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Analysis of multi storey building with precast load bearing walls

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ABSTRACT

Pre-cast construction is gaining significance in general and urban areas in particular. It is gaining more popularity with the rapid urban infrastructure growth. In this context G+11 storey residential building with precast reinforced concrete load bearing walls has been attempted for analysis. The structural system consists of load bearing walls and one-way slabs for gravity and lateral loads have been taken for analysis using ETABS. Various wall forces, displacements and moments have been worked out for different load combinations. Data base is presented for the worst load combination. This work is limited to the analysis of structural elements only not the connection details.

Keyword: precast load bearing wall, ETABS, Pier and spandrel labeling, lateral load analysis.

1. Introduction

Now a day, there is an increase in housing requirement with increased population and urbanization. Building sector has gained increasing prominence. However, the fact that the suitable lands for building/construction. Precast load bearing walls provide an economical solution when compared to the conventional column beam in fill wall system for the advantage of speed of construction and elimination of wet trades. In multi-storey buildings, lateral loads that arise as a result of winds and earthquakes are often resisted by a system of shear walls acting as vertical cantilevers. Such walls are usually perforated by vertical bands of openings which are required for doors and windows to form a system of shear walls. Mazen (2013) has stressed that the small openings in the shear wall will yield minor effect on the load capacity of shear walls, cracking pattern and maximum drift. In case of small openings, the shear walls behave as coupled shear walls. Thakkar (2012) has concluded that the design of shear wall is a complex procedure, especially if the cross section of the shear wall is not regular in shape. The design of shear walls takes horizontal forces into account by shear and bending. The design of shear in the walls can be managed by computing the shear stress distribution over the cross section and reinforcing appropriately. Potty (2008) has concluded that the difference in the deflection of shear wall modeled by beam element and the shell element is only 1.6 mm for the ten storey building.

Habibullah (2007) has worked on physical object based analysis and design modeling of shear wall system using ETABS. It has been concluded that grouping of the area objects into piers is a very powerful mechanism to automatically obtain design moments and shear across a wall section from a finite element analysis. Dar (2007) had stressed that the large openings are generally achieved by use of large transfer beams to collect loading from the upper shear walls and then distribute them to the widely spaced columns that support the transfer girders.

Wdowicki and Wdowicki (1993) have stressed calculating stress and displacements in three-dimensional shear wall structure with uniform properties throughout the height. The analysis is carried out on the basis of the continuous connection method. The system allows for considering lateral and gravity loads, arbitrary located in the plan and arbitrary distributed along the height.

Benjamin (1968) worked on variability analysis of shear wall structure where both rigidity and the strength of shear walls are highly variable. Bozdogan et, al. (2010) carried out vibration analysis of asymmetric shear wall structures using the transfer matrix method. He concluded that the governing differential equations of equivalent bending-warping torsion beam are formulated using the continuum approach. Xiaolei et, al. (2008) worked on numerical analysis of cyclic loading test of shear walls based on openSEES. Carpinteri et, al. (2012) carried out lateral load effects on tall shear wall structures of different heights. The accuracy of the results is investigated by a comparison with finite elements solutions, in which the bracings are modeled as three-dimensional structures by means of shell elements. Biswas et, al. (1977) carried out three dimensional analysis of shear wall multi storey building. He studied the importance of torsion in multi storey building having asymmetric layout of shear walls. Greeshma et. al., (2011) carried out the analysis of flanged shear walls using ANSYS concrete model. He has studied the possibilities of modeling reinforcement detailing of reinforced concrete models in practical use. Fahjan et, al. (2010) studied nonlinear analysis method for reinforced concrete buildings with shear walls. The different approaches for linear and non linear modeling of shear walls in structural analyses of buildings are studied and applied to RCC buildings with shear walls.

In this present study, G+11 storey precast load bearing wall structure is taken for analysis. The modeling and analysis has been done in using ETABS. The parametric study has been done to observe the effect of axial compression load, out of plane moments, tensile force, shear force, storey drift, lateral load and storey shear on shear walls. Finally data base is prepared for various storey levels. Although the connection details in the precast construction plays vital role but presently the details of connections not included in the present paper. Hence the emphasis on the analysis of load bearing wall structure.

2. Modeling of shear wall structure

In this present study Ground +11 storey shear wall building is considered for one acre of site with 350 units. Around 400sqft of carpet area per unit is taken with 300 units per floor. The constriction Technology is total precast solution with load bearing RCC shear walls and slabs. The modeling is done in ETABS as follows.

1. The structure is divided into distinct shell element. The shell element combines membrane and plate bending behavior, as shown in Figure1. It has six degrees of freedoms in each corner point. It is a simple quadrilateral shell element which has size of 24 x 24 stiffness matrix.
2. Grid lines are made for the x, y and z coordinates and the wall is drawn from scratch.
3. Boundary conditions are assigned to the nodes wherever it is required. Boundary conditions are assigned at the bottom of the wall i.e., at ground level where restraints should be against all movements to imitate the behavior of shear wall.
4. The material properties are defined such as mass, weight, modulus of elasticity, Poisson's ratio, strength characteristics etc. The material properties used in the models are shown in table 1.

5. The geometric properties of the elements are dimensions for the wall section.
6. Elements are assigned to element type, as shown in Table.2
7. Loads are assigned to the joints as they will be applied in the real structure.
8. The model should be ready to be analyzed forces, stresses and displacements.

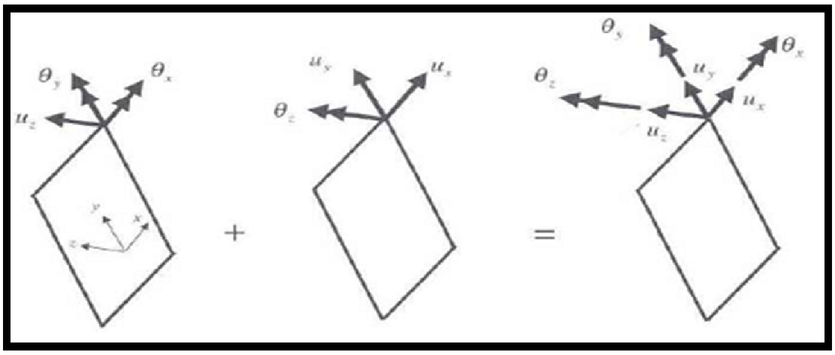


Figure 1: Shell element

Table 1: Material and element property for wall element

Material name	Concrete
Type of material	Isotropic
Mass Per Unit Volume	2.5 kN/m^3
Modulus of elasticity	32 kN/mm^2
Poisson's ratio	0.2
Concrete strength	30 MPa
Section name	Wall
Wall thickness	150 mm

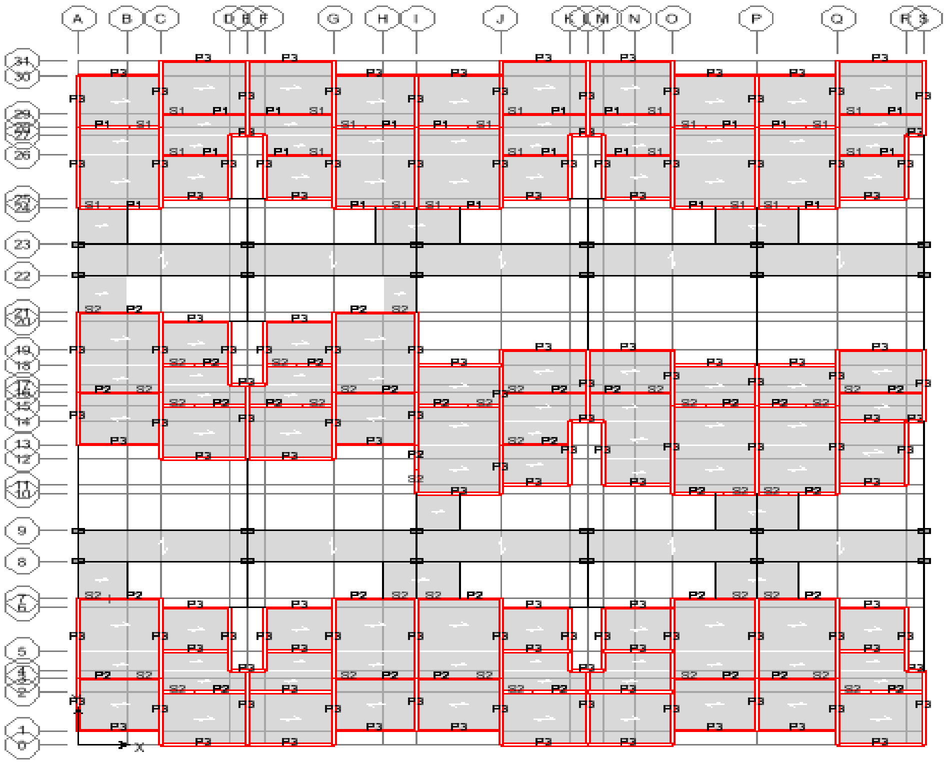
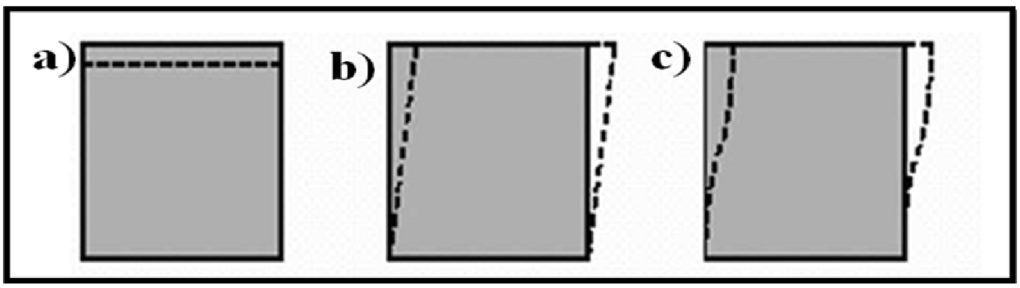


Figure 2: A typical floor plan of structure under consideration

In ETABS single walls are modeled as a pier/spandrel system, that is, the wall is divided into vertical piers and horizontal spandrels. This is a powerful mechanism to obtain design moments, shear forces and normal forces across a wall section. Appropriate meshing and labeling is the key to proper modeling and design. Loads are only transferred to the wall at the corner points of the area objects that make up the wall. Generally the membrane or shell type element should be used to model walls. Here the shell type is used for modeling the wall element. There are three types of deformation that a single shell element can experience axial deformation, shear deformation and bending deformation as shown in Figure3



a) Axial Deformation b) Shear Deformation c) Bending Deformation

Figure 3: Deformation of a shell element

Wall pier forces are output at the top and bottom of wall pier elements and wall spandrel forces are output at the left and right ends of wall spandrel element, see Figure4

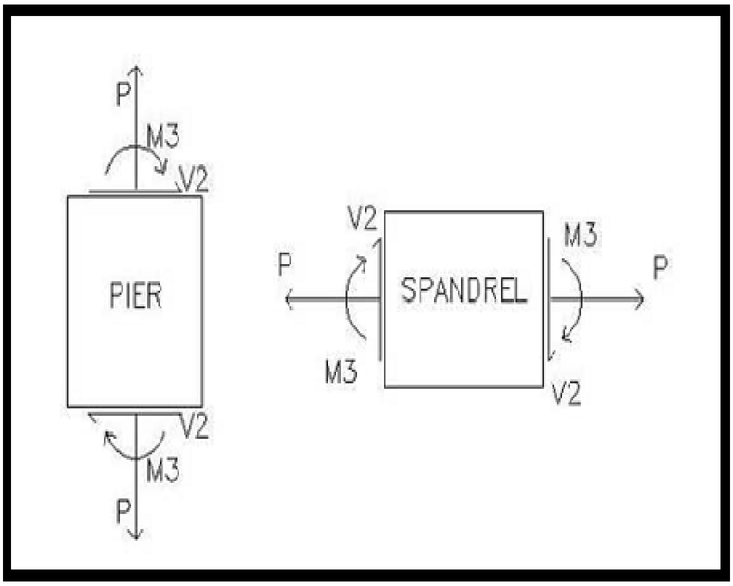


Figure 4: Pier and Spandrel forces in ETABS

At the upper level of this model, pier P1 is defined to extend all the way across the wall above the openings. Pier P2 makes up the wall pier to the left of the top window. P3 occurs between the windows. Spandrel labels are assigned to vertical area objects (walls) in similar fashion to pier labels. The pier and spandrel labels must be assigned to wall element before performing analysis. The lateral load analysis that is seismic and wind analysis requires certain parameters to be assigned in ETABS. These parameters are listed in table.2

Table 2: Seismic and wind parameters

Seismic coefficients AS PER IS: 1893-2000			**Wind Coefficients AS PER IS: 875-1987**	
Seismic Zone Factor	0.1		Wind speed (V_b)	50m/s
Soil Type	III		Terrain Category	I
Importance Factor (I)	1		Structure Class	B
Response Reduction (R)	3		Risk Coefficient k_1 factor	1
			Topography k_3 factor	1
			Windward coefficient	0.8
			Leeward coefficient	0.5

3. Results and discussion

Shear wall structure having G+11 storey is analysed for garvity and latral loads. The effect of axial force, out of plane moments, lateral loads, shear force, storey drift, storey shear and tensile force are observed for different stories. The analysis is carried out using ETABS and data base is prepared for different storey levels as follows

Table 3: Axial force and out of plane moments for different storey levels

Storey	Wall location	Axial compression load (KN)	Out of plane moments (KN-M)
12	Top	15.358	20.010
	Bottom	57.277	21.573
11	Top	91.473	-37.385
	Bottom	131.874	34.478
10	Top	170.653	-42.314
	Bottom	209.962	45.532
09	Top	253.931	-46.156
	Bottom	291.969	57.054
08	Top	340.620	-47.442
	Bottom	377.376	68.345
07	Top	430.030	-46.705
	Bottom	465.494	79.316
06	Top	521.423	-46.841
	Bottom	555.598	89.867
05	Top	614.088	-55.166
	Bottom	646.985	100.005
04	Top	707.363	-63.545
	Bottom	739.008	109.844
03	Top	800.846	-71.943
	Bottom	831.300	120.038
02	Top	894.543	-80.360
	Bottom	924.026	132.461
01	Top	994.804	-89.367
	Bottom	1026.764	142.603

Table 4: Shear force and displacements for different storey levels

Storey	Maximum tensile force (kN)	Maximum shear force (kN)	Storey drift (mm)	Lateral load In (kN)	Storey shear (kN)
12	-16156.865	-907.77	0.199	736.67	-608.25
11	-35756.738	-2012.3	0.199	734.36	-598.27
10	-51933.454	-2925.14	0.201	730.37	-1337.36
09	-65018.616	-3664.54	0.2	604.65	-1946.62
08	-75343.36	-4248.75	0.197	494.90	-2436.02
07	-83237.752	-4696.04	0.189	387.14	-2855.50
06	-89030.468	-5024.66	0.177	293.35	-3125.17
05	-93048.654	-5252.87	0.16	217.52	-3334.92
04	-95617.871	-5398.93	0.138	151.66	-3504.71
03	-97062.088	-5481.08	0.11	97.78	-3604.59
02	-97703.854	-5517.6	0.077	55.88	-3634.55
01	-97864.264	-5526.73	0.036	25.94	-3674.50

3.1 Effect of axial force on shear wall

The load bearing wall structure mostly caries axial compression force and transfer on to the foundation. The entire vertical load of all the stories is carried by ground floor load bearing wall. In order to design that wall it is quite essential to understand the variation of axial force in the walls. This force in the shear wall is from worst load combination of gravity and lateral loads. For the worst load combination, the axial force in the wall is plotted on y-axis against at each storey level. From Figure5, it is observed that maximum axial force in storey one is 1026.764 kN. The difference in maximum axial force between storey 11 and 12 is 7.26%. It indicates that the variation in maximum axial force with storey level is linear for worst load combination.

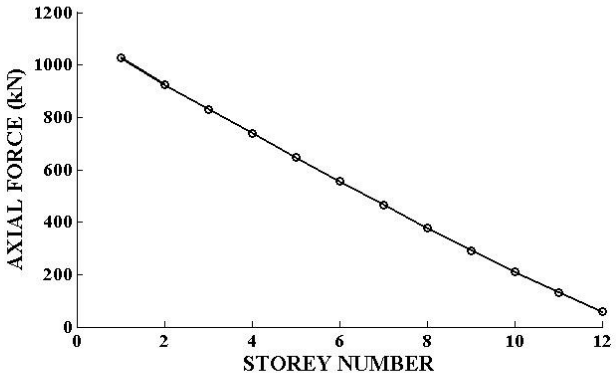


Figure 5: Axial force on shear wall

3.1 Effect of out-of-plane moments on shear walls

Load bearing RCC walls are slender compression elements subjected to in and out-of-plane bending. For the worst load combination, out-of- plane moments in the wall is plotted on y-axis against at each storey level. it is concluded from Figure6 that the maximum out-of- plane moments in walls of storey one is 142.603kN-m. The difference in maximum out of plane moment between storey 11 and 12 is 9.04% .It indicates that the variation in maximum out of plane moment with storey level is linear for worst load combination.

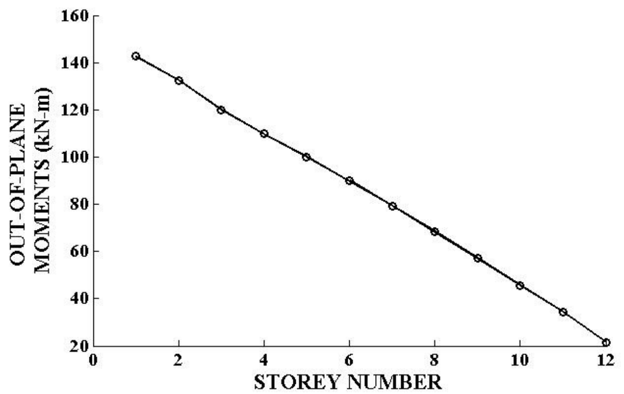


Figure 6: Out of plane moments on shear walls

3.2 Effect of storey lateral load on shear wall

Most lateral loads are live loads whose main component is horizontal force acting on the structure. The intensity of these loads depends upon the building's geographic location, height and shape. For the worst load combination lateral load in the wall is plotted against each storey level. From Figure8, it is observed that maximum lateral load in storey 12 is 736.67 kN. The difference in maximum lateral loads between storey 11 and 12 is 0.54%. It is observed form Figure7 that this is non-linear variation of lateral load.

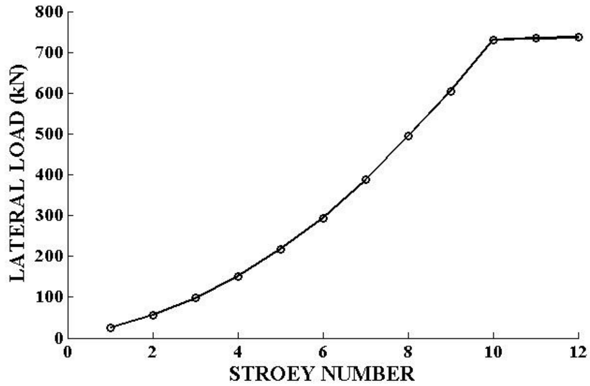


Figure7: Lateral loads on shear walls

3.3 Effect of shear force on shear wall

Shearing forces are unaligned forces pushing one part of a body in one direction, and another part the body in the opposite direction. For the worst load combination shear force in the wall is plotted against at each storey level. From the Figure8, it is observed that maximum lateral load in storey one is 5526.73 kN. The difference in maximum lateral loads between storey 11 and 12 is 19.98%. It indicates that the variation in maximum shear force with storey level is non-linear for worst load combination.

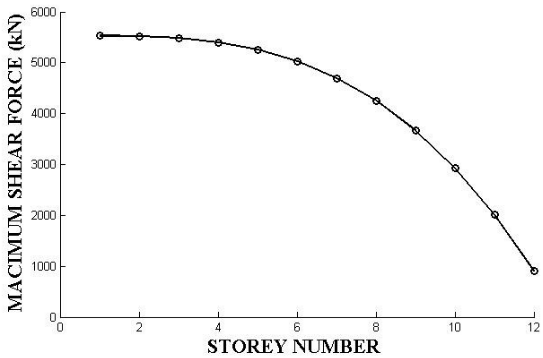


Figure8 Shear force on shear walls

3.4 Effect of storey drift on shear wall

One of the major shortcomings high-rise structures is its increasing lateral displacements arising from lateral forces. For the worst load combination storey drift in the wall is plotted on y-axis against at each storey level. From the Figure9, it is observed that maximum storey drift in between storey 12 is 0.199 mm. It indicates that the variation in maximum storey drift with storey level is non linear for worst load combination.

Figure 9: Storey drifts on shear walls

3.5 Effect of Storey shear on shear wall

For the worst load combination storey shear in the wall is plotted on y-axis against at each storey level. From the Figure10, it is observed that maximum storey shear in storey one is 608.25kN. It indicates that the variation in maximum storey shear with storey level is non linear for worst load combination.

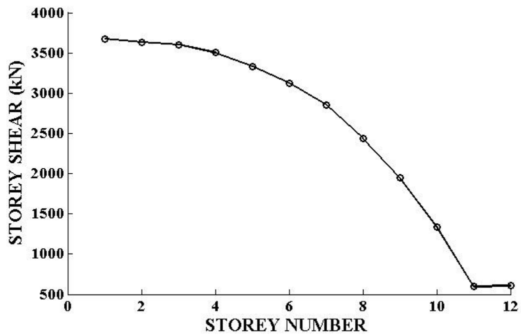


Figure 10: Storey shear on shear walls

3.6 Effect of tensile force on shear wall

The tensile force is the maximum stress that a structure can withstand while being stretched or pulled before failing or breaking. Tensile strength is the opposite of compressive strength and the values can be quite different (Wikipedia, 2013). For the worst load combination tensile force in the wall is plotted against at each storey level. From the figure 11, it is observed that maximum tensile force in storey one is 97864.264 kN. The difference in maximum tensile force between storey 11 and 12 is 20.02% .It indicates that the variation in maximum tensile force with storey level is non-linear for worst load combination

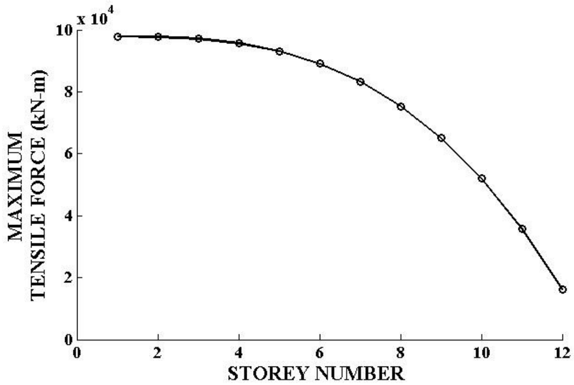


Figure 11: Tensile forces on shear walls

4. Summary and conclusion

In this present work ETABS is used to analysis the shear wall structure of G+11 considering the gravity and lateral loads. The following conclusion is drawn from present work.

1. The variation of axial force with stories is linear. The difference in maximum axial force between storey 11 and 12 is 7.26 %.
2. The variation of out-of-plane moment with stories is linear. The difference in maximum out-of-plane moment storey 11 and 12 is 9.04 %.
3. The variation of lateral loads with stories is non-linear. The difference in maximum lateral loads between storey 11 and 12 is 0.54 %

4. The variation shear force with stories is non-linear. The difference in maximum shear force between storey 11 and 12 is 19.98 %.
5. Variation of storey drift with storey is non-linear. The maximum storey drift in storey 12 is 0.199 mm.
6. Variation of storey shear with storey is non-linear. The maximum storey shear in storey one is 608.25kN.
7. The variation of tensile force with stories is non-linear and the difference in maximum tensile force between storey 11 and 12 is 20.02 %

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