Parametric Study on Performance of Multi-Storey Irregular Building With Different Lateral Load Resisting System

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Abstract- *Lateral load resisting systems have gained importance in structural design decades ago. A new system of steel plate shear wall has been developed in early 1970 in Japan, Canada& United states which is getting popularity worldwide. As the new building techniques started developing, more and more buildings with irregular shapes construction were gaining popularity. The reason was to give the building a unique aesthetic appearance. My urge to explore about lateral load resisting system led me to Steel Plate shear wall, and further their usage in multi-storey irregular building. In this paper, a geometric irregularity in the form of Plan irregularity of Re-entrant corner is selected & tried to show how steel plate shear wall system singularly, and combination of steel plate shear wall and conventional bracing system can prove to be an innovative and efficient system for resisting wind loads. Study tries to explore the behaviour of new system and also the economy factor associated with it. The results of the study indicate that such system can prove to be efficient in such Structures and can be used in near future.*

Keywords- Steel Structure, Steel plate shear wall, Bracing, Re-entrant corner, STAAD Pro, 10 Storey.

I. INTRODUCTION

Multi-storey Buildings are most common and important part of the Structural projects. They are mostly made up of structural steel. Structural system consists of beams columns, bracings, roof girders, seismic ties etc. When the center of mass and center of stiffness does not coincide, eccentricities are developed in the buildings which further generate torsion. Phenomenon of torsional coupling occurs due to interaction between lateral loads and resistant forces when the buildings are subjected to lateral loads. Greater damages are generated in the buildings due to torsional coupling. A structure can be classified as irregular if the structure exceeds the limits of irregularities as prescribed by different seismic design codes. In this paper, we have selected Plan irregularities. As of Plan irregularity we have taken re-entrant corner. According to IS: 1893-2002, Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction. Presence of re-entrant corners are one the serious plan irregularity that results in poor seismic performance of buildings. There are two problems created by these shapes - first is that they tend to produce differential motions between different wings of the building that result in local stress concentrations at the re-entrant corner, or "notch" and second is torsion which is caused because the center of mass and the center of rigidity in this form cannot geometrically coincide for all possible lateral load directions, resulting in rotation.

Steel plate shear walls have been used in significant number of buildings, beginning decades ago, before the existence of design requirements specifically addressing this structural system. Implementation has accelerated significantly since the recent publication of various design standards, specification and other guidelines providing design requirement in both high-seismic applications and wind and low-seismic applications.

Steel plate shear walls have been used in large number of buildings, including in United States, Canada, Mexico and Japan. Buildings type have ranged from residential to high rise construction. In addition to new construction steel web plates have been added to retrofit existing frame buildings requiring additional strength and stiffness.

Steel plate shear wall offer significant advantages over many other systems in terms of cost, performance and ease of design.

Compared to concrete shear walls, the reduced thickness represents a substantial benefit. The reduced mass can also be significant in design of foundations. Most importantly, however, steel plate shear walls can be erected in less time than concrete shear wall structures.

SPSW may be considered as an alternative to braced frames. They can provide equivalent strength and stiffness and require same or less plan area.

The speed of construction of SPSW is comparable to that of braced frames as well. While there is significant amount field welding most if not all web plate field welding can be selected as single pass fillet wallets and thus erection typically proceeds at rapid pace.

The strength and stiffness of the system ensure good performance under moderate lateral loads. The ductility of the steel web plates in SPSW results in good performance under severe seismic loading.

Because SPSW can provide significant strength and stiffness shorter bays can be used. This results in greater flexibility for use of space.

SPSW are relatively easy to design- the capacity design calculations can be performed with the help of a simple spreadsheet.

SPSW can be modelled with either membrane element or truss element using many of the structural engineering programs typically employed by design office.

II. NUMERICAL STUDY

In the numerical study carried out herein, the G+10 storey steel building is considered in STAAD Pro.

The details for generating structural model in the software are given as follow:

Type of building: Office building
Height of storey: 3 m
No. of bays: 5 (both directions)
Bay width: 5 meter
Plan dimension of building :25 x 25 m
Number of storey: G + 10
Loading: Dead Load, Live Load, Wind Load.

Modelling of mainly four types of models

(A) Model of multi-storey building without any lateral load resisting system
(B) Model of multi-storey building with conventional bracing system as lateral load resisting system,
(C) Model of multi-storey building with steel plate shear wall system as lateral load resisting system
(D) Model with combination of bracing and steel plate shear wall as the lateral load resisting system.

% of irregularity is calculated as below.
(Area of bay removed / Total Bay Area) x 100 = % of Irregularity.

For example, irregularity of Model A2 = [(5 x 5) / (25 x 25)] x 100 = 4.00%

Sr. No.	Irregularity In %	Regular (A)	Bracing (B)	Shear wall (C)	Combine (D)
1	0	A1	B1	C1	D1
2	4	A2	B2	C2	D2
3	8	A3	B3	C3	D3
4	12	A4	B4	C4	D4
5	16	A5	B5	C5	D5
6	24	A6	B6	C6	D6
7	36	A7	B7	C7	D7
8	48	A8	B8	C8	D8

Table 1: Model Numbering

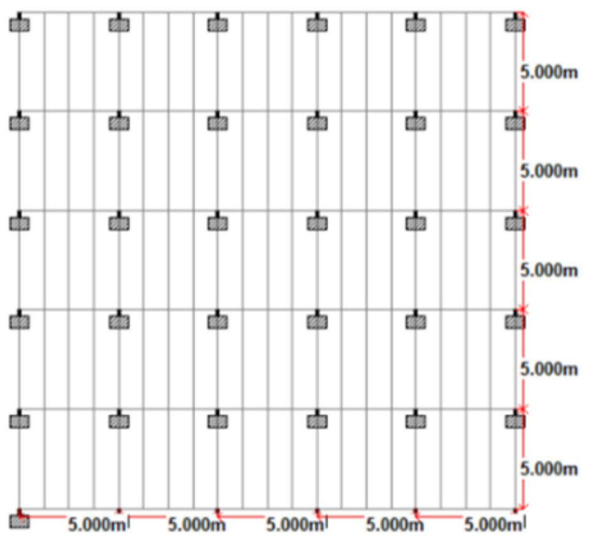

Fig 1: Plan of Building (A1)

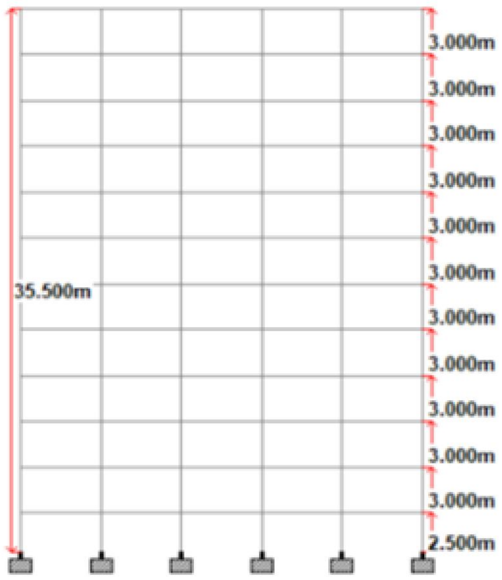

Fig 2: Elevation of Building

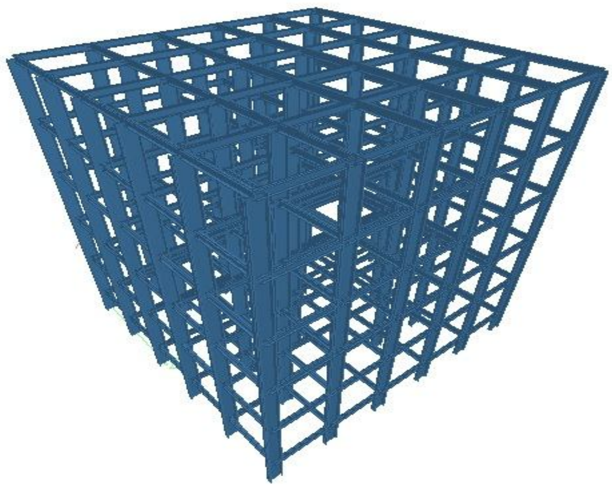

Fig3: 3D view of building

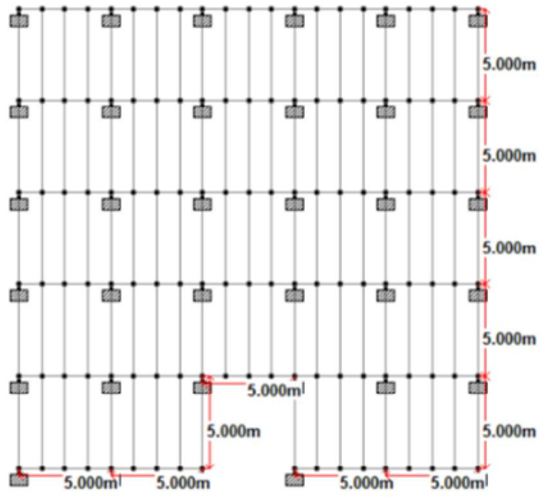

Fig 4: Plan of model 'A2' – 4 % irregularity.

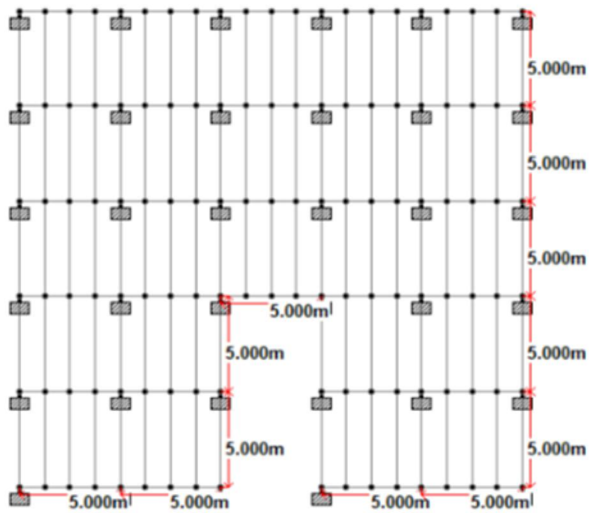

Fig 5: Plan of model 'A3' – 8 % irregularity.

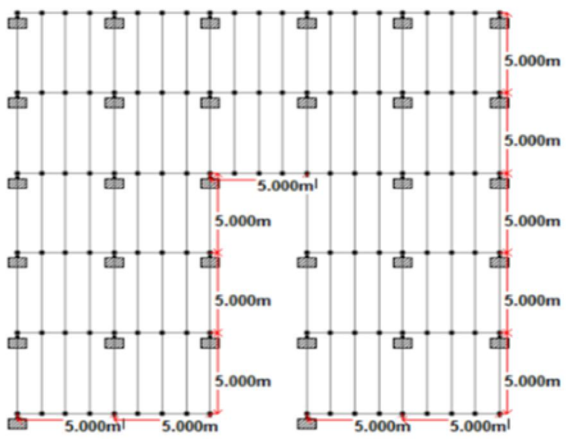

Fig 6: Plan of model 'A4' – 12 % irregularity.

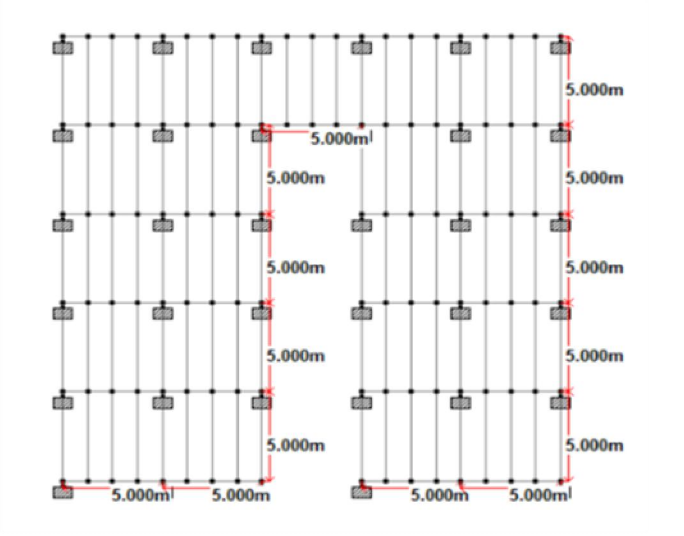

Fig 7: Plan of model ‘A5’ – 16 % irregularity.

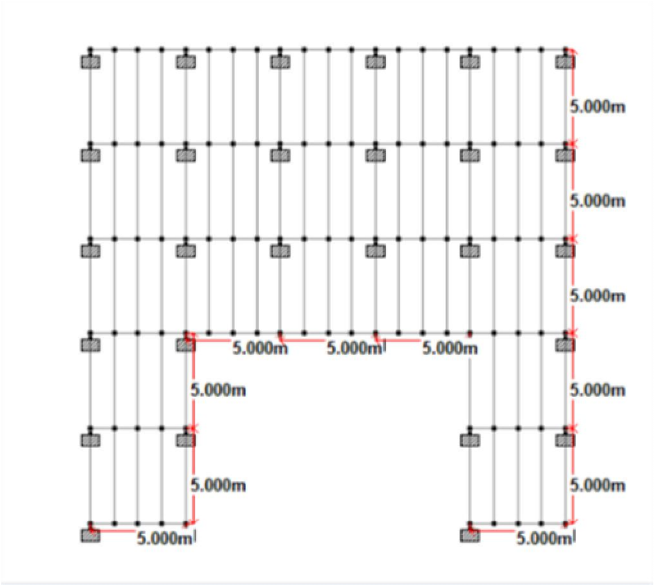

Fig 8: Plan of model ‘A6’ – 24 % irregularity.

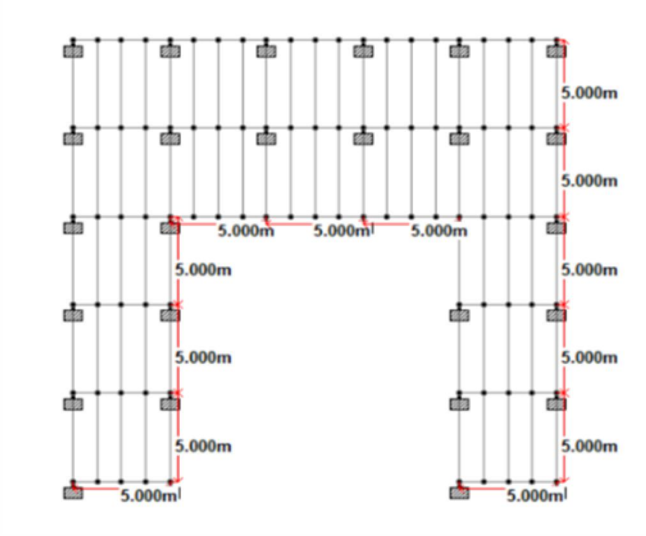

Fig 9: Plan of model ‘A7’ – 36 % irregularity.

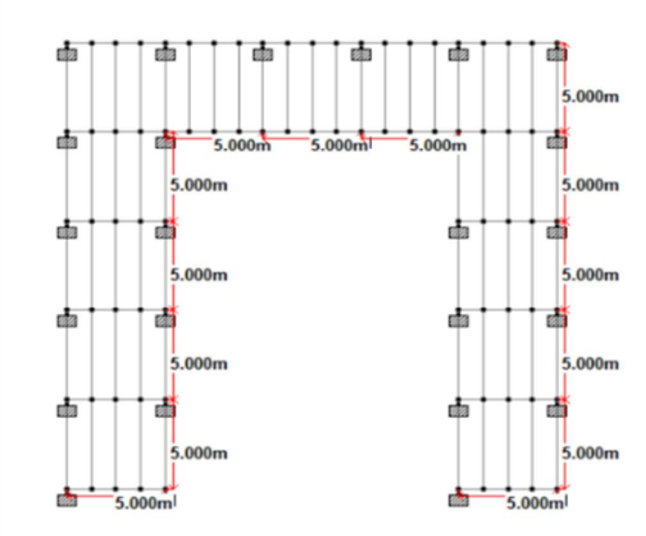

Fig 10: Plan of model ‘A8’ – 48 % irregularity.

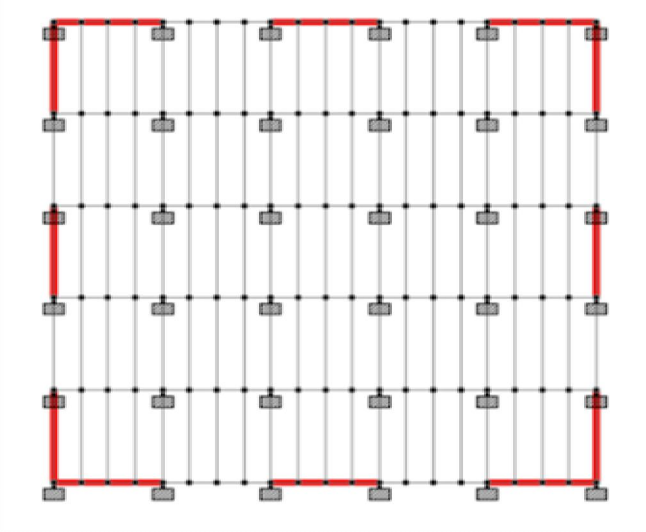

Fig 11: Plan of model ‘B1’

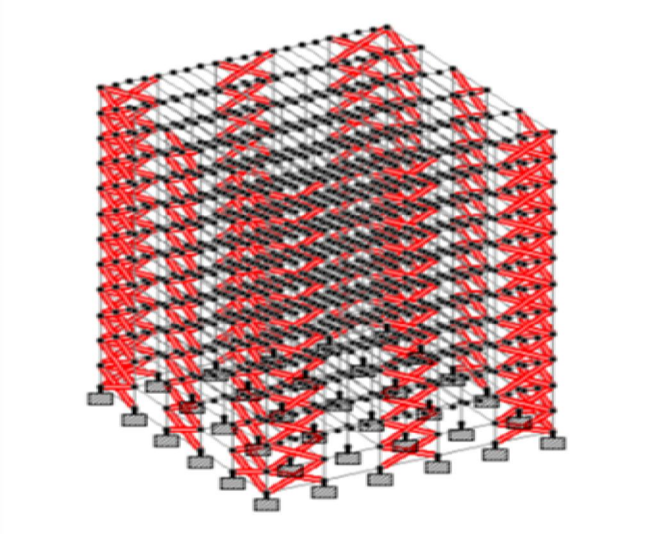

Fig 12: 3D view of model 'B1'

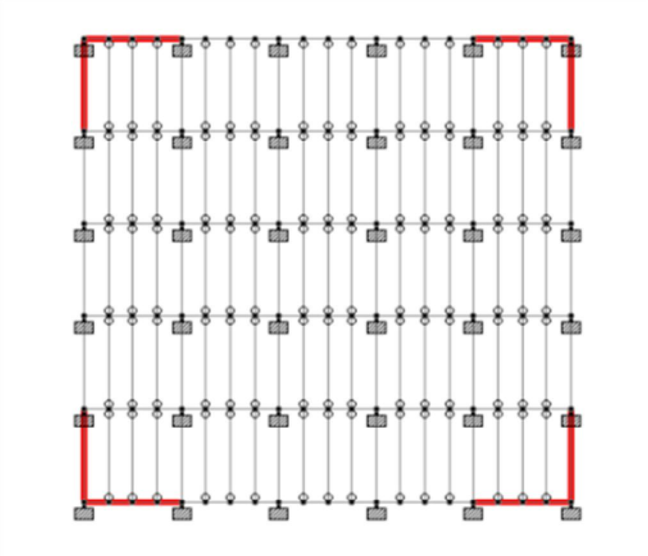

Fig 13: Plan of model 'C1'

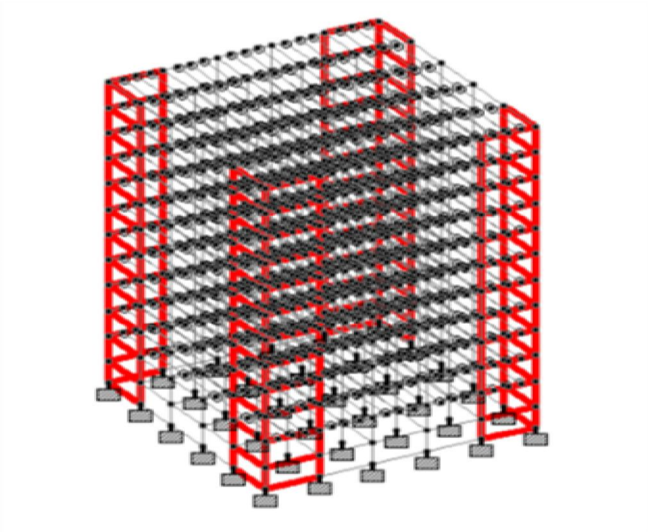

Fig 14: 3D view of model 'C1'

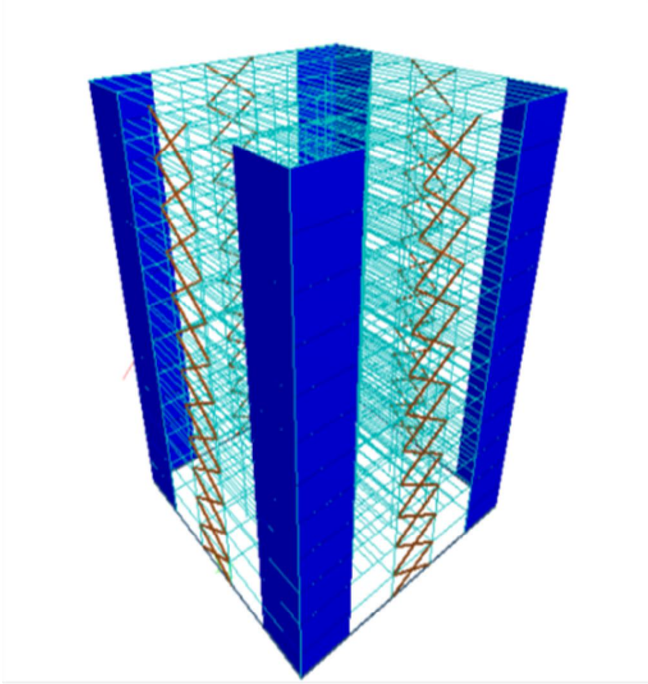

Fig 15: 3D rendered view of model 'D1'

III. LOAD CALCULATION

1. Dead Load Calculation

Dead Load is applied in accordance to IS: 875 (Part I).

Dead load includes – self weight of the members, external wall load, partition wall load, parapet wall load, composite slab self-weight and floor finish.

Load	Thickness	Calculation	Value
External Wall Load	230 mm	0.23 x 2.7 x 22	13.5 (kN/m)
Partition Wall Load	115 mm	0.115 x 2.7 x 22	6.7 (kN/m)
Parapet Wall Load	115 mm	0.115 x 1.2 x 22	3.036 (kN/m)
Deck Slab Weight	125 mm	0.125 x 25	3.125 (kN/m^2)
Floor Finish	-	1.25	1.25kN/m^2)

2. Live load Calculation

Live Load is applied in accordance to IS: 875 (Part II).
According to the code, Live Load for a building to be used as Office is to be taken as = 4 kN/m^2
Above stated Live load is for a typical floor and excludes Ground floor and Terrace floor.
For Terrace, Live Load is taken as = 2 kN/m^2

3.Wind load Calculation

Wind Load is applied in accordance to IS:875(part3)-2015.

The basic wind speed (V_b) = 39 m/s for location: Ahmedabad.

Design Wind speed (V_z) = $V_b * k_1 * k_2 * k_3 * k_4$
Where
V_z = design wind speed at height z, in m/s
K_1 = probability factor (risk coefficient)
K_2 = terrain roughness and height factor
K_3 = topography factor
K_4 = importance factor for the cyclonic region
Design Wind Pressure $P_z = 0.6V_z^2$
Using this pressure coefficients & Force intensity is calculated.

Load Combination

According to IS 800:2007 Table-4, load combination of limit state of serviceability are as follows.

- DL+LL
- DL+LL+(WL+X+CPI)
- DL+LL+(WL+X-CPI)
- DL+LL+(WL+Z+CPI)
- DL+LL+(WL+Z-CPI)
- DL+LL+(WL-X+CPI)
- DL+LL+(WL-X-CPI)
- DL+LL+(WL-Z+CPI)
- DL+LL+(WL-Z-CPI)
- DL+(WL+X+CPI)
- DL+(WL+X-CPI)
- DL+(WL+Z+CPI)
- DL+(WL+Z-CPI)
- DL+(WL-X+CPI)
- DL+(WL-X-CPI)
- DL+(WL-Z+CPI)
- DL+(WL-Z-CPI)

IV. EXPERIMENTAL RESULTS

Comparing the result for different geometries with different loading condition for displacement and steel consumption.

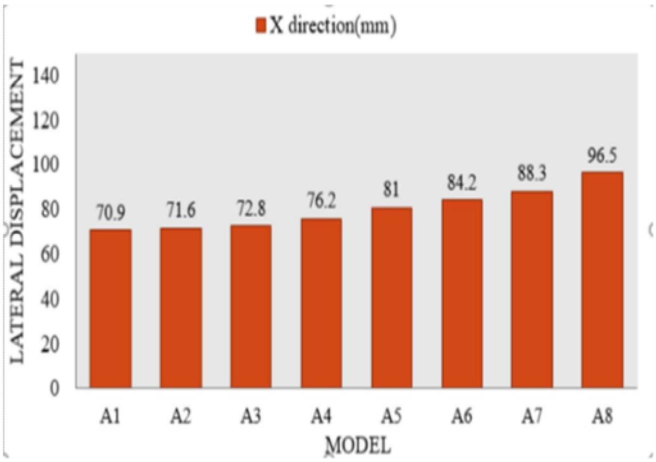

Chart-1 Lateral displacement in X direction for model 'A'

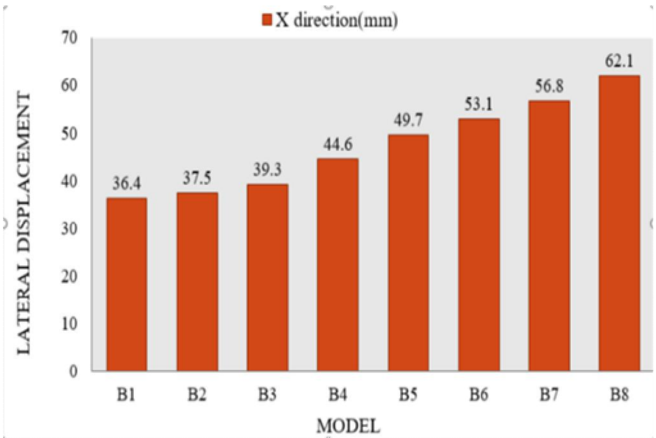

Chart-2 Lateral displacement in X direction for model 'B'

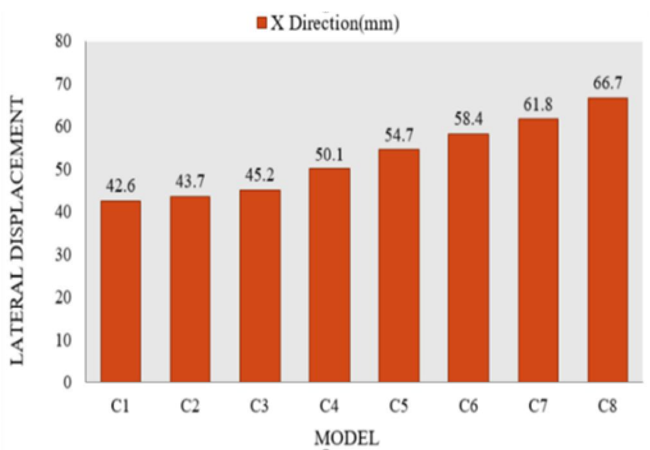

Chart-3 Lateral displacement in X direction for model 'C'

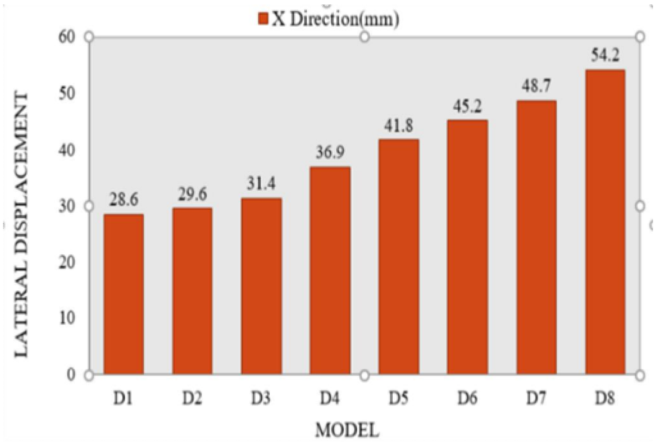

Chart-4 Lateral displacement in X direction for model 'D'

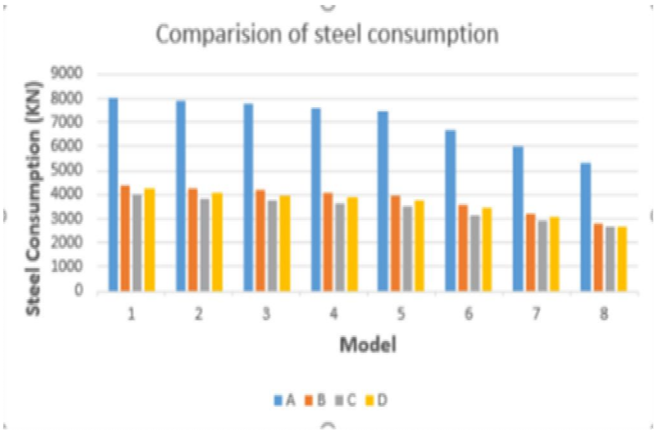

Chart-5 Comparison of steel consumption

V. CONCLUSION

After viewing the results of study it is seen that model D i.e. system with steel plate shear wall combined with bracing is the best as per design and economy considerations.

Also such system will provide speedy construction, and more flexibility to utility conduits, due to less clashing of conduits with the members of lateral load resisting system.

Building with re-entrance corner experienced more lateral displacement compared to regular building.

VI. ACKNOWLEDGEMENT

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