Comparative Study on Building with Post Tensioned Shear Wall and RCC Shear Wall

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Abstract—In the seismic design of buildings, shear walls act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In this paper our main focus is to determine the seismic behavior of building with post tensioned shear wall. For that Storey displacement and interstorey drift were computed using SAP2000 and compared with RCC shear wall Building.

Key words: RCC, SAP2000, DBE, ITG 5.2-09

I. INTRODUCTION

Seismic loading is one of the most important load considered while designing the structure. For the improvement of structure there is increase in materials and technologies. One of the common system is used in designing structures are shear wall system. RCC shear wall has shown good performance in earthquake but two inherent limitations found in commonly used rcc walls are: (1) the required nonlinearity or softening of the wall is caused by damage (i.e., yielding of reinforcing steel and softening of concrete in compression); and (2) residual lateral drift after a major seismic event. Both these limitations can be addressed through the use of post tensioning. The post-earthquake residual lateral deformation of a structural can be controlled by use of posttensioning which provides a restoring force against the lateral load which enables the wall to rock back to its original upright position. Using precast concrete panels accelerates the construction process as they can be fabricated in workshops and easily erected on-site. Therefore, several analytical and experimental studies have been conducted in last decade or two to combine the two components of precast construction and post-tensioning to improve lateral load behavior of structural walls.

The precast Posttensioned concrete shear wall shown in Figure 1, is constructed by stacking rectangular precast wall panels along horizontal joints above the foundation and at the floor levels.

![Fig. 1: Elevation, Exaggerated Displaced Position, And Cross Section of Posttensioned Wall System](image)

II. DESIGN REQUIREMENTS OF POSTTENSIONED SHEAR WALLS

Post tensioned shear walls are designed based on ACI ITG 5.2-09. It includes the determination of the seismic design forces, lateral drift demands, flexural and shear design of the horizontal joints, design and detailing of the wall reinforcement, and various design checks.

A. Seismic Design Forces

The design base shear force can be obtained using any of the procedures allowed in codes, such as the equivalent lateral force procedure or the modal analysis procedure. Once the design base shear force, V_{ad} is found, the design base moment, M_{ad} and the other design forces (e.g., story shear forces and bending moments) can be found from a linear-elastic analysis of the structure under the vertical distribution of the design base shear force.
B. Wall Drift Demands
The design is conducted at two drift levels: (1) the design-level wall drift, $\Delta_{wd}$ corresponding to the design basis earthquake (DBE); and (2) the maximum-level wall drift, $\Delta_{wm}$ corresponding to the maximum considered earthquake (MCE).

$$\Delta_{wm} = 0.95 \Delta_{wc}$$

Where,

$$\Delta_{wc} = 0.9\% \leq \left(\frac{H_{w}}{L_{w}}\right) \times 0.8\% + 0.5\% \leq 3.0\%$$

C. Preliminary Proportioning Of Wall Cross Section Geometry
The preliminary proportioning of a hybrid wall can be done by limiting the nominal shear stress at the design-level drift, $\Delta_{wd}$, such that

$$\frac{\sqrt{\tau_{w}}}{\sigma_{gross}} \leq \sqrt{\tau_{c}}$$

D. Design of Base Joint
The design of the base joint includes the E.D. and PT steel areas, probable (maximum) base moment strength of the wall, contact length and confinement reinforcement at the wall toes, E.D. steel strains and stresses (including the determination of the unbonded length for the E.D. bars), and PT steel strains and stresses (including the determination of the PT stress losses).

E. Flexural Design of Upper Joints
The philosophy behind the flexural design of the upper panel-to-panel joints is to prevent significant gap opening and nonlinear behavior of the material through $\Delta_{wm}$. Except for the base joint where the wall is designed to rotate about the foundation, the structure should behave essentially as a rigid body through $\Delta_{wm}$. Thus, the design of the upper panel-to-panel joint is conducted for the maximum joint moment demand, $M_{wm}$.

F. Shear Design across Horizontal Joints
To prevent significant horizontal slip of the wall during loading up to the maximum level drift, $\Delta_{wm}$, the shear friction capacity at the horizontal joints, $V_{ss}$ should be greater than the joint shear force demand, $V_{jm}$. The resulting design equation can be written as:

$$\phi V_{ss} > V_{jm}$$

Where, $\phi = 0.75$ represents a capacity reduction factor against shear slip failure. $V_{jm}$ should be calculated from the maximum base shear force.

G. Design of Panel Reinforcement
1) Distributed Reinforcement in Wall Panels
The distributed reinforcement in the base panel of solid walls (i.e., without perforations) should be designed following the applicable requirements in Sections 21.9.2 and 21.9.4 of ACI 318 (2011). In addition, the requirements in Section 21.9.6.4(e) of ACI 318 should be satisfied for the development of the wall horizontal reinforcement in the confined boundary regions at the wall toes.

2) Edge Reinforcement in Wall Panels
Reinforcement should be placed around the entire perimeter of each wall panel using mild steel bars placed parallel to each panel edge.

3) Other Panel Reinforcement
All other panel reinforcement, including but not limited to any additional reinforcement to control temperature and shrinkage cracks as well as to support lifting inserts, should be designed according to Chapter 16 of ACI 318 (2011).

H. Design Checks:
1) Wall Restoring Force
Walls must maintain an adequate amount of axial restoring force (i.e., self-centering capability) to ensure that the gap at the base joint is fully closed upon removal of the lateral load after tensile yielding of the E.D. bars.

2) Yielding of E.D. Steel
As required by Section 5.3.2 of ACI ITG-5.2, the E.D. steel should reach the yield stress, $f_{y}$, before the PT steel stress reaches 0.95$f_{py}$.

III. PROBLEM FORMULATION

A. Description of Building
Typical storey height = 3 m
Grade of concrete = M25
Grade of RCC Shear wall = M25
Grade of PT Shear wall = M35
Grade of steel = Fe 415
Grade of PT steel = ASTM Grade-270 with 12.7 mm diameter & 98.4 mm2 area.
Beam Size = 0.23* 0.45 m
Column size (5 & 7 storey) = 0.30*0.45 m
Column size 10 storey = 0.30*0.5 m
Column size 15 storey = 0.30*0.6 m
B. Modeling of Post Tensioned Shear Wall:
After modeling the ordinary frame structure with shear wall, tendons should be modeled as follows:

1) Step 1: Go to Define section > area section > Add new area section > Select Shell layered section > Define concrete and steel layer definition.
2) Step 2: After defining the shear wall section next task is to model the unbonded PT tendons.
3) Step 3: Go to Define > Material properties to assign the tendon material property.
4) Step 4: After defining properties for tendons. Define tendon section
5) Step 5: Go to draw tendon section. Draw tendon as required.
6) Step 6: Now assign the initial prestress force to the tendon.
7) Step 7: For allowing gap opening behavior of precast wall assign Gap link element at each shear wall panel.
8) Step 8: Define Gap link element properties.

C. Loads Considered:
1) Dead Load – Self weight
2) Live Load – 5 KN/m² (except roof)
3) Earthquake Load – As per IS 1893:2002 for Zone III and Zone IV

Load Cases

IV. RESULTS
Results are presented in terms of maximum storey displacement of 5, 7, 10 and 15 storey RCC shear wall building and PT shear wall building for zone IV and Zone III.
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V. DISCUSSION

- For building in zone 4 max percentage change in storey displacement in X direction is 31.25% for five storey, 37.5% for seven storey, 20.33% for ten storey and 13% for fifteen storey building with shear wall and with post tensioned shear wall.

- For building in zone 3 max percentage change in storey displacement in X direction is 14.63% for five storey, 20.33% for ten storey, 11.75% for ten storey and 7.53% for fifteen storey building with shear wall and with post tensioned shear wall.

- For Building with RCC shear wall and PT shear wall Displacement in Y direction is almost same. But for PT shear wall added advantage of reduction in displacement of X direction.

VI. CONCLUSION

- For RCC shear wall and PT shear wall displacement in Y direction is almost same. But for PT shear wall added advantage of reduction in displacement of X direction.

- For seven storey building results are more satisfactory or PT shear wall is more effective as compared with five storey, ten storey or fifteen storey building.

- Effectiveness of PT shear wall increases with increase in height but after some height its effectiveness is decreasing.

- After certain height it behaves as a RCC shear wall. No added advantage of PT steel observed after 15 storey building.

REFERENCE

Walls Based on Validation Testing and Commentary.” ACI Innovation Task Group 5.


