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Comparative Seismic Analysis of G+ 6 Composite Frame Building in Zone III & Zone V

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ABSTRACT
In recent times, there is great need to make the structure efficient, reliable and sustainable to all adverse circumstances. The most dangerous and disastrous one is earthquake. So there is a need to evaluate and improve the seismic performance of multistoried buildings. Composite structures have been known to perform well under earthquake loads. Composite structures are good at resisting earthquake. The use of these so-called composite-frame structures has as its underlying principle, the combination of these two distinctive and different building materials to benefit from the advantages of both-namely, the inherent stiffness and economy of reinforced concrete and the speed of construction, strength and light weight of structural steel. In this study we are dealing with comparative study of seismic analysis of G+6 composite frame building in Zone III and Zone V. The equivalent static analysis is carried out on the entire mathematical 3D model using the software "STAAD Pro V8i" and the comparison of some factors like axial forces, shear forces & bending moments in both the zones are presented in graphical form. For resisting lateral loads, steel plate shear wall is to be used. This will help us to find the various analytical properties of the structure.

Keywords – Composite Building, Seismic Analysis, Steel Plate Shear Wall, STAAD- Pro, Structural Analysis

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I. INTRODUCTION

Earthquakes are natural hazards under which the damage is the collapse of buildings and other man- made structures. In most of the past earthquakes it has been observed that numbers of buildings are affected severely and maximum loss of lives and property occurred due to sudden failure of structures. This is evident from recent North Kashmir earthquake of October 8, 2005 and Bhuj earthquake of January 26, 2001. Earthquake causes enormous damage to the structures. So there is increased awareness for the need to evaluate and improve the seismic performance of buildings. Earthquake is perceptible movement of earth surface. Primary cause of earthquake is the rapture of fault in earth crust and associated rapid slip on the faults. Large strain energy released during an earthquake travels as seismic wave in all direction through earth's layers. There are basically two types of seismic wave as Body wave and Surface wave. Body wave consist of Primary wave (P-wave) and Secondary wave (S-wave) whereas surface wave consist of L-wave and Raleigh wave.

1.1 Composite structures

Over the past 25 years, numerous innovative structural systems have evolved in tall building design where structural steel and reinforced concrete have been combined to produce a building having the advantages of each material. The use of these so-called composite-frame structures has as its underlying principle, the combination of these two distinctive and different building materials to benefit from the advantages of both—namely, the inherent stiffness and economy of reinforced concrete and the speed of construction, strength and light weight of structural steel. The term composite-frame structure has taken on numerous meanings in recent years in utilizing several different building materials. Here composite structure is taken to mean a building employing a structural steel frame and reinforced cement concrete slab.

1.2 Steel-Concrete Composite Building under Seismic Forces

Steel-concrete composite systems have become quite popular in recent times because of their advantages against conventional construction. Composite construction combines the better properties of both i.e. concrete and steel and results in speedy construction with a possibility of working on parallel front. In case of a composite structure, steel imparts ductility to the structure which has ability to absorb seismic energy imparted on the structure by the earthquakes and concrete prevents steel from corrosion and fire. The key feature of this system is composite action between a concrete slab and a steel beam which is achieved through the shear connection system which significantly increases the rigidity and the ultimate moment capacity.

1.3 Seismic behavior of steel structure

There are two means by which the earthquake may be resisted:

- Structures made of sufficiently large sections that they are subject to only elastic stresses
- Structures made of smaller sections, designed to form numerous plastic zones.

A structure designed to the first option will be heavier and may not provide a safety margin to cover earthquake actions that are higher than expected, as element failure is not ductile. In this case the structure's global behavior is 'brittle' and corresponds for instance to Fig 1.1 (a).

In a structure designed to the second option selected parts of the structure are intentionally designed to undergo cyclic plastic deformations without failure, and the structure as a whole is designed such that only those selected zones will be plastically deformed.

Steel Structures Good at Resisting Earthquakes as the structure's global behavior is 'ductile' and corresponds to Fig. 1.1 (b). The structure can dissipate a significant amount of energy in these plastic zones.

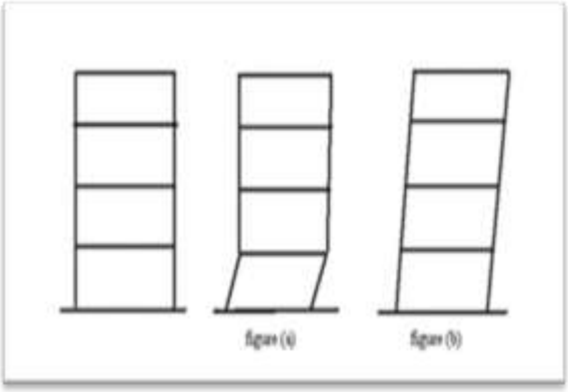


Fig. 1.1 Global behavior of structure

1.4 Steel plates shear walls. (SPSWs):

These are the walls like vertically aligned structural components which are subjected to lateral loads in their plane. These have proved to be very effective for lateral load resistance particularly in the medium to high-rise buildings. These depending upon the material of construction they may be classified as the RCC and steel shear walls.

1.5. Behavior & mechanism of shear resistance of steel plate shear wall.

Its behavior is analogous to a vertical plate girder. In this columns acts as a flanges, beams as stiffeners & steel plate as a web.

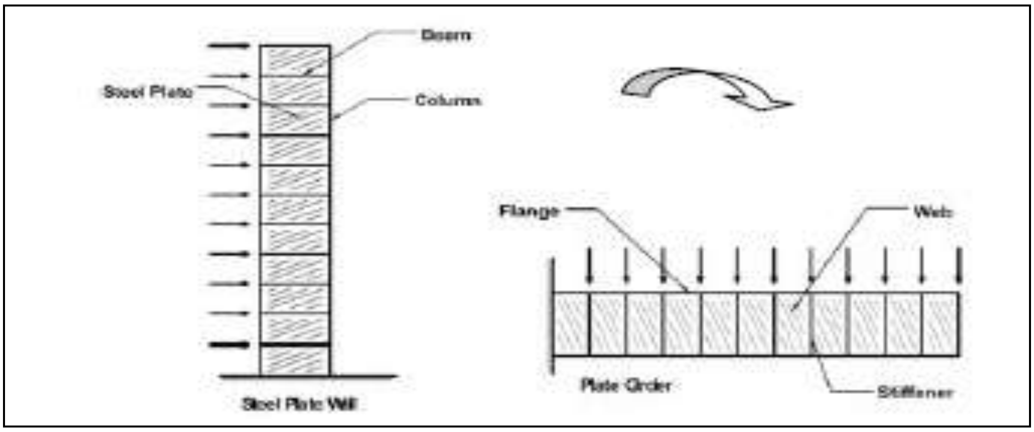


Fig.1.2 Steel Plates Shear Wall and Plate Girder Analogy

During the application of cyclic loads to the frame, three phases may be observed

- First, critical elastic buckling occurs in the plate,
- Then, diagonal tension field forms in it
- Finally by yielding of the steel plate, a significant amount of energy dissipate during cyclic loading.

Fig.1.3 Diagonal tension field action developed in steel shear wall

Types of steel plate shear wall:

i) Un-stiffened steel plate shear walls

These are latest and more preferred as compared to the other types. These consist of a thin steel plate welded or bolted to the surrounding beams and the columns. There are no stiffeners on the steel

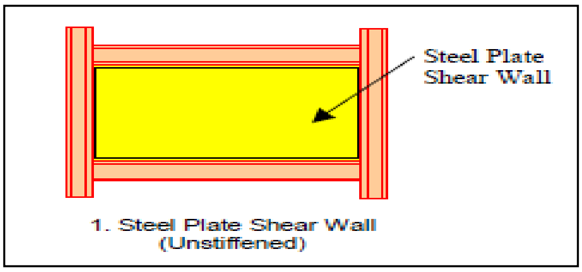


Fig. 1.4 Unstiffened steel plate shear wall

plate. This makes it relatively more economical and easy to fitting and handling. Being thin, it buckles at a relatively small lateral force. But after that it shows full strength & stiffness.

ii) Stiffened steel plate shear walls

These consist of a relatively thick steel plate connected to the beams and columns on its periphery. The plate is stiffened by the horizontal and vertical stiffeners running over it. Thus the plate has got relatively higher strength and stiffness before buckling. The buckling is the criteria used for the design of this shear wall. The cost of fabrication of the stiffeners and the extra material cost increases the overall cost of the shear wall. The tension field stresses do not develop in this case. The yielding of plate occurs before the buckling.

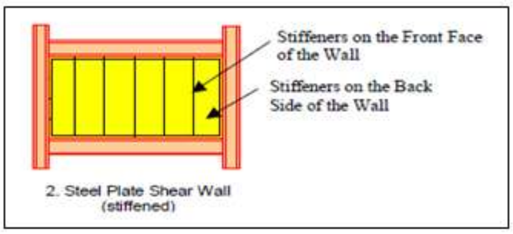


Fig. 1.5 stiffened steel plate shear wall

II. MODELLING

The STAAD Pro V8i software is utilized to create 3D model of G+6 building and carry out the analysis. The lateral loads to be applied on the buildings are based on the Indian standards. The study is performed for seismic zone III and zone V as per IS 1893:2002 and the results of bending moment, shear force and axial force in both the zones are compared. The building adopted is composite frame building with steel plate shear wall.

Table 2.1: Analysis Data for Example Building

Plan dimensions	20m X 16m	
Total height of building	23.2m	
Height of each storey	3.10m	
Height of parapet	1.0m	
Depth of foundation	1.5m	
Beam sections	ISHB 300	
Column sections	ISHB 350	
Thickness of slab	125mm	
Thickness of external walls	230mm	
Thickness of internal walls	115mm	
Thickness of Steel plate shear wall	10mm	
Seismic zones	III	V
Response reduction factor	0.16	0.36
Importance factor	1.0	1.0
Soil condition	Hard	
Floor finishes	3 KN/m^2	
Live load at roof level	3 KN/m^2	
Live load at all floors	3 KN/m^2	
Grade of Concrete	M20	
Grade of steel	Fe415	
Density of Concrete	25 KN/m^3	
Density of brick masonry	20 KN/m^3	

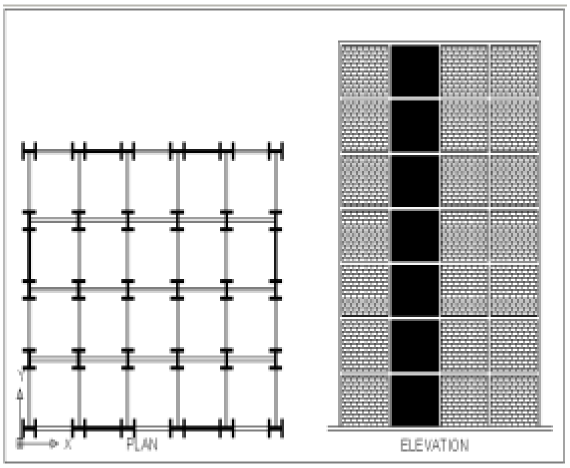


Fig. 2.1 Building with Steel Plate Shear Wall in Zone III (Model I)

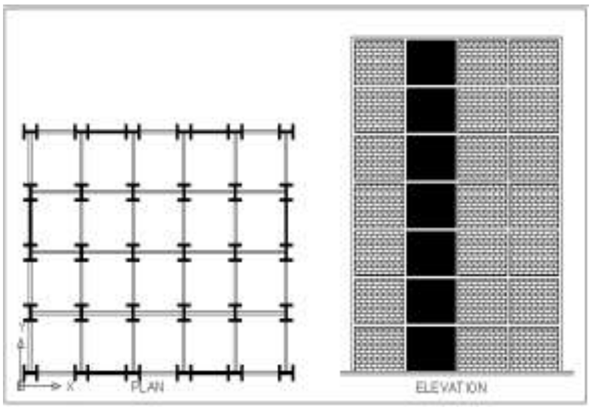


Fig. 2.2 Building with Steel Plate Shear Wall in Zone V (Model II)

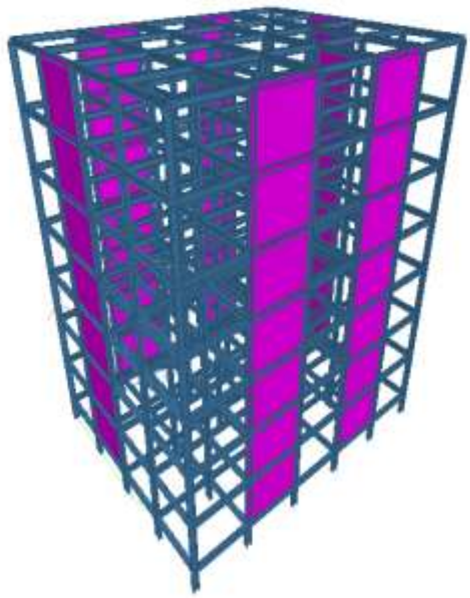


Fig. 2.3 Model of Building Generated in STAD.Pro V8i

III. SEISMIC ANALYSIS PARAMETERS

Behaviour of structure subjected to earthquake loading is a complicated phenomenon. There is several numbers of factors affecting the behaviour of building out of which the Axial Force, Shear Force & Bending Moment are considered for study. For this, building models in zone III and zone V are considered. In the model I SPSW is provided in the entire storey in zone III and in model II SPSW is provided in the entire storey in zone V. The 3D analysis is carried out in both the zones. The equivalent static analysis is carried out on both the 3D model using the software STAAD Pro V8i. The results obtained from the analysis are discussed.

3.1 Maximum Forces and Bending Moments results

The maximum axial forces in columns, shear forces and bending moment in beams & columns of building frame with steel plate shear wall are presented in Table 3.1 to Table 3.5.

Table 3.1 Maximum of Axial force of columns in ZoneIII & ZoneV

Sr. No	Storey Level	Zone III	Zone V
1	I	2190	2190
2	II	2080	2080
3	III	1740	1740
4	IV	1480	1480
5	V	898.001	899.335
6	VI	818.112	818.112
7	VII	487.746	487.746
8	VIII	157.576	157.576

Table 3.2 Maximum Shear Force in Columns in Zone III & Zone V

Sr.No.	Storey Level	Longitudinal Direction		Transverse Direction	
		Zone III	Zone V	Zone III	Zone V
1	I	24.16	40.96	116.82	186.04
2	II	10.11	17.16	21.7	48.64
3	III	14.61	22.71	21.5	48.2
4	IV	16.09	23.78	22.87	46.98
5	V	18.07	24.03	23.22	45.87
6	VI	19.48	22.9	21.85	41.14
7	VII	20.51	20.51	19.14	31.7
8	VIII	20.4	20.39	18.28	34.6

Table 3.3 Maximum Shear Force in Beams in Zone III & Zone V

Sr.No.	Storey Level	Longitudinal Direction		Transverse Direction	
		Zone III	Zone V	Zone III	Zone V
1	I	0.53	0.89	81.87	87.05
2	II	1.22	2.55	88.28	89.28
3	III	2.43	5.35	88.66	88.66
4	IV	3.67	8.17	90	90.27
5	V	4.67	10.88	91	91.75
6	VI	5.96	13.4	91.7	92.36
7	VII	6.51	14.8	92.83	93.2
8	VIII	6.3	13.99	45.66	47.3

Table 3.4 Maximum Bending Moment in Columns in Zone III & Zone V

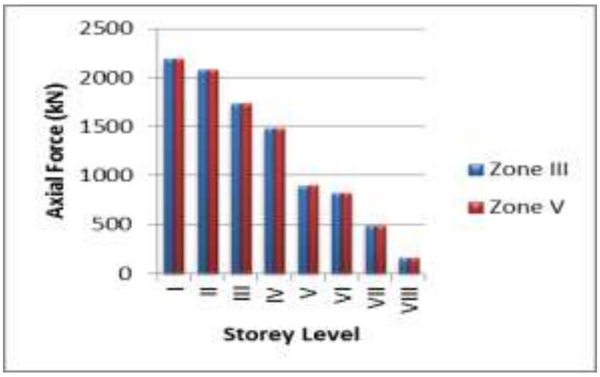
Sr. No.	Storey Level	Longitudinal Direction		Transverse Direction	
		Zone III	Zone V	Zone III	Zone V
1	I	106.13	139.3	20.063	30.8
2	II	29.233	65.51	17.2	28
3	III	24.504	73.64	22.93	35.41
4	IV	36.47	74.568	25.54	37.28
5	V	37.71	74.31	28.44	37.66
6	VI	36.5	69.23	30.42	35.97
7	VII	31.34	56.79	32.02	32.01
8	VIII	31.62	60.25	31.47	60.25

Table 3.5 Maximum Bending Moment in Beams in Zone III & Zone V

Sr.No.	Storey Level	Longitudinal Direction		Transverse Direction	
		Zone III	Zone V	Zone III	Zone V
1	I	77.33	88.24	1.063	1.84
2	II	70.192	109.865	2.403	5.107
3	III	71.04	110.486	4.87	10.71
4	IV	75.43	106.84	7.413	16.52
5	V	78.3	99.16	9.93	22.21
6	VI	79.88	96.87	12.15	27.2
7	VII	81.36	98.06	13.41	31.1

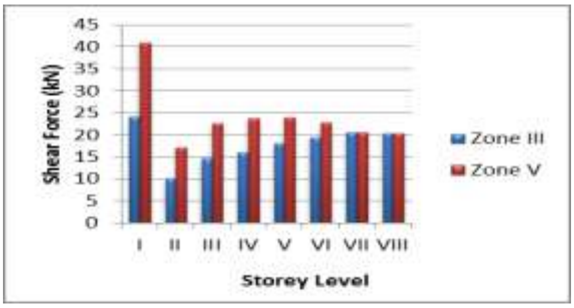
IV. COMPARISON OF ANALYSIS RESULTS:

The analysis results obtained for maximum axial force in columns and maximum shear force & bending moment in beams & columns in both Zone III & Zone V are compared. The variations are presented in the form of graph as below.

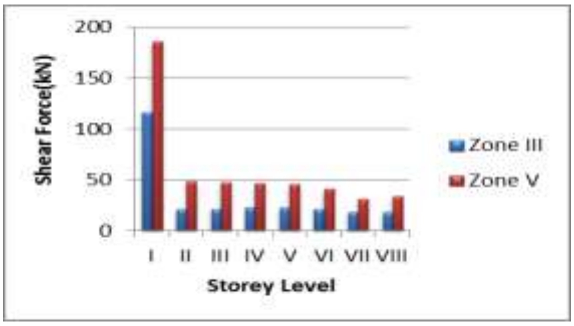


Graph 4.1 Comparison of Maximum Axial Forces in Column in Zone III and Zone V

There is no increment in axial forces in Zone III & Zone V. The values of axial forces in both the zones are same. The use of steel plate shear wall reduces the axial force to some extent. The axial force from footing level to top most floors gradually decreases.

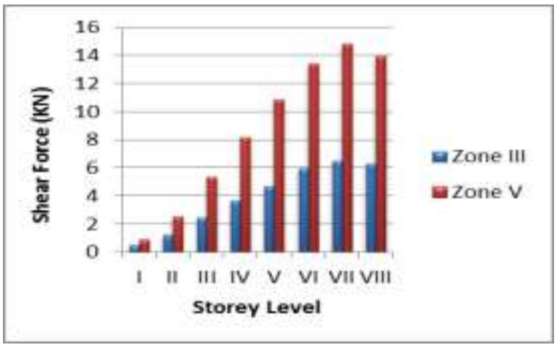


Graph 4.2 Comparison of Maximum Shear Force in Columns in Longitudinal Direction for Zone III and Zone V

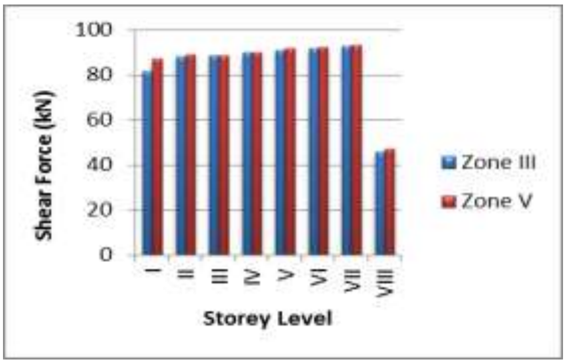


Graph 4.3 Comparison of Maximum Shear Force in Columns in Transverse Direction for Zone III and Zone V

Comparison of maximum shear force in columns in longitudinal as well as in transverse direction for Zone III and Zone V shows noteworthy results. For both the directions the shear force for Zone V is greater than that for Zone III. The shear force is considerably large for first storeys in both the directions as compared to other seven storeys but constantly remain at higher value for Zone V than Zone III.

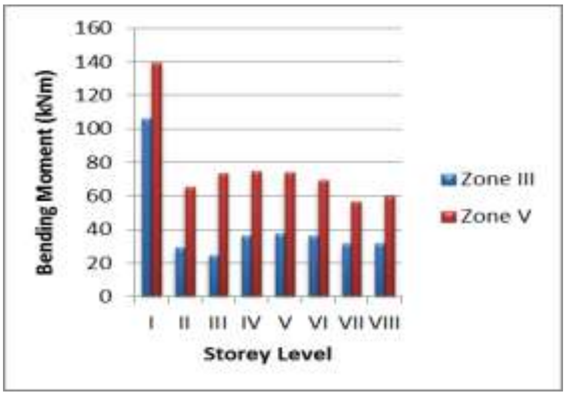


Graph 4.4 Comparison of Maximum Shear Force in Beams in Longitudinal Direction for Zone III and Zone V

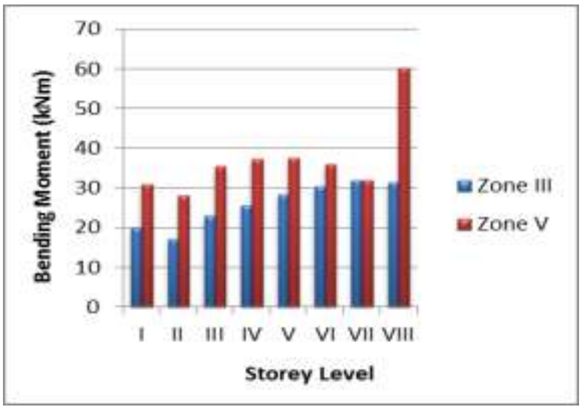


Graph 4.5 Comparison of Maximum Shear Force in Beams in Transverse Direction for Zone III and Zone V

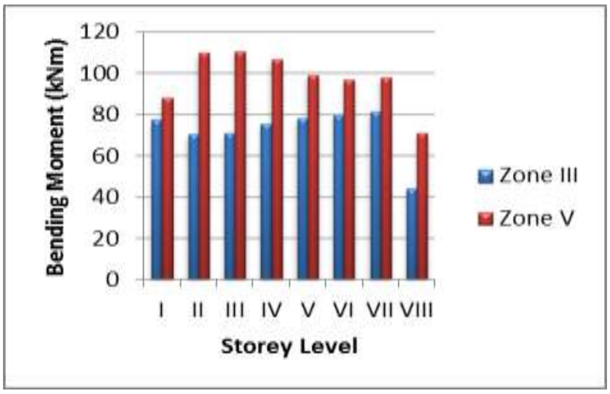
In case of beams, longitudinal direction the shear force goes on increasing up to seventh storey and then slightly decreases. However shear force has considerably higher value for Zone V than that for Zone III.



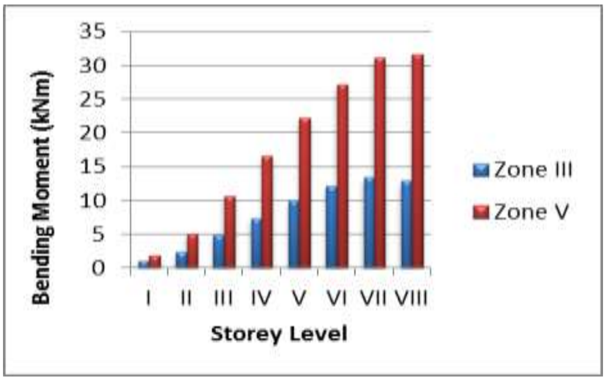
Graph 4.6 Comparison of Maximum Bending Moment of columns in Longitudinal Direction for Zone III and Zone V



Graph 4.7 Comparison of Maximum Bending Moment of columns in Transverse Direction for Zone III and Zone V



Graph 4.8 Comparison of Maximum Bending Moment of beams in Longitudinal Direction for Zone III and Zone V



Graph 4.9 Comparison of Maximum Bending Moment of beams in Transverse Direction for Zone III and Zone V

Comparisons of bending moment in beams in longitudinal and transverse direction have higher value for Zone V than that for Zone III. In transverse direction the bending moment in beams for Zone V in comparatively greater than that for Zone III and also it goes on increasing gradually from first storey to top storey slightly decreases for last storey.

V. CONCLUSION

Based on the analysis results following conclusions are drawn:

1. With the use of steel plate shear walls in the building, the bending moments in the beams are observed to reduce due to the nearly equal and opposite pull exerted by the vertical components of diagonal tension of the SPSWs present on both side (lower and upper) of the beams.
2. The bending moment's values in longitudinal and transverse direction in zone V are observed to be greater as that of zone III.
3. The shear force obtained in longitudinal and transverse direction is lesser in zone III than zone V.

4. The axial force in the building is fairly same in both zone III and zone V.
5. Change of thickness of the SPSWs has a very small effect on the lateral deflection, bending moment and shear forces of the building.

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