Comparative Study of P-Delta Effects of Rectangular and Circular Hollow Core Wall Panels using LECwall

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Abstract – *This paper summarizes the research work on P-Delta analysis of rectangular and circular hollow core wall panels. The concept of P-Delta analysis is that when a member is critically loaded, it undergoes deflection which in turn induces secondary moments on the member. The analysis based on these secondary moments is known as P-Delta analysis. In this paper Modeling and P-Delta analysis are done by LECwall software*

Key Words: Precast Wall panels, Hollow core Wall panel, P-Delta Analysis, LECwall

1. INTRODUCTION

Precast concrete wall panels gained popularity due to its speed of erection, design flexibility, thermal efficiency, competitive cost etc. Precast Concrete Wall Panels are cast in the yard, then cured in a controlled environment, then transported to the construction site and lifted with crane.
A hollow core wall panel is a precast, pre-stressed concrete member with continuous voids provided to reduce weight and, therefore, cost. As a side benefit, voids can be used to conceal electrical or mechanical runs. The hollow core can be of either rectangular or circular shape.

As per PCI Design Handbook section 5.9.3, the most effective design of precast wall panel can be done by using either moment magnification method or by second order P-Delta analysis. P-Delta analysis is an iterative second order analysis of the member. Second order analysis means it analyses the member based on the secondary moments induced in the member due to deflection caused by critical loads.

LECwall software does an iterative second-order analysis of the member under each of the six specified load cases. The PCI 7th Edition Handbook procedure (Section 5.9.3.1) is used to calculate bow and P-Delta forces. If stresses exceed the modulus of rupture at any point along the member, the section is assumed to be cracked and the analysis is repeated using cracked section properties.

Forces and deflections due to wind are calculated by slope-deflection method. Member bow is calculated based on differential temperature strains, wind load deflection and member bow due to applied gravity and earth pressure loads. Wind pressure acts inward, towards the inside of the member, while suction acts outward. For wall panels, the main structural layer is usually on the inside, to better carry any applied loads from the inside structure of the building. The midpoint bow of the member is calculated for both suction and pressure.

2. SOFTWARE USED

LECwall is a product of Losch software having hyper-specialized software tools to analyze precast wall panels.P-Delta slenderness and temperature effects combined with wind, earth pressure and gravity load analysis under service conditions or at ultimate strength using ACI 318 can be done by LECwall.

3. MODELLING OF WALL PANEL

3.1 Defining section properties

Thickness of wall panel = 8in
Outer layer = 3in
Inner layer = 3in
Insulation layer = 2in
Width of the panel = 96in
Length of the panel = 360in
Size of opening = 30x30in
Panel with rectangular hollow core
Size of hollow core =4.75 x 5.25 in^2
No. of hollow cores =15

Figure 1 shows the cross section of precast concrete wall panel with rectangular hollow cores.

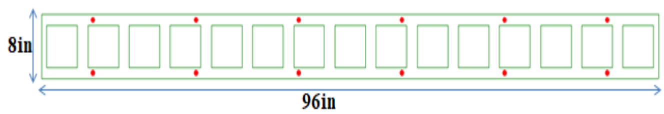

Fig -1: Precast concrete wall panel with rectangular hollow cores

Panel with circular hollow core
Size of hollow core =5.63in dia.
No. of hollow cores =15

Figure 2 shows the cross section of precast concrete wall panel with circular hollow cores.

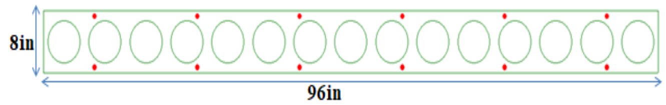

Fig -2: Precast concrete wall panel with circular hollow cores

3.2 Defining material properties

Grade of concrete = 5000 psi
Grade of pre-stressing strands = 60 ksi
Cracking stress coefficient = 7.5 (ACI 318-9.5.2.3)

3.3 Defining pre-stressing strands

Diameter of pre-stressing Stand = 0.375
Number of pre-stressing Strand = 12

3.4 Defining loads

Wind load = 160 plf
Roof dead load = 4 kip
Roof live load = 4 kip

3.5 Defining Load Combinations (As per ACI 318-11)

0.9DL+1.3WL
1.4DL+1.7WL
0.75(1.4DL+1.7LL+1.7WL)
Service DL+LL
Service DL+ LL+WL

4. P-DELTA ANALYSIS

4.1 Shear force of hollow core wall panels

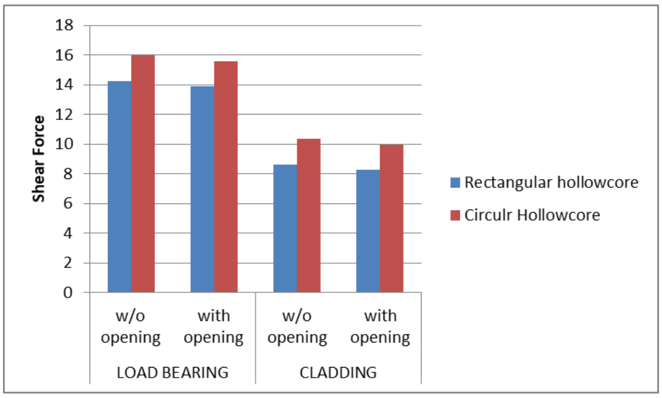

Chart -1: Shear force of wall panels

Chart 1 depicts the shear force of both rectangular and circular hollow core wall panels. It also compares the shear force of wall panel with or without opening. From the chart it is clear that circular hollow core panels have more shear force than rectangular hollow core panels. With opening in the panel shear force gets reduced. Load bearing panel have more shear force than cladding panel

4.2 Secondary moment of hollow core wall panels

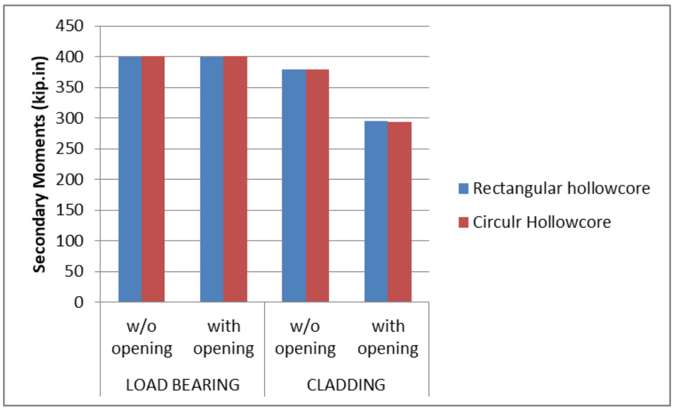

Chart -2: Secondary moments of wall panels

Chart 2 depicts the secondary moments of both rectangular and circular hollow core wall panels. It also compares the secondary moments of wall panel with or without opening. From the chart it is clear that for load bearing panel the secondary moment is same for both circular and rectangular hollow core wall panels and it is irrespective of opening. But for cladding panels with opening secondary moment gets reduced also the secondary moment is same for both load bearing and cladding panel.

4.3 Cracking moment of hollow core wall panels

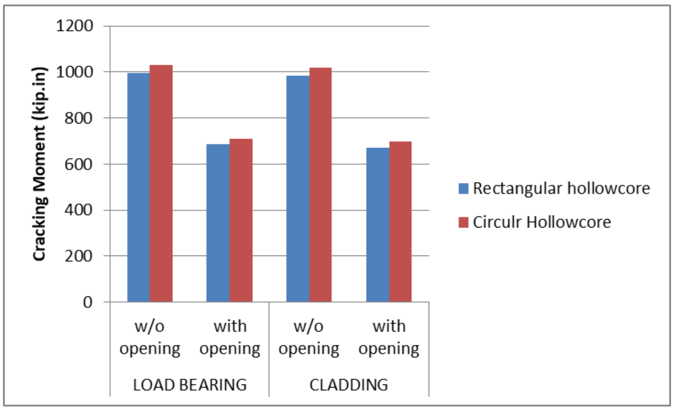

Chart -3: Cracking moments of wall panels

Chart 3 depicts the cracking moments of both rectangular and circular hollow core wall panels. It also compares the cracking moments of wall panel with or without opening. From the chart it is clear that circular hollow core panels have more cracking moment than rectangular hollow core panels. With opening in the panel cracking moment gets reduced. Load bearing and cladding panel behaves in similar way.

4.3 Midpoint Bow of hollow core wall panels

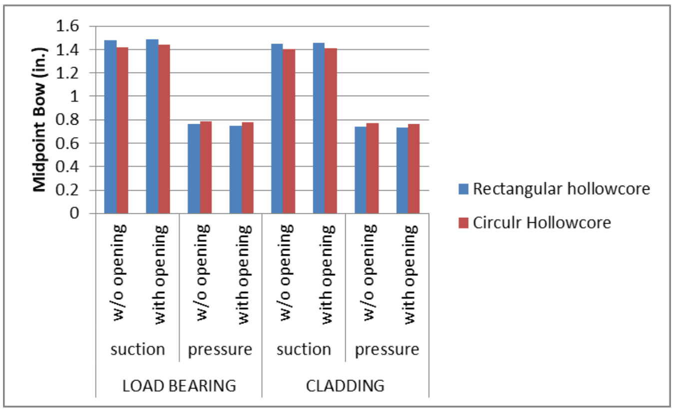

Chart -4: Midpoint bow of wall panels

Chart 4 depicts the midpoint bow of both circular and rectangular hollow core wall panels with and without opening. It also compares the bow with respect to load bearing nature of the panel. Midpoint bow is analyzed for both suction and in pressure. From the chart it is clear that midpoint bow is irrespective of opening and load bearing nature. Due to suction rectangular hollow core panels have undergo more bow but due to pressure circular hollow core panel undergo more bow.

3. CONCLUSIONS

Shear force and cracking moments are more for circular hollow core panels than rectangular hollow cores. This increase of cracking moment is mainly due to self-weight, applied axial load and pre-stress force. Mild steel needs to be added to pre-stressed members to satisfy the ACI cracking moment requirement. With opening shear force and cracking moment gets reduced because axial strength ratio decreases due to increase in slenderness ratio of the panel.

The secondary moments created by load bearing panel is more than cladding panel and there is not much variation in secondary moment when opening is provided for load bearing panel this was due to the increase of tension stresses than that recommended by PCI for serviceability (see PCI Handbook, 7th Ed. Example 5.2.2.1).

Midpoint bow is irrespective of opening and load bearing nature. Due to suction rectangular hollow core panels have undergo more bow but due to pressure circular hollow core panel undergo more bow.

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