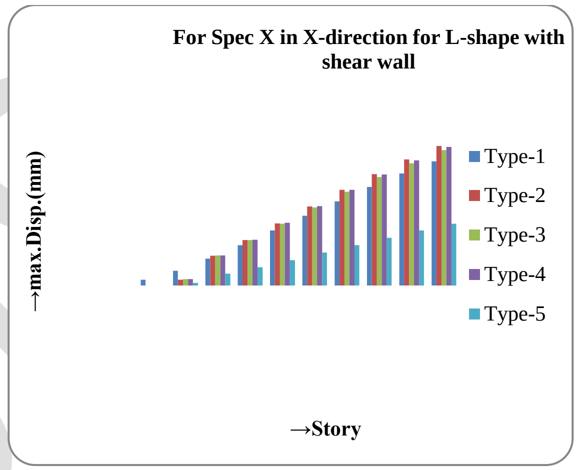
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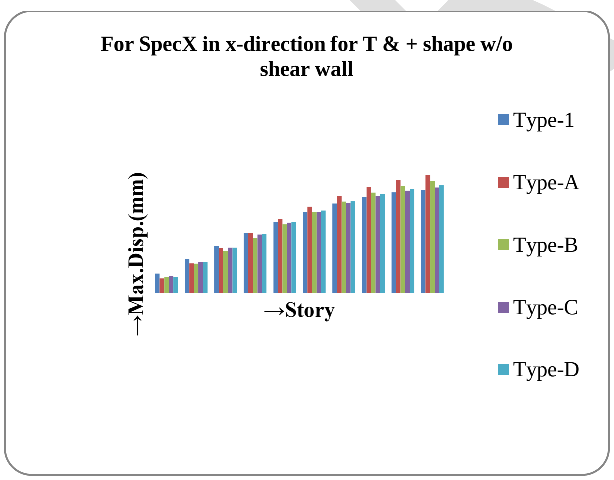
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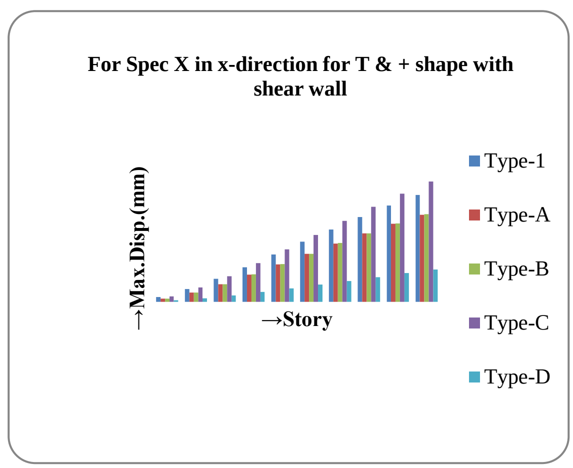
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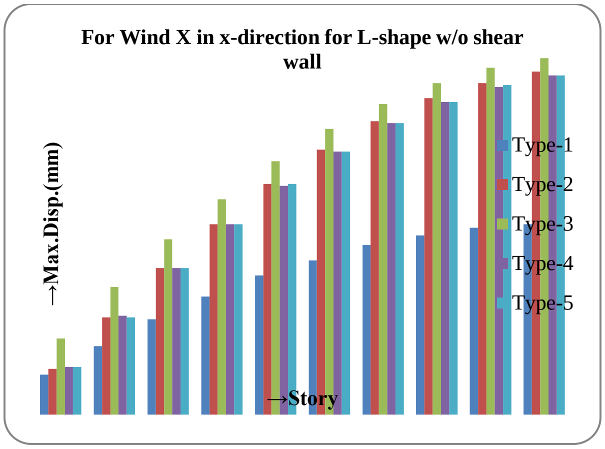
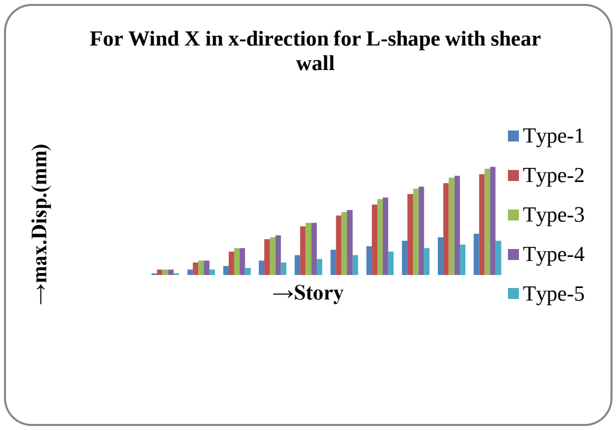
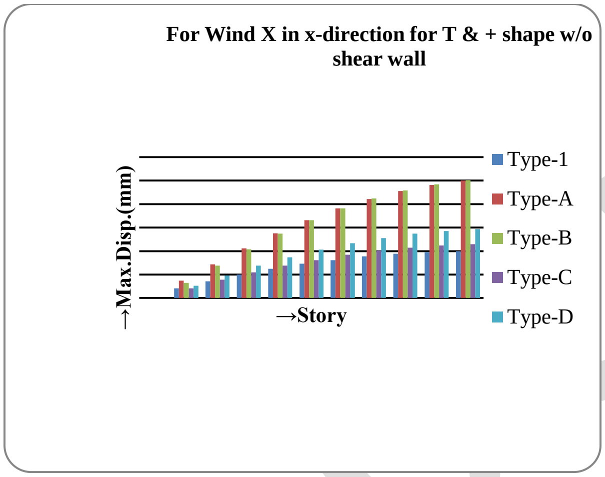
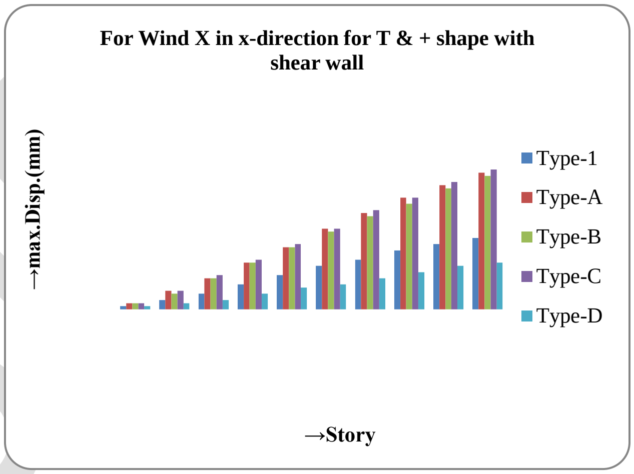
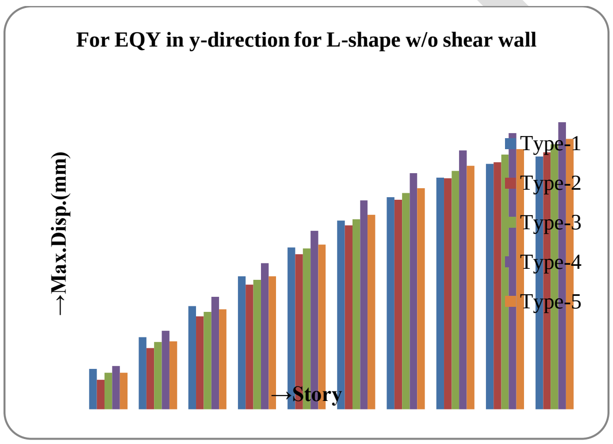


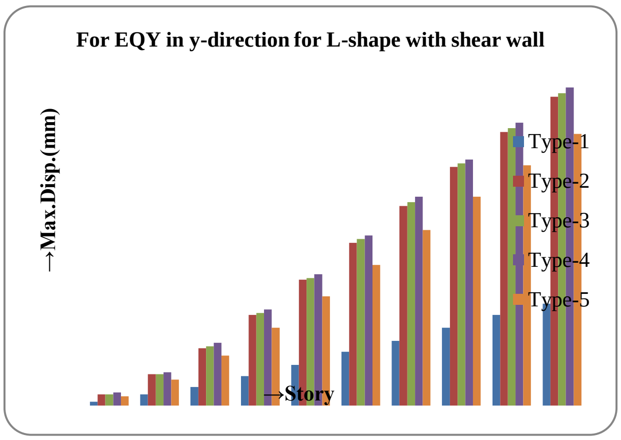


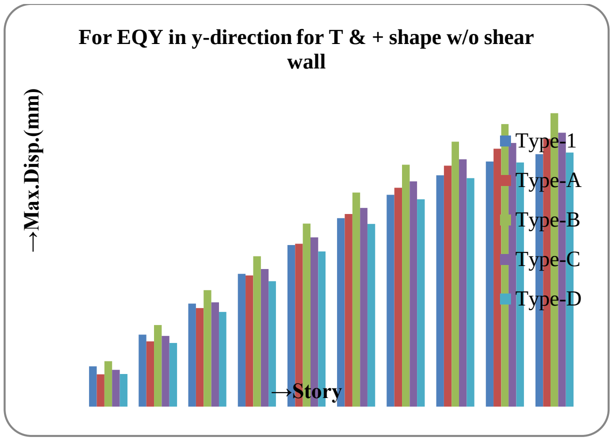




5.1.3 Storey displacement in y-direction



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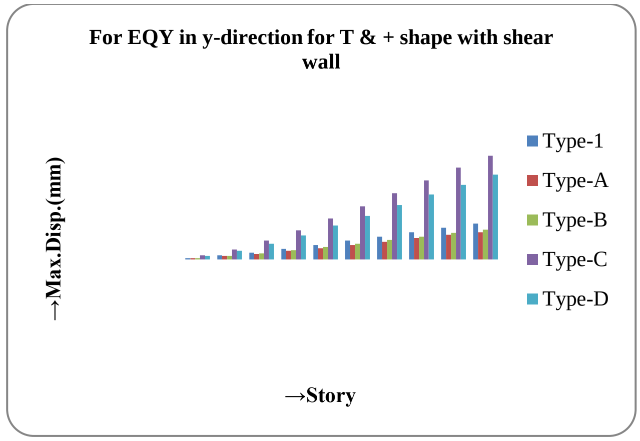
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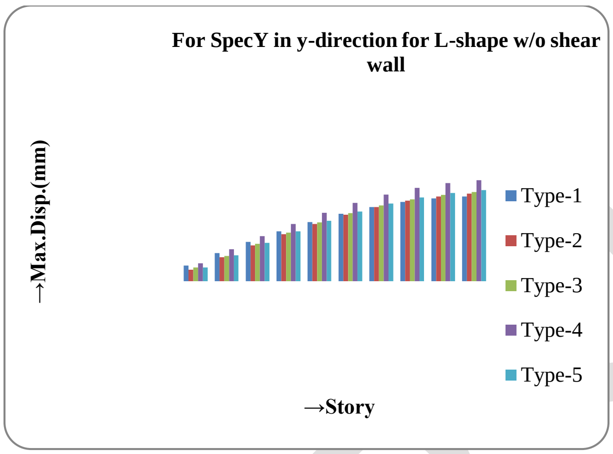
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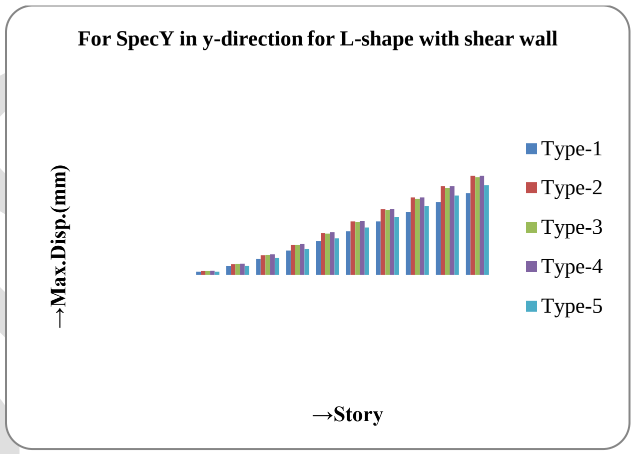
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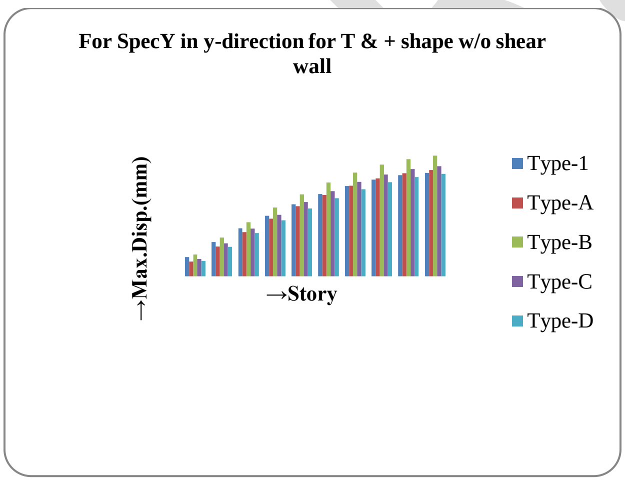
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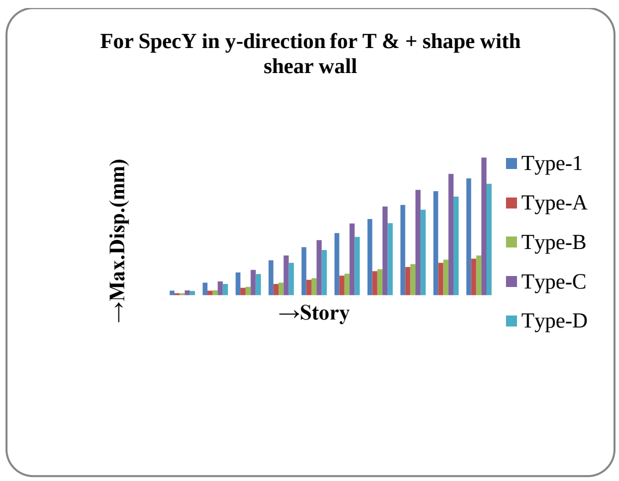
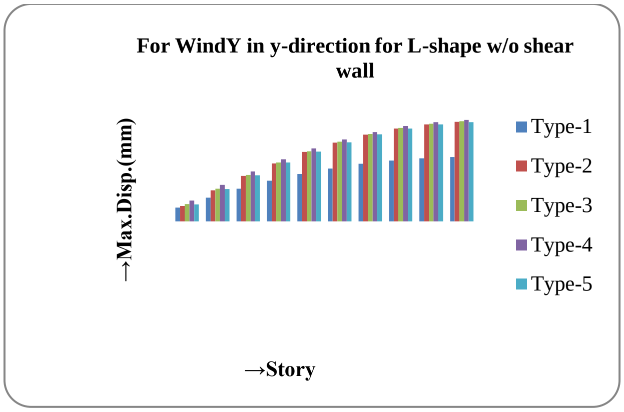
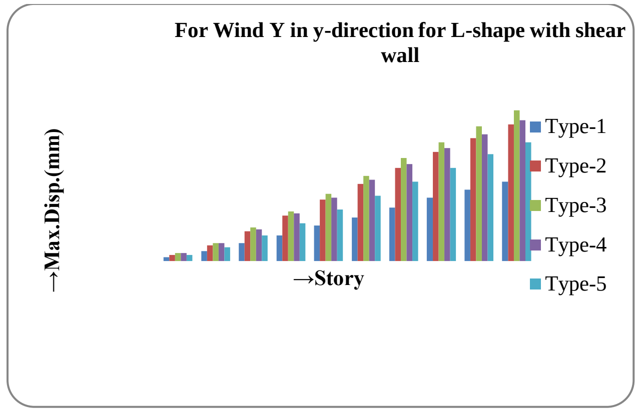
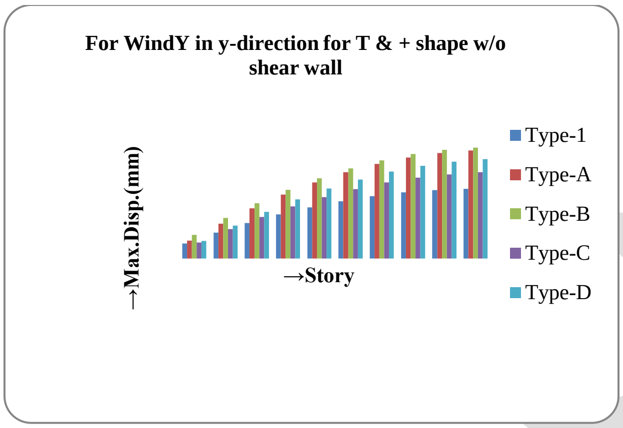
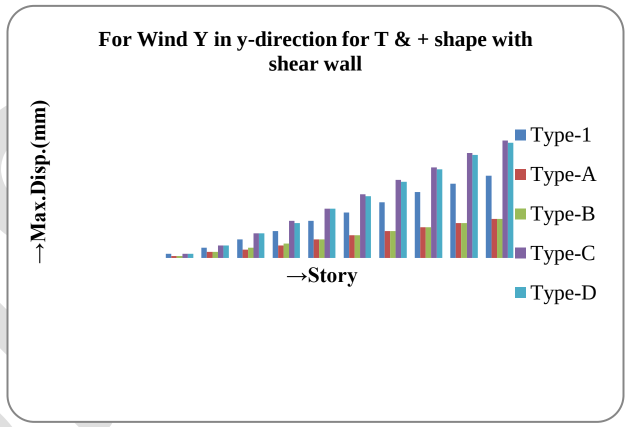
→Max.Disp.(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D


For SpecY in y-direction for T & + shape with shear wall
→Max.Disp.(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

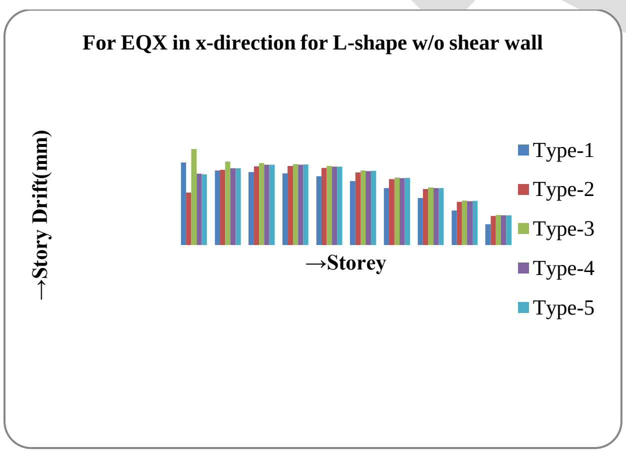


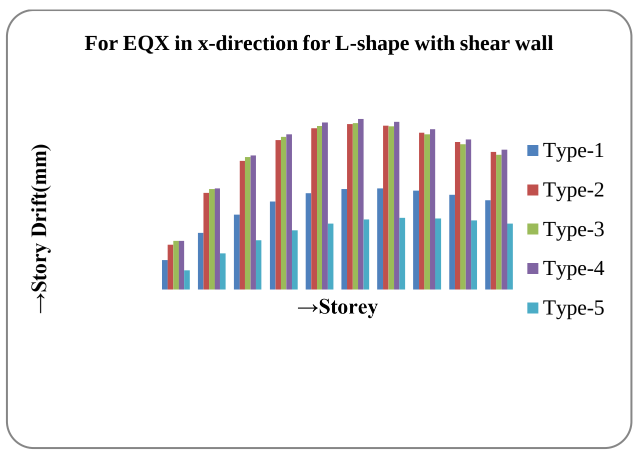


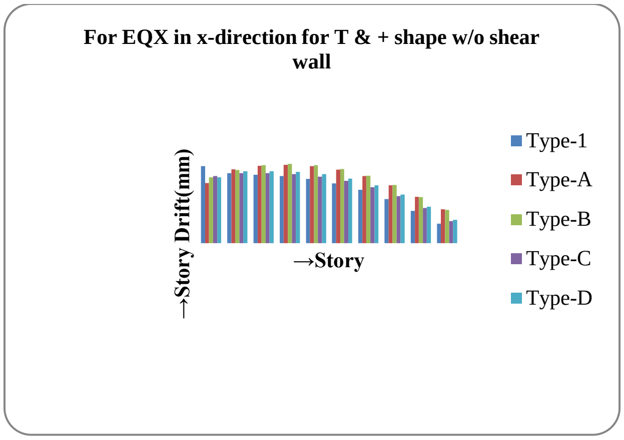


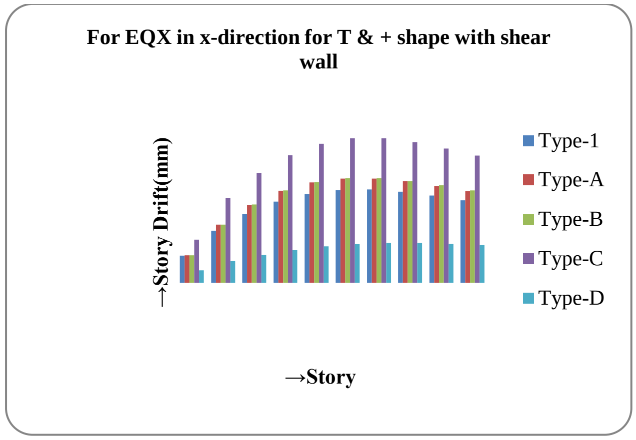


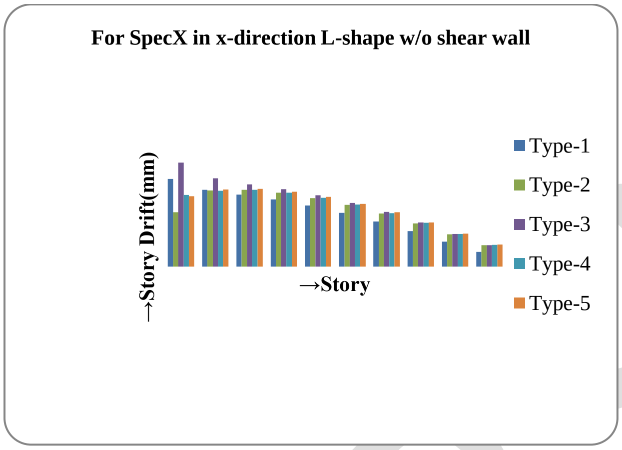
5.1.4 Storey Drift in x-direction

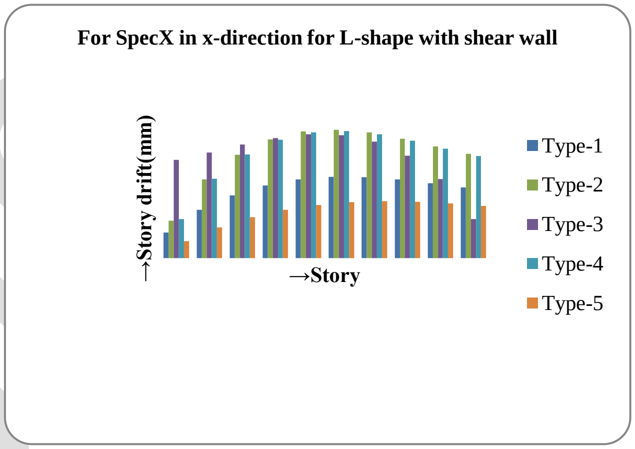


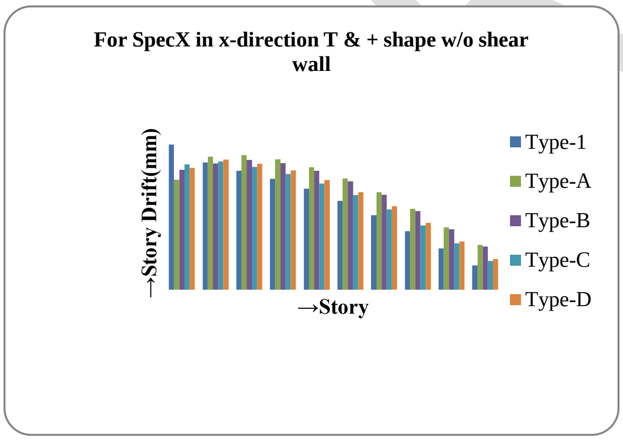


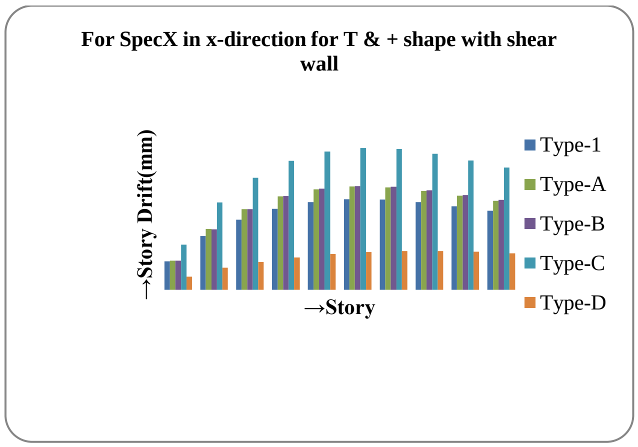

For EQX in x-direction for T & + shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

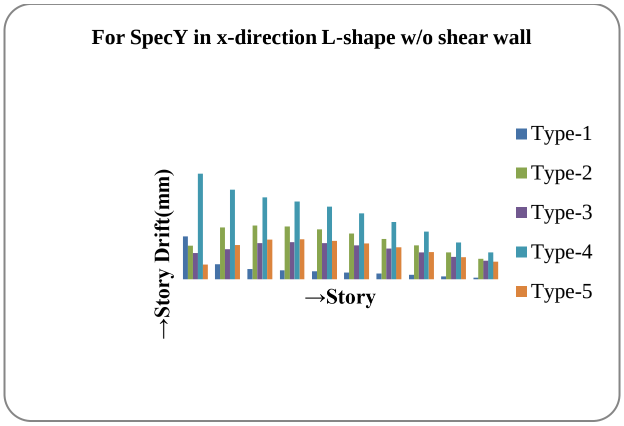

For EQX in x-direction for T & + shape with shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

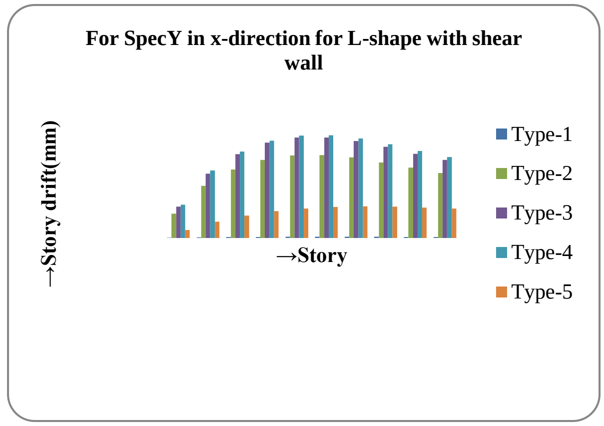

For SpecX in x-direction L-shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

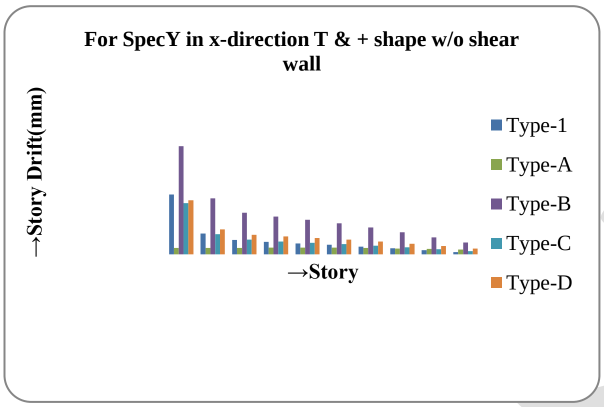

For SpecX in x-direction for L-shape with shear wall
→Story drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

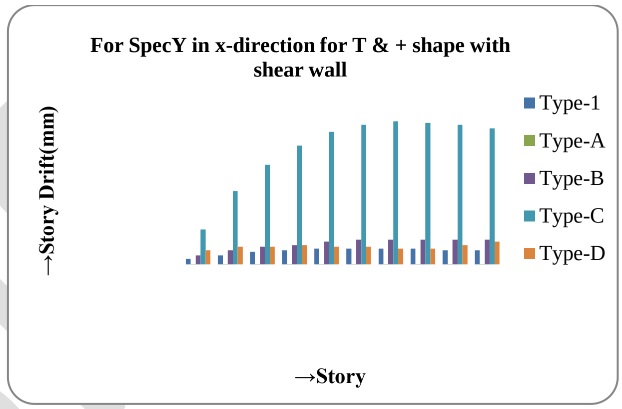

For SpecX in x-direction T & + shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

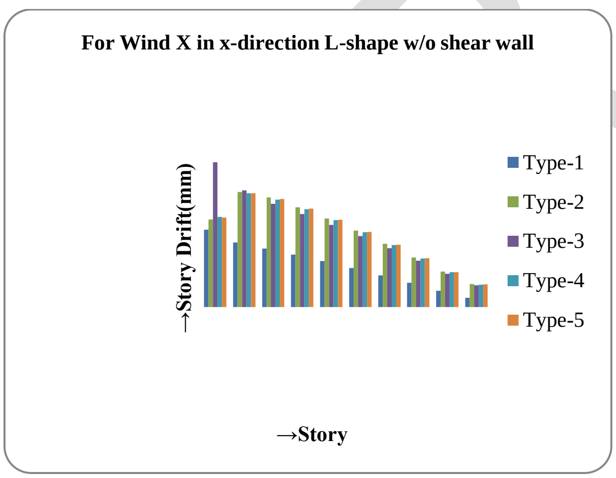

For SpecX in x-direction for T & + shape with shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

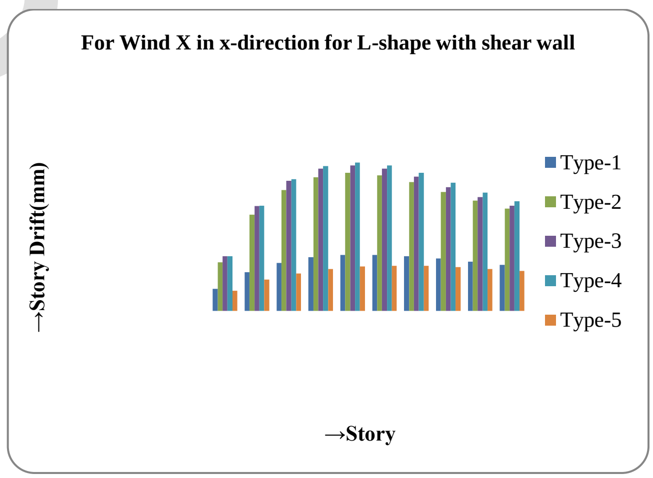

For SpecY in x-direction L-shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

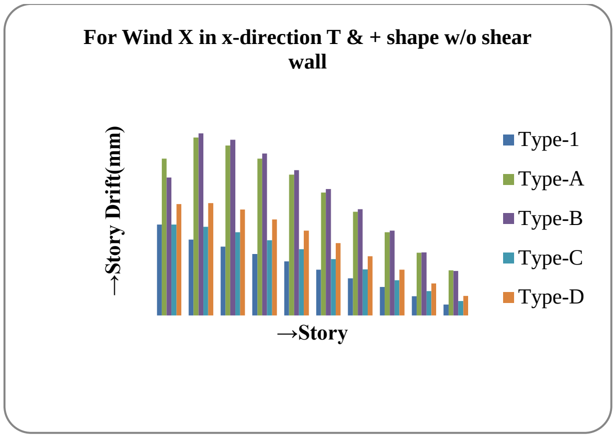

For SpecY in x-direction for L-shape with shear wall
→Story drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

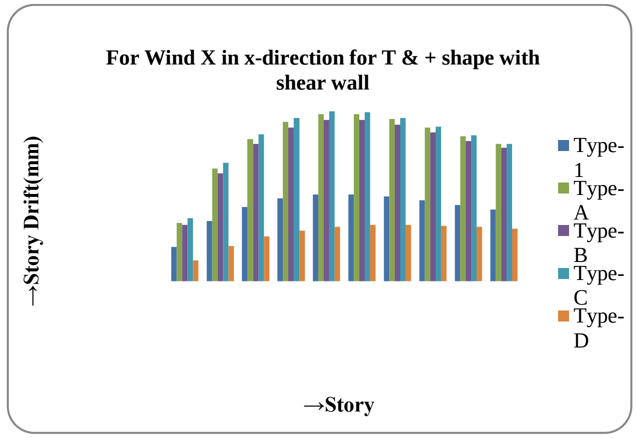

For SpecY in x-direction T & + shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D


For SpecY in x-direction for T & + shape with shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

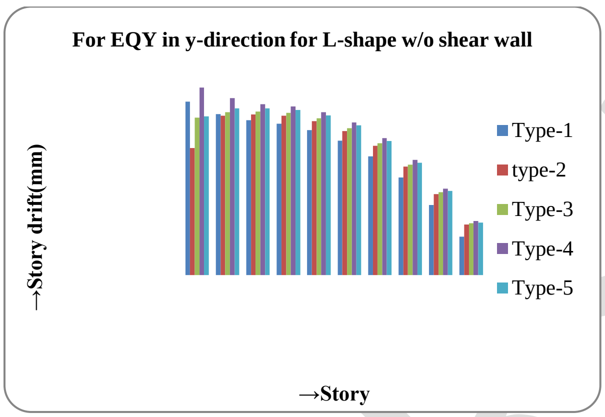

For Wind X in x-direction L-shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

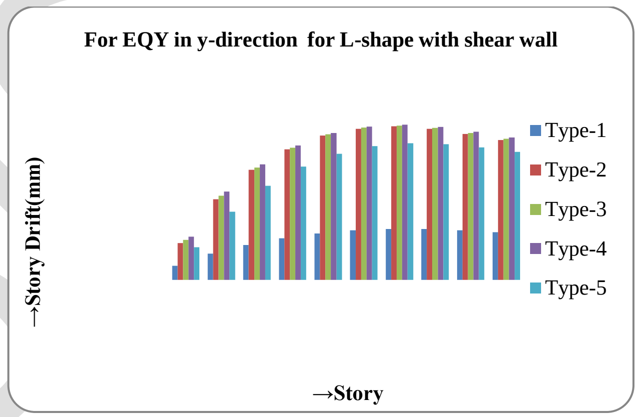

For Wind X in x-direction for L-shape with shear wall
→Story Drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

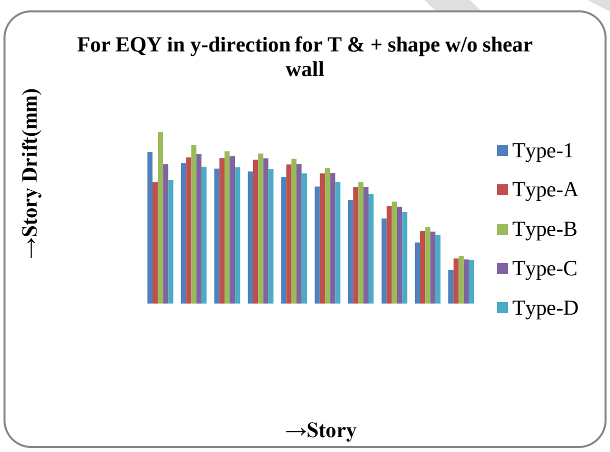


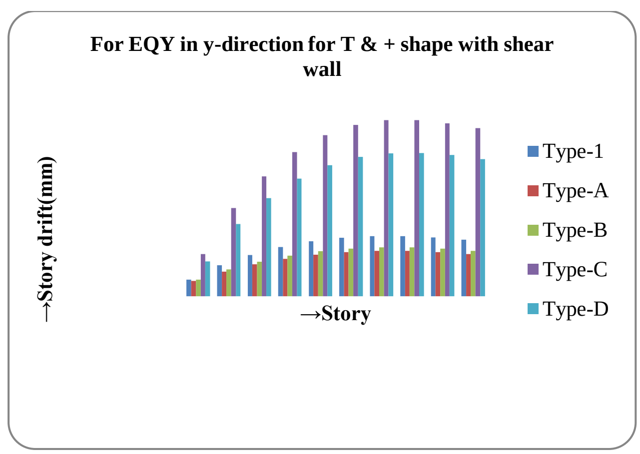


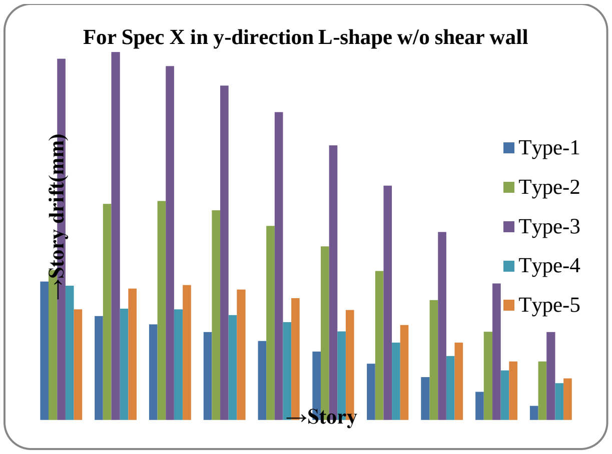
5.1.5 Storey drift in y-direction

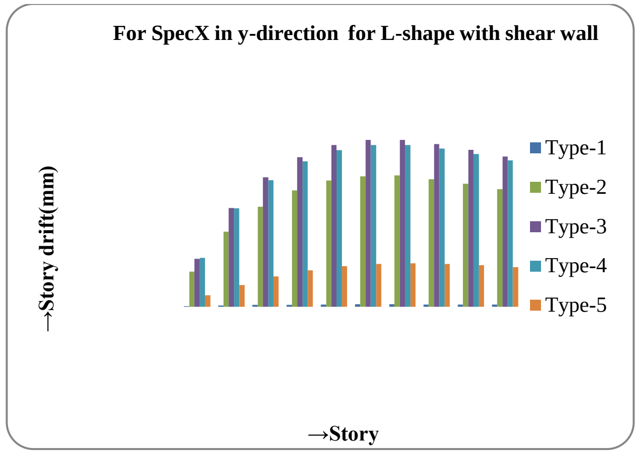


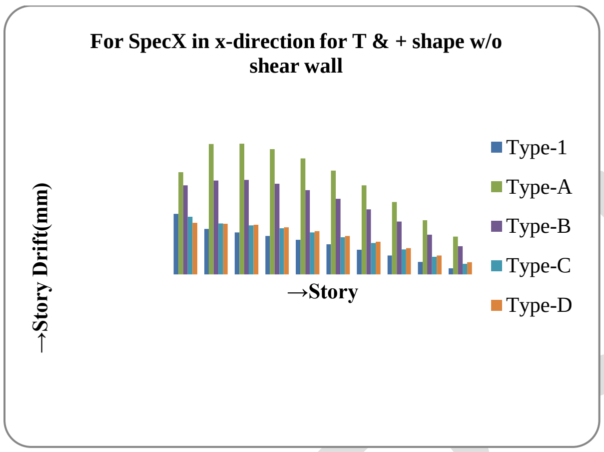


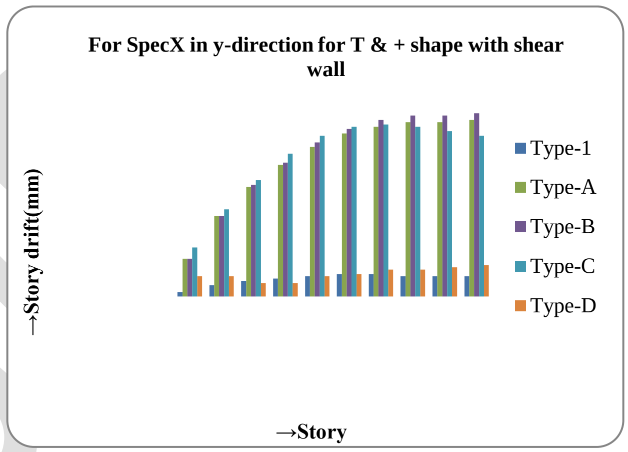


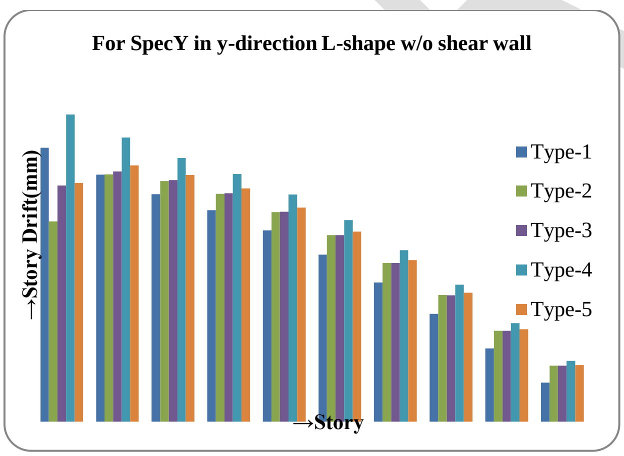


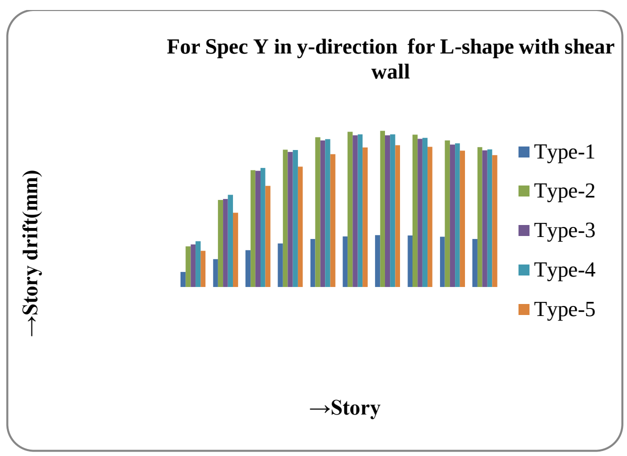

For Spec X in y-direction L-shape w/o shear wall
→Story drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

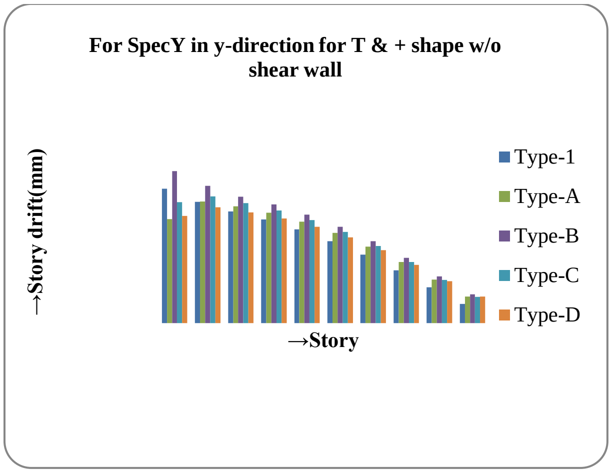

For SpecX in y-direction for L-shape with shear wall
→Story drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

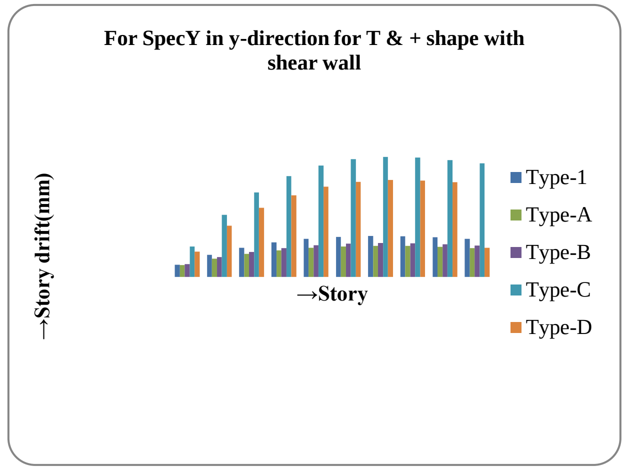

For SpecX in x-direction for T & + shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

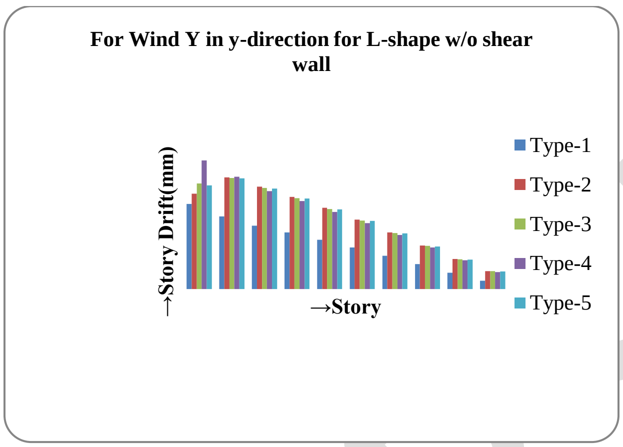

For SpecX in y-direction for T & + shape with shear wall
→Story drift(mm)
→Story
Type-1
Type-A
Type-B
Type-C
Type-D

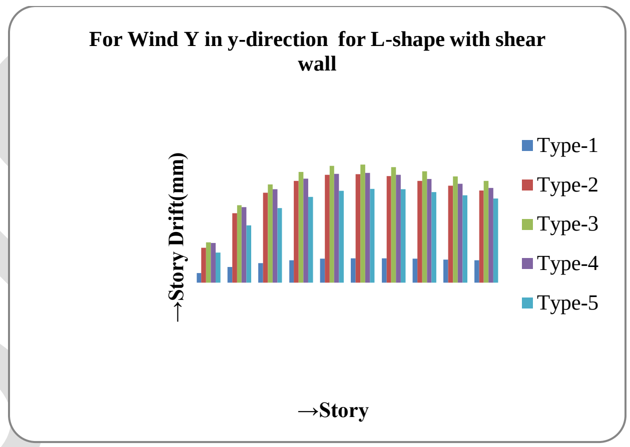

For SpecY in y-direction L-shape w/o shear wall
→Story Drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

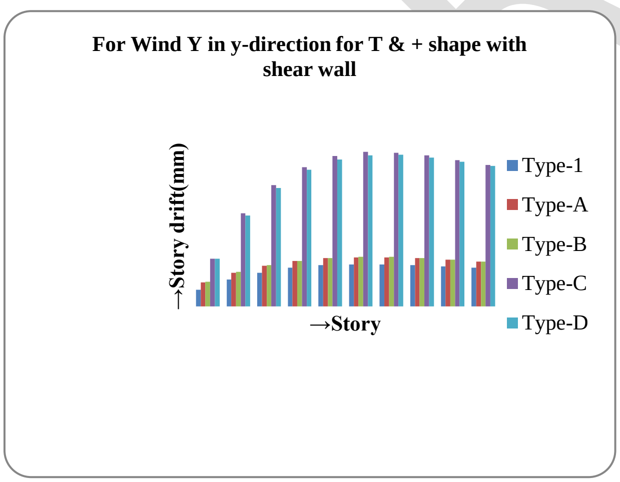

For Spec Y in y-direction for L-shape with shear wall
→Story drift(mm)
→Story
Type-1
Type-2
Type-3
Type-4
Type-5

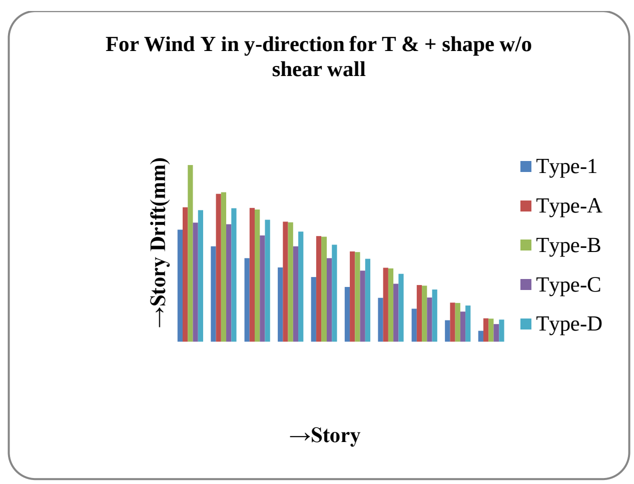












VI. CONCLUSIONS

The overall conclusion between different types of 10 storey structure without shear wall for mode Vs. modal period in chronological order are Type-2,Type,A,Type-1,Type-D,Type-C,Type-B,Type-5,Type-4 and Type-3.But in case of with shear wall structure these are Type-1,Type-A,Type-B,Type-D,Type-5,Type-3,Type-4,Type-5 and Type-C.

Storey Displacement in x-direction due to EQX for 10 storey building without shear wall are in chronological order are Type-2,Type-B,Type-4,Type-5,Type-C,Type-1,Type-D,Type-3 and Type-A. And with shear wall the performance of structure are Type-D, Type-5, Type-B, Type-A, Type-1, Type-2, Type-C, Type-3 and Type-4.

Story Displacement in y-direction due to EQY for different types of 10 storey building without shear wall are Type-D,Type-2,Type-1,Type-3,Type-A,Type-5,Type-C,Type-4 and Type-B. And with shear wall are Type-A, Type-B,Type-1,Type-D,Type-5,Type-C,Type-2,Type-3 and Type-4

Story Displacement in x-direction due to SPEC X for different types of 10 storey building without shear wall are Type-2,Type-1,Type-C,Type-D,Type-4,Type-5,Type-A,Type-B and Type-3.and with shear wall are Type-D,Type-5,Type-A,Type-B,Type-1,Type-3,Type-C,Type-4 and Type-2.

Storey Displacement in y-direction due to SPEC Y for different types of 10 storey building without shear wall are Type-D,Type-1,Type-2,Type-3,Type-C,Type-5, Type-B,Type-4 and Type-A.. And with shear wall are Type-A, Type-B, Type-D, Type-1, Type-5, Type-C, Type-3, Type-4 and Type-2

Here we can clearly see that in case of 10 storey building without shear wall Type-1, Type-2, and Type-D are good on performance wise. And with shear wall Type-D, Type-2, Type-5, Type-A, Type-B.

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