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ANALYSIS OF POST-TENSIONED AND RCC FLAT SLABS IN MULTI-STOREY FRAMED STRUCTURES BY USING ETABS SOFTWARE

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Abstract —*Today Post-tensioning is a mature technology, providing efficient, economic and elegant structural solutions for a wide range of applications. Post-tensioned flat slab could be a better option compared to RCC flat slab, in respect of the cost of project and time of construction.The aim of this project is to compare the behaviour of RCC flat slabs, Post-tensioned flat slabs and conventional structure and also to analyze the behaviour of Post-tensioned flat slab structure with and without shear walls under seismic effect.In multi-storey framed structures flat slabs have weak resistance to the lateral loads. So to provide stiffness to structures against lateral forces shear walls are used. In this paper, a study of 15 storey building in zone IV is considered, and a comparative analysis of conventional structure with Post-tensioned and RCC flat slab is done to determine various parameters like base shear, storey drift, and displacement. Also, the building is analyzed with Post-tensioned flat slab by changing various location of shear wall. ETABS 2016 software is used for the analysis.*

Keywords-*post-tensioned flat slab structure; RCC flat slab structure; shear wall; storey shear; storey displacement; storey drift; ETABS 2016;*

I. INTRODUCTION

Due to the rapid increase in the shortage of land, construction of vertical structures is becoming a necessary part of our living. But this kind of construction brings challenges to counteract additional lateral load due to wind and earthquake. Flat slabs are one of the common floor systems for the construction of structures in earthquake sensitive areas. Flat slab structures have various advantages over conventional slab and beam structures. Flat slabs can be constructed by conventional reinforced concrete or by post-tensioning. Post-tensioned flat slab could be a better option compared to RCC flat slab, in respect of the cost of project and time of construction. In multi-storey framed structures flat slabs have weak resistance to the lateral loads. To provide stability to structures from lateral loads, shear walls are used. It provides large stiffness and strength to structures and reduces damage to structures.

A. Post-Tensioning

In prestressed concrete structures to counteract the stresses arising during the service period, an initial load is applied to the structure prior to its use. Prestressing of concrete can be classified into Pre-tensioning and Post-tensioning. Pre-tensioning is a method in which the tendons are tensioned before the casting of concrete and in Post-tensioning tension is applied to the tendons after hardening of the concrete. Today Post-tensioning is a mature technology, providing efficient, economic and elegant structural solutions for a wide range of applications. In Post-tensioned construction, the ducts in which the tendons are to be placed must be placed before the casting of concrete. The tendons are placed in these ducts after the casting of concrete. The tendon is anchored at one end and tensioned at other end. After the tensioning of tendons, a system of self-equilibrating forces develops. The Post-tensioned slab is much stronger as well as more durable than the normal concrete slabs.

B. RCC Flat Slabs

A Flat slab is a two-way reinforced concrete slab which directly supported by columns and doesn’t have beams. So the loads are transferred directly to the supporting columns. In Flat slab structures, the absence of beams gives a plain ceiling and so an attractive appearance. The Flat slab is easier to construct and requires cheaper formwork. In Flat slab structures, partition walls can be placed anywhere and these structures are less vulnerable in the case of fire than the conventional slab-beam structures.

C. Shear Walls

Lateral loads such as earthquake and wind loads can produce sway movement, high stresses and cause vibration to the structures. So the structure must have sufficient strength and stiffness against both vertical and lateral forces. Shear walls are structural elements which are usually used in high rise buildings to resist lateral forces parallel to the plane of the wall. It provides large stiffness and strength to structures and reduces damage to structures. Shear walls are continuous throughout the building height and are generally start at the foundation. The thickness of shear wall varies from 140mm to 500mm.

D. Objectives of the Study

The main objectives of this work are

- Study and compare the behaviour of multi-storey conventional structure, RCC flat slab building and Post-tensioned flat slab building.
- Study and compare the behaviour of Post-tensioned flat slab building with and without shear wall.
- Study and compare the behaviour of Post-tensioned flat slab building with shear wall at various locations.

II. METHODOLOGY

For the study, a 15 storey building with different floor systems as, Post-tensioned flat slabs, RCC flat slabs and conventional slab-beam are taken. Also for the comparative analysis of Post-tensioned flat slabs with and without shear walls, three locations of shear walls are considered. The modeling and the analysis of RCC flat slab, Post-tensioned flat slab and conventional slab structures have been done by using ETABS 2016 software package. Plan dimensions, storey levels, section properties, material properties and load patterns are defined and assigned. The models are analyzed by considering seismic zone IV to determine various parameters like storey shear, storey displacement, storey drift etc.

A. Details of Building

Type of building: Symmetrical commercial building
Plan dimension: 27.5m x 27.5m
Total height of building: 54m
Height of each storey: 3.6m
Total no. of storeys: 15

B. Material Properties of the Building

Grade of concrete: M40
Grade of steel: Fe500

C. Post-tension Strand Details

Ultimate strength: 1860 N/mm^2
Nominal area of strands: 98.7mm^2
Strand diameter: 12.7mm

D. Sectional Properties of Building

Beam dimensions for conventional structure: 300mm x 350mm
Thickness of slab for conventional structure: 150mm
Thickness of slab for RCC and Post-tensioned flat slab structures: 200mm
Thickness of shear wall: 250mm
Dimension of drop panel: 2000mm x 2000mm
Column dimensions:

    1 to 5 storeys: 850mm x 850mm
    6 to 10 storeys: 750mm x 750mm
    11 to 15 storeys: 600mm x 600mm

E. Loads on the Building

Seismic zone: Zone IV
Site type: II
Importance factor: 1
Wind speed: 39m/s^2
Terrain category: 4
Live load on terrace: 1.5kN/m^2
Live load on floors: 3kN/m^2

F. Models Considered for the Study:

1. G+14 story RCC conventional structure
2. G+14 story RCC flat slab building
3. G+14 story PT flat slab building
4. PT flat slab building with “L” shaped shear wall at corners
5. PT flat slab building with non-parallel shear wall along periphery
6. PT flat slab building with parallel shear wall along periphery

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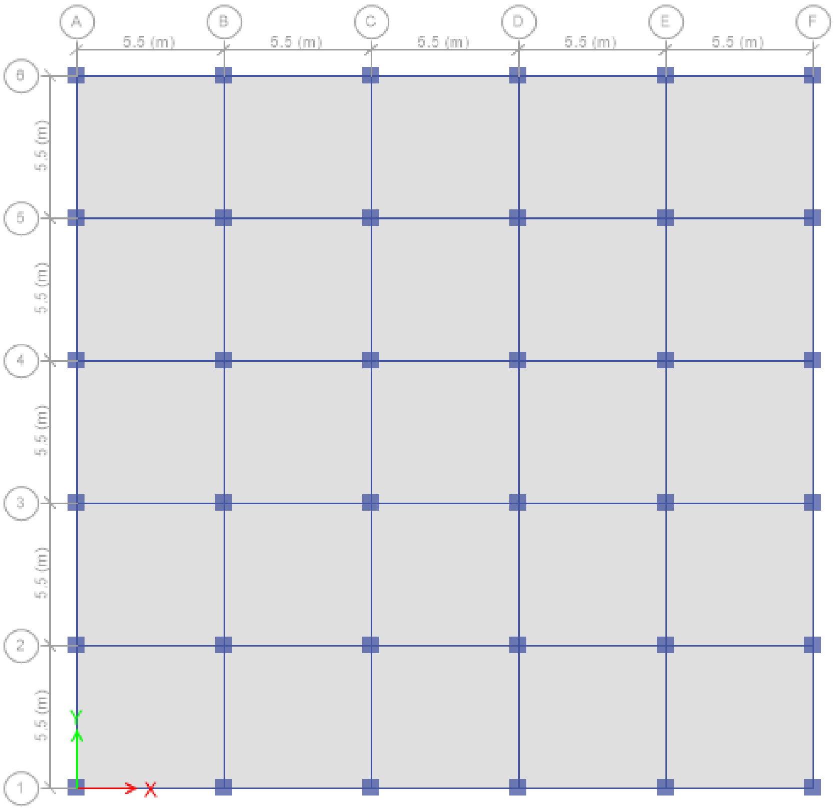

Figure 1.Plan of Conventional structure

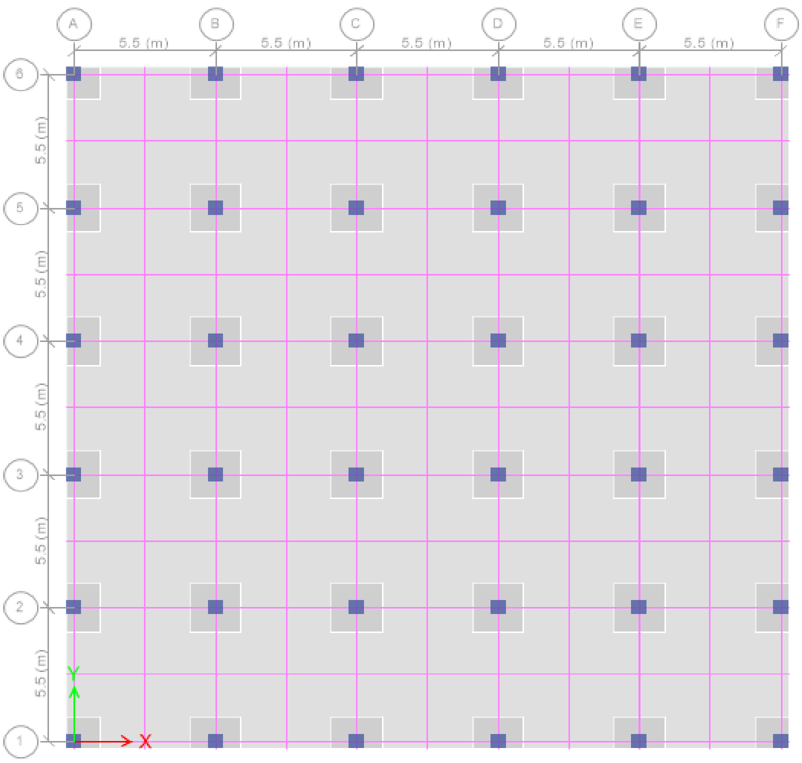

Figure 2. Plan of RCC Flat slab structure

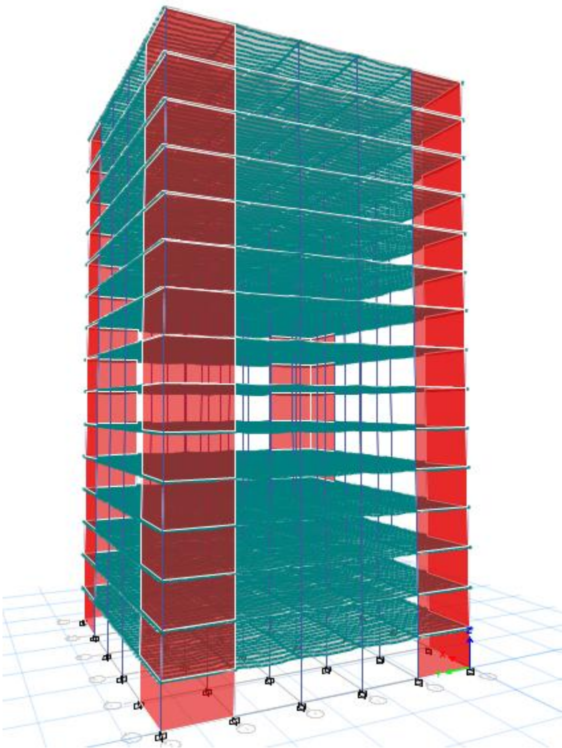

Figure 3. Elevation of Post-tensioned Flat slab Structure with "L" shaped Shear wall at corners

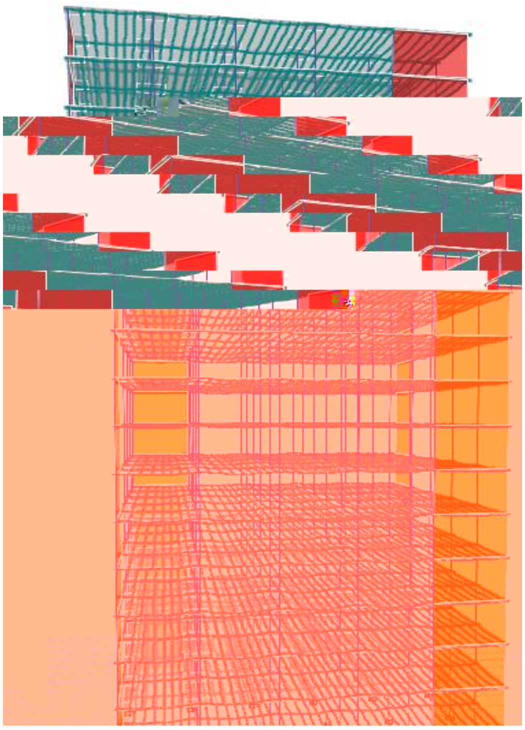

Figure 4. Elevation of Post-tensioned Flat slab structure with Non-parallel Shear wall along periphery

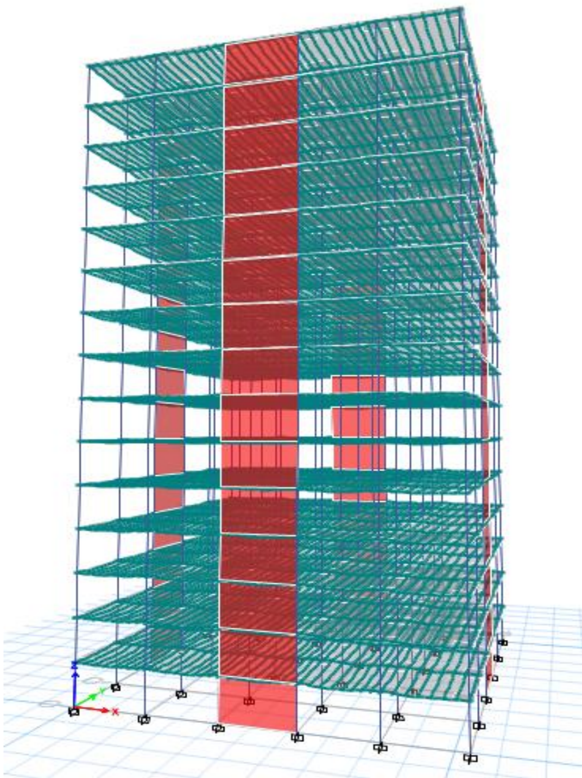

Figure 5. Elevation of Post-tensioned Flat slab structure with Parallel Shear wall along periphery

III. RESULTS AND DISCUSSION

The results are obtained from the analysis of building models and compared for the parameters like base shear, storey displacement, storey drift etc.

3.1. Comparison on Behaviour of Conventional structure, RCC Flat slab and Post-tensioned Flat slab structures

A. Storey Displacement

Storey displacement is the total displacement of a storey with respect to ground and is due to the lateral forces in X and Y directions. The data of displacement of storey in X-direction is collected for seismic loading from conventional structure, RCC Flat slab structure and Post-tensioned Flat slab structure. Figure 6 represents the variation of displacement of storey in X- direction under seismic effect.

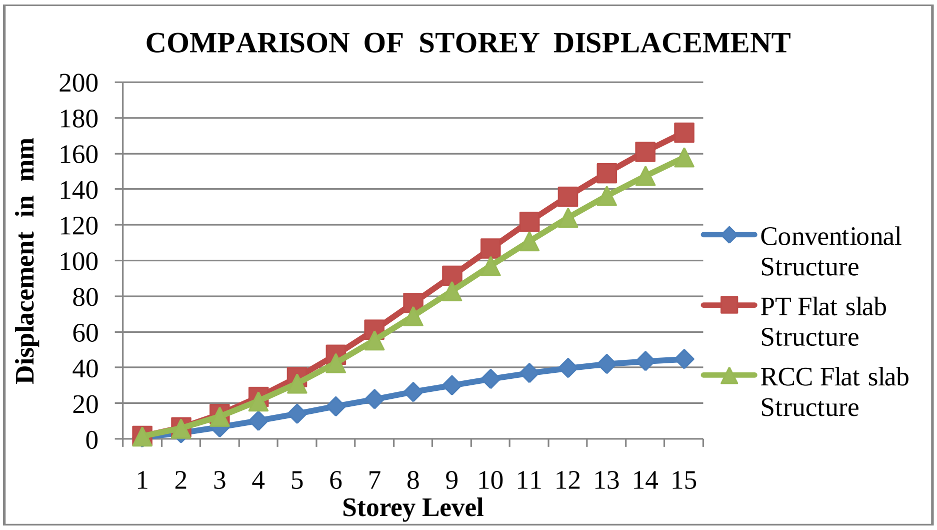

Figure 6. Graphical representation of Storey Displacement I

It is found that the displacement of conventional building is less than that of RCC flat slab and Post-tensioned flat slab structures. Also, displacement of RCC flat slab structure is relatively less when compare with that of Post-tensioned flat slab structure. The displacements of conventional structure and RCC flat slab structure are decreased by 68% and 8% respectively when compared to that of Post-tensioned flat slab structure.

B. Storey Drift

Storey drift is defined as the ratio of displacement of two consecutive floors to the height of that floor. The data of drift of storey in X-direction is collected for seismic loading from conventional structure, RCC Flat slab structure and Post-tensioned Flat slab structure. Figure 7 shows the graphical representation of story drift in studied models.

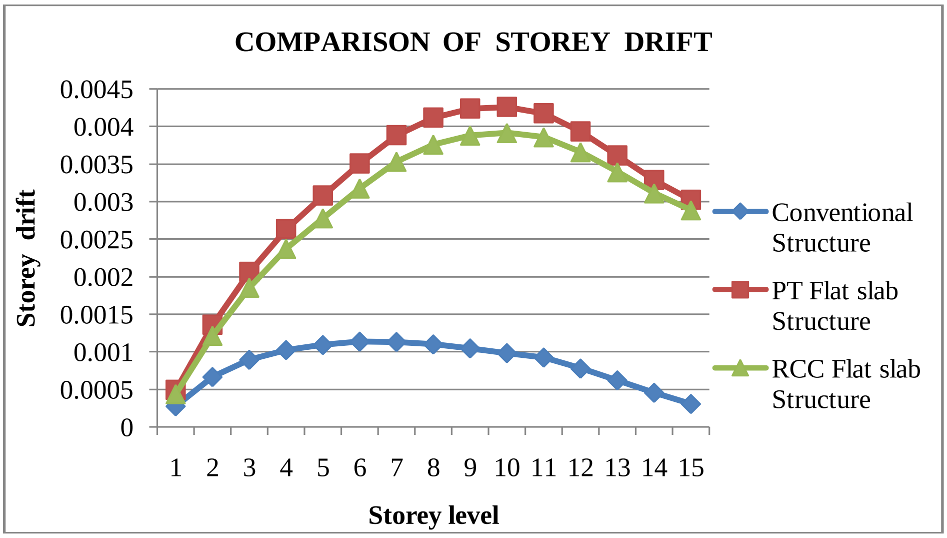

Figure 7. Graphical representation of Storey Drift I

It shows that as displacement and drift are directly proportional, when displacement is smaller in conventional structure story drift is also smaller than RCC flat slab and Post-tensioned flat slab structures. As in the case of displacement here also the storey drift value is slightly higher in Post-tensioned flat slab structure when compared to RCC flat slab structure. The storey drift of RCC flat slab structure and conventional structure are decreased by 8% and 73% respectively when compared to that of Post-tensioned flat slab structure.

C. Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to the seismic ground motion at the base of a structure. Figure 8 shows the base shear values of conventional structure, RCC Flat slab structure and Post-tensioned Flat slab structures.

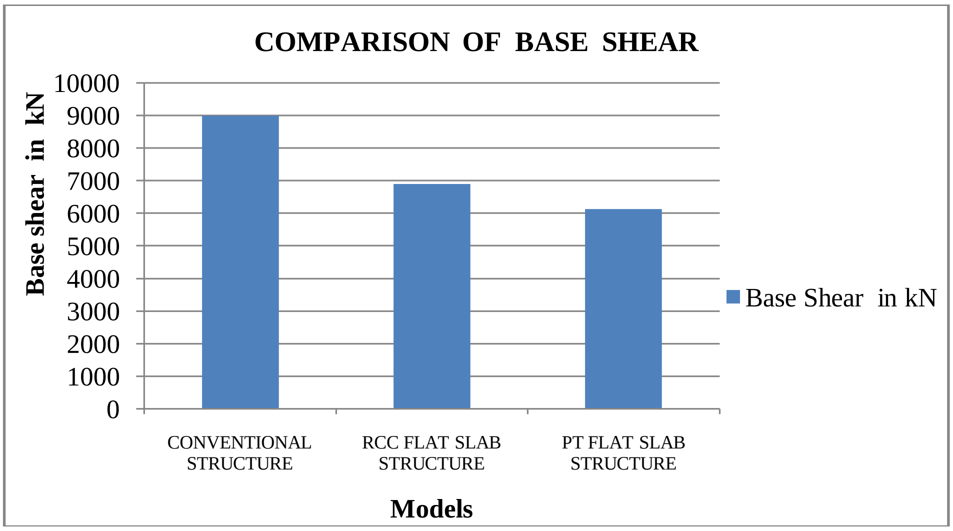

Figure 8. Graphical representation of Base Shear

From the figure, it can be seen that the base shear is maximum in conventional structure and minimum in Post-tensioned flat slab structure. Base shear of RCC flat slab and Post-tensioned flat slab structures are decreased by 23% and 31% respectively when compared to that of conventional structure.

From this study, it is clear that the RCC flat slab structure and Post-tensioned flat slab structure have weak resistance to the lateral loads as both types of flat slabs shows less base shear and higher displacement values when compared to the conventional structure. When considering RCC flat slab and Post-tensioned flat slab structures, Post-tensioned flat slab structure shows poor resistance to lateral loads than that of RCC flat slab structures.

3.2. Comparison on Behaviour of Post-tensioned Flat slab structures with Shear wall at various locations

A. Storey Displacement

Figure 9 represents the variation of displacement in Post-tensioned flat slab without Shear wall and with Shear wall at various locations.

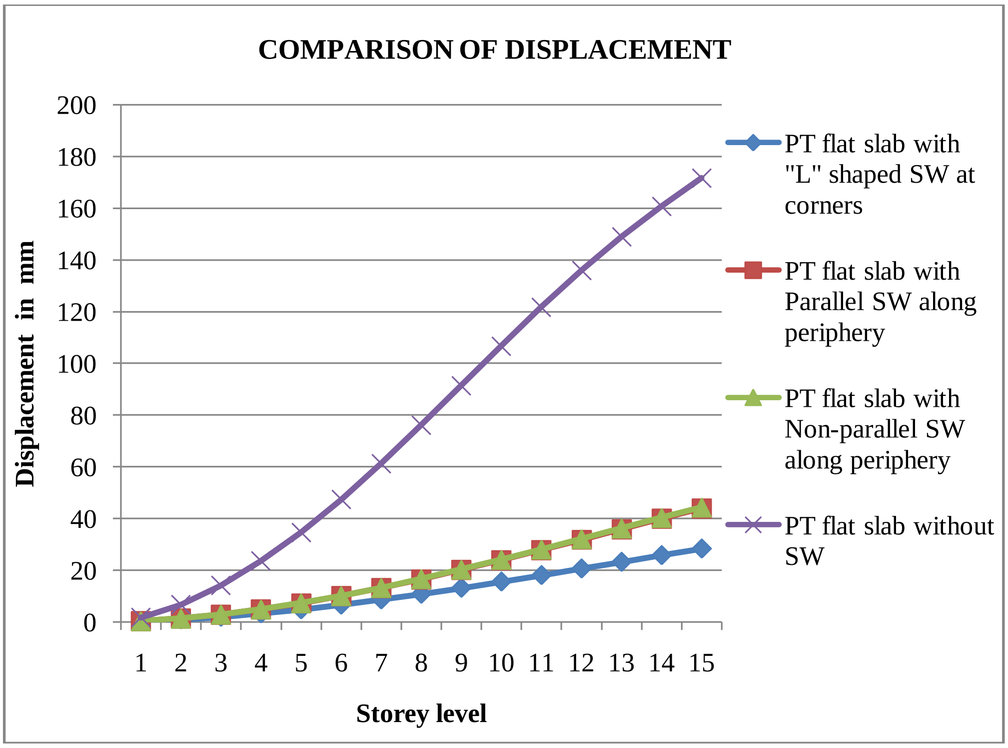

Figure 9. Graphical representation of Storey Displacement II

It is found that Post-tensioned flat slab with “L” shaped Shear wall at corners experience lesser displacement than that of all other models. Therefore considering only displacement we can say Post-tensioned flat slab building with “L” shaped Shear wall at corners is safer than that of all other models. Post-tensioned flat slab without Shear wall has very high displacement when compared to Post-tensioned flat slab with Shear wall. The displacements of Post-tensioned flat slab with “L” shaped Shear wall at corners, Post-tensioned flat slab with parallel Shear wall along periphery, and Post-tensioned flat slab with non-parallel Shear wall along periphery are decreased by 84%, 77% and 76% respectively compared to conventional structure.

B. Storey Drift

The data of drift of storey in X-direction is collected for seismic loading from all the models. Figure 10 shows the variation of story drift in Post-tensioned flat slab structure without Shear wall and with Shear wall at various locations. As like displacement, Post-tensioned flat slab with “L” shaped Shear wall at corners has lesser story drift than that of all other models. In Post-tensioned flat slab without Shear wall, storey drift is much higher. The drift value of Post-tensioned flat slab with “L” shaped Shear wall at corners, with parallel Shear wall along periphery, and with non-parallel Shear wall along periphery are decreased by 83%, 75% and 74% respectively compared to conventional structure.

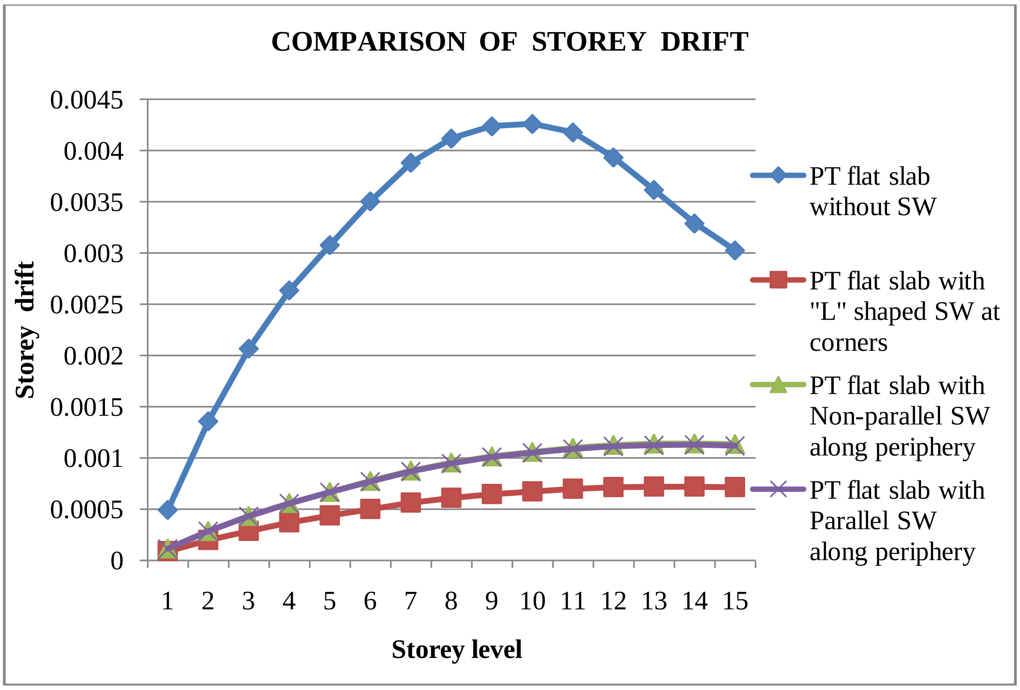

Figure 10. Graphical representation of Storey Drift II

C. Storey Shear

Story shear is distributed along the height of the structure in terms of lateral force. The design seismic force to be applied at each floor level is called storey shear. It is a fraction of total dead load and a part of the live load acting at each floor level. Figure 11 shows the variation of story shear in Post-tensioned flat slab structure without Shear wall and with Shear wall at various locations.

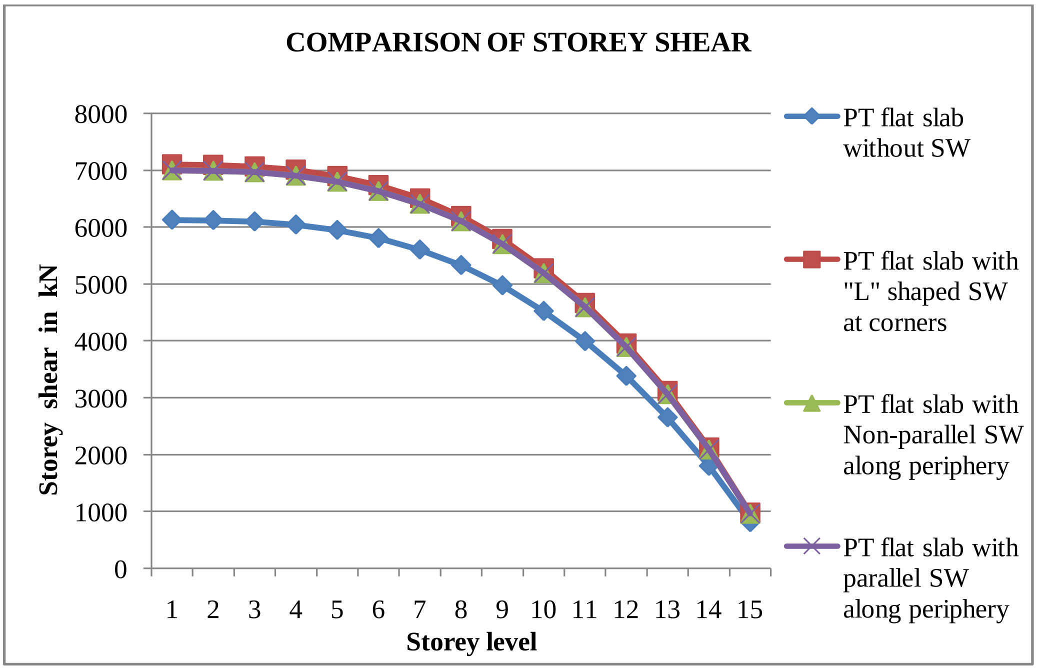

Figure 11. Graphical representation of Storey Shear

From the figure, it's found that the storey shear of Post-tensioned flat slab without Shear wall is much lesser than Post-tensioned flat slab with shear wall. Storey shear of Post-tensioned flat slab with non-parallel Shear wall along periphery and with Parallel shear wall along periphery shows equal values. The storey shear value of Post-tensioned flat slab with "L" shaped Shear wall at corners, with parallel Shear wall along periphery, and with non-parallel Shear wall along periphery are increased by 14%, 12% and 12% respectively compared to conventional structure.

IV. CONCLUSIONS

On the basis of the results the following conclusions have been drawn:

1. The displacement is always higher for flat slabs made of RCC and Post-tensioning compared to conventional structure. The displacements of conventional structure and RCC flat slab structure are decreased by 68% and 8% respectively compared to that of Post-tensioned flat slab structure.
2. The story drift is also higher in RCC flat slabs and Post-tensioned flat slabs than that of conventional structure. The storey drift of RCC flat slab structure and conventional structure are decreased by 8% and 73% respectively compared to that of Post-tensioned flat slab structure.
3. Base shear is maximum in conventional structure and minimum in PT flat slab structure. Base shear of RCC flat slab and PT flat slab structures are decreased by 23% and 31% respectively compared to that of conventional structure.
4. RCC flat slab structure and Post-tensioned flat slab structure have weak resistance to the lateral loads as both types of flat slabs show less base shear and higher displacement values when compared to conventional structure.
5. The displacement and drift of Post-tensioned flat slab structure with shear wall are decreased by 84% and 83% respectively compared to structure without shear wall. Also the base shear value of structure with shear wall is found to be 14% more than structure without shear wall.
6. Post-tensioned flat slab with shear wall is safer as it shows considerable difference in displacement, drift and storey shear.
7. Post-tensioned flat slab with "L" shaped shear wall at corners are suitable for the effect of lateral loads on the performance of building because it shows less displacement and drift, large base shear values when compared to all other models.

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