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Numerical Analysis of Post Tensioned Shear Walls Constructed within Multi Storey Buildings

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Abstract - Walls with prestressed tendons along with energy dissipating devices are called as Hybrid PT Shear Walls. A simplified numerical model will be used with good correlation of past experimental studies. The model will be developed in computational software SAP2000. Further this validate model will be integrated into a multi storey building frame. And the performance of the building is compared with conventional & hybrid PT shear wall. Performance of the building is compared in terms of strength, stiffness, ductility, energy dissipation capacity and residual lateral displacement.This study examines the behaviour mentioned above.

KeyWords: Post-tensioned shear wall (PT shear walls),PRESS, Prestress, Tendons, Seismic loads,
Hybrid PT walls, Energy Dissipators.

1. INTRODUCTION

The PT shear wall incorporates high-strength tendons that maintain elastic behavior throughout seismic events and restore the wall to its original position post-unloading, thus demonstrating the self-centering characteristics of PT walls . A hybrid post-tensioned shear wall integrates post-tensioned tendons for self-centering with external energy dissipators to attenuate energy and avert damage to structural elements, thereby ensuring both self-centering and energy dissipation within a singular framework, referred to as hybrid modeling or hybrid post-tensioned shear wall construction. For energy dissipation generally mild steel plates are used. Mild steel plates have different shape and size based on requirement. The primary aim of this study is to acquire a thorough comprehension of the seismic behavior of structures employing unbonded post-tensioned concrete shear walls in conjunction with external energy dissipators.

2. METHODOLOGY

Two full-scale G+10 storey concrete edifices are simulated to evaluate the response of the structures in terms of strength, stiffness, base shear capacity, moment-carrying capacity, energy dissipation capacity, and residual drift. One structure incorporates reinforced concrete moment frames and conventional shear walls to withstand lateral loads, while the other structure employs unbonded post-tensioned (PT) concrete shear walls alongside reinforced concrete beams and columns equipped with external energy dissipators. (i) modelling analysis and design are conducted utilizing the software SAP2000, which is recognized for its efficiency and reduced time consumption. Various steps involved are as follows:

- Building details
- Reinforcement in each Storey as per IS 456-2000 (Flexural reinforcement)
- Detailed tendon layouts
- Beam & column & cross section details
- Material properties
- Energy dissiptors details
- Loading details
- Computational building model
- Overall model

3. MODELLING AND ANALYSIS

3.1Buildingdetails

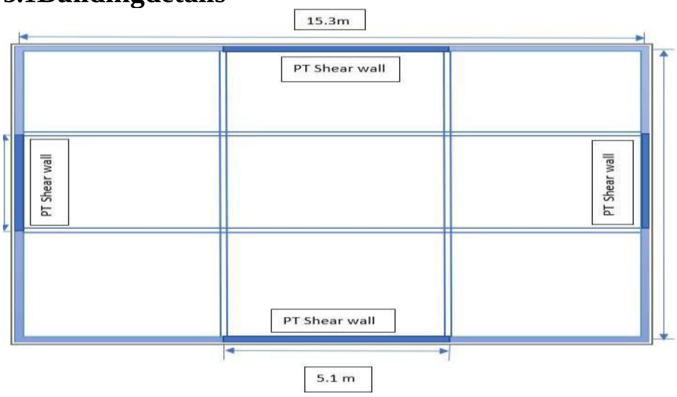
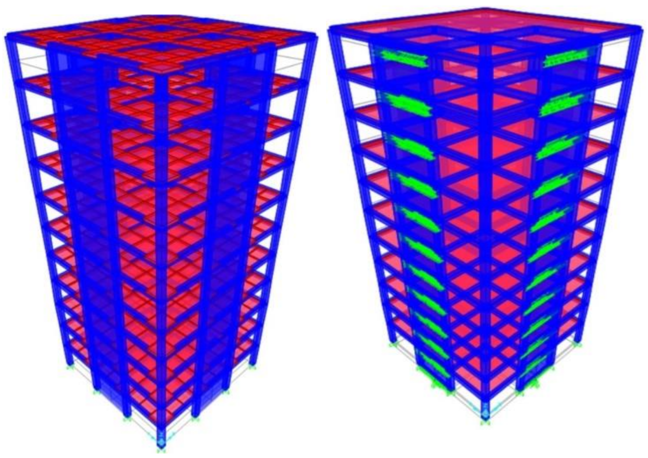


Figure 1 Plan of the G+10 -Storey design building (Square)

The simplified analytical model has demonstrated that both the in-plane and out-of-plane behaviors of the floor must be accurately represented in the computational model to achieve a comprehensive understanding of the building's response. Consequently, a three-dimensional model was employed to integrate both the in-plane and out-of-plane floor behaviors, thereby explicitly capturing the interaction between the wall and the floor.

A three-dimensional graphical depiction of the computational model formulated for the structure within SAP2000.

3.2 Wall cross section details



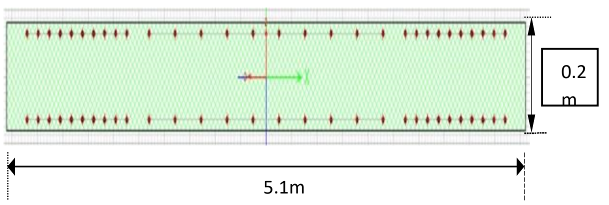
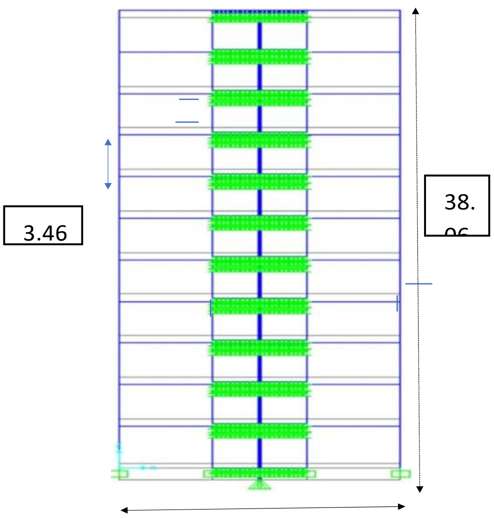


Figure 2 Reinforced detailing in shear wall

Figure 3 G+10 storey building (a) conventional shear wall (b) Hybrid shear wall Budling

Figure4 Elevation of the G+10 -Storey design building (Square) (XZ view @Y=0)



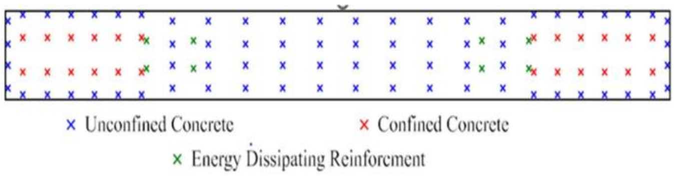


figure5 concrete and EDR layout

Reinforcement in each Storey as per IS 456-2000 (Flexural reinforcement

Note- Confining reinforcement is 1000 mm²/m; 16mm dia bars at 200mm c/c spacing.

3.3Beam & column & cross section details

Table 4: Beam and column cross section		
Storey	Beam (mm×mm)	Column (mm×mm)
Up to 4Th Storey	500×400	550×550
5-11th Storey	450×350	500×500
Note- 200mm thickness slab is provided on each Storey.		

Storey	**Bottom reinforcement**				**Top reinforcement**			
	%	Area (mm²)	Dia (mm)	No.	%	Area (mm²)	Dia (mm)	No.
1	0.48	6120	20	20	0.25	3188	20	10
2	0.44	5610	20	18	0.25	3188	20	10
3	0.30	3825	20	12	0.25	3188	20	10
4	0.25	3188	20	10	0.25	3188	20	10
5-10	0.25	3188	20	10	0.25	3188	20	10
11	0.48	6120	20	20	0.73	9307	20	30

3.4 Loading details

Dead load of each element, super dead load as floor finishing 1.5kN/m², Live load on the Slab as 3kN/m², seismic and wind load in both directions. Seismic load is assigned as mass source considering 100% dead load + 50% live load. Building model is assumed in seismic zone V and soil type is medium. And the temperature load for prestressing the tendons is same as used in validated model that is 0.25% ultimate tensile load, which is 127.9kN. the tendon force is provided as temperature difference that is -176.82 degree Celsius.

3.5 Detail tendon layout

The characteristic yield stress of the prestressing strands was 1650 MPa. The wall tendons were anchored underneath the foundation and at the top of the wall. Prestressing force in the tendons are applied using temperature difference. Initial prestressing force is taken as 25% of the yield prestressing force.

4.0 Design calculation for PT hybrid shear wall

Force equilibrium and compatibility conditions at the wall's base are used to compute the area of the EDR and PT tendons. Along with design tests to guarantee the wall performs satisfactorily, the maximum capacity of the wall is computed at maximum drift after the reinforcement is estimated at design drift, corresponding to design forces. The edges of the wall elevate from the wall base at design drift, which shortens the contact length. The neutral axis depth over which the compressive forces act is equal to this shortened contact length. Assuming an effective stress distribution of 0.85fck throughout a length of β1 (= 0.75 times), the compressive force in concrete is computed. Equation 1 is the depth of the neutral axis.

$Cd = 0.85\ fck\ tw\ \beta1\ cd$ ………………………………………………………….. (1)

$Mwd = 0.9\ Cd\ (0.5\ Lw - 0.5\ \beta1\ cd)$ …………………………………………... (2)

The elongation of PT tendons and EDR at design drift are dependent on their distance from the neutral axis and are given by equations 3 and 4 respectively. Corresponding stress in PT tendons is given by equation 5. The stress in EDR is noted from the stress strain curve, corresponding to the strain given by equation 6. For equilibrium at the base section, the forces generated due to EDR, PT tendons and self- weight should be equal to the compressive forces generated in contact length, equation 7.

$\delta pd = \Delta wd\ (0.5\ Lw - cd + ep)$ ……………………………………………..…..(3)

$\delta edr = \Delta wd\ (0.5\ Lw - c\ d + es)$ ……………………………………………….(4)

$fpd = fpi + (Epi.\ \delta pd)/lpu$ ……………………………………………………(5) $\varepsilon edr = \delta edr/lsw$ …………………………………...…………………………(6)

$Cd = As\ fsd + Ap\ fpd + N$………………………………………………………….……..……...(7)

Here, δpd, fpd, lpu, Ap and Epi denote the elongation, stress, un-bonded length, area, and modulus of elasticity PT tendons, respectively. Further, δedr, εedr, fsd, As and lsw denote the elongation, strain, stress, area and unbonded length of EDR, respectively.

Nd is the axial force, which is equal to the self-weight of the wall. ep and es denote the eccentricity of PT tendons and EDR from the center of the wall which are taken as 0.1m and 0.2m, respectively. The eccentricity of PT tendons is assigned lower than the eccentricity of EDR to limit the strains in PT and ensure that it remains in the elastic state.

Since the EDR is designed to yield it is placed at a higher eccentricity from the center of the wall. Additionally, a moment contribution ratio (Kd) is established (8), governing the contribution of EDR, PT tendons and axial forces in resisting the lateral moments. To ensure proper self-centering of the wall, this ratio should be maintained between 0.5 and 0.85. In this study, a moment contribution ratio of 0.5 is adopted.

$Kd = Ms/\ (Mpt+Mn)$ ……………………………………………………………… (8)

Medr, Mpt and Mn are moment contributions due to EDR, PT tendons and axial force, respectively**.**

5.0 Results

5.1 Pushover analysis

5.1.1 Base shear Versus lateral displacement

Equivalent static load analysis is done to calculate the loading pattern in multistorey building. Inverse triangle load is provided in pushover analysis. This is an applied load, monitored displacement control analysis. The lateral load is applied at the center of the outer plane in global X direction. The lateral load pattern for the pushover analysis is shown in figure

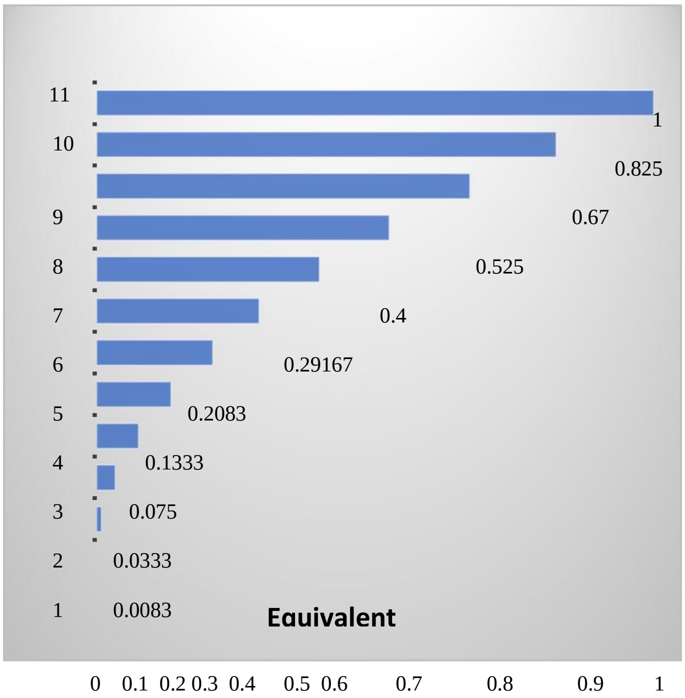


Figure 6 Lateral load pattern

Conclusion

- When controlled lateral displacement reached up to a 68.9 mm, there will be formation of plastic hinges start at upper 2 stories. In this case building is in the range of damage initiation.
- Now the monitored displacement is again increased to 196mm, the formation of plastic hinges is increases up to 4 stories. And the building is still in operational condition.
- Again, the monitored displacement is increased to 250mm, the plastic hinges form in each story. Top 3 stories are in immediate occupancy to life safety zone. Remaining all stories are in operational zone.
- After this point, if lateral displacement is increase there is a formation of mechanism and complete structure going to collapse at about 48.75m.

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