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A Study on Hybrid Precast walls

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A Study on Hybrid Precast walls

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Abstract. This study proposes an innovative wall system so called as hybrid precast walls (HW). HW uses both mild steel and high strength steel angles for flexural resistance across horizontal joint. High strength steel plates are used for steel angles connection at the horizontal precast joint and also at places where angles cross which assist for the re-centering property of the HW walls. HW is designed with mild steel to yield both tension and compression whereas the steel angles provide re-centering capability and thereby reducing lateral displacements. Efficiency of the structure depends upon the performance of both reinforcements accordingly to what it is meant to be. This paper presents the seismic performance studies of HW under gradually applied lateral static load. Experimental studies were carried out which account for steel yielding, concrete cracking and crushing.
Key words: *Hybrid walls, precast walls, Experimental study and Static lateral load.*

1. Introduction

The main challenge faced by Indian construction industry is maintaining quality as well as speed of building constructions. For tackling this major challenge hybrid precast walls can be used with wide range of applicability from moderate to high seismic regions. The research works in abroad included both monolithic and hybrid precast wall which gave an overview of drafting, design, construction and codes to be followed [1, 2]. Special design and detailing of hybrid walls are required for the seismic regions [3, 4]. Perforated walls have been also used to study the behavior under lateral loads [5, 6, 7].

2. Experimental Study

2.1 Material Properties

Ordinary Portland Cement (OPC) of grade 53, fine aggregate conforming to zone II and coarse aggregate were used in the study. The material properties are shown in Table 1.

2.2Wall Specimens

Three hybrid precast wall models and one monolithic model was used in the study. All the specimens were of size 400 mm wide, 80 mm thick and 950 mm tall. These walls were casted on a footing slab of size 800 mm x 500 mm x 150 mm. The wall was provided with double steel mesh of #8 mm at 120 mm spacing, one mesh on each face of the wall. The footing slab was provided with double mesh of #12 mm at 150 mm c/c, one mesh on each face of the slab. The bottom end of vertical reinforcement of the walls was extended into footing slab for a length equal to the development length of the bar. The connection between the wall and footing slab was monolithic. M30 grade concrete and HYSD steel bars were used for the study. The precast specimens were made by introducing a joint 300 mm above the footing slab. The bottom part was cast monolithically with the footing slab. The top part was cast separately. The top part was connected to the bottom part by means of bolting and then covered by grouting. The monolithic wall (MW) is shown in Figure 1.

Table 1. Material Properties

Property	Values
Specific gravity of fine aggregate	2.6
Specific gravity of coarse aggregate	2.6
Specific gravity of cement	3.15
Bulk density of fine aggregate	1467 kg/m^3
Bulk density of coarse aggregate	1492 kg/m3
Bulking of sand	8%

The precast specimens had structural steel angle embedment arranged in different patterns. The angles were jointed near the horizontal joints of the walls using gusset plates to ensure safe and secure connection of the top part to the bottom part. The angles 25 x 25 x 3 were of grade E250 (Fe410) and the M10 bolts were of grade 8.8. The gusset plate of thickness 3 mm was used and it was of grade E250 (Fe410). The back to back angles placed vertically near the ends of the walls were used in hybrid wall 1 (HW1)as shown in Figure 2. In case of hybrid wall 2 (HW2), single angles were used and they were placed diagonally as shown in Figure 3. In case of hybrid wall 3 (HW3), single angles were used and they were placed diagonally and also vertically near the ends of the walls as shown in Figure 4.

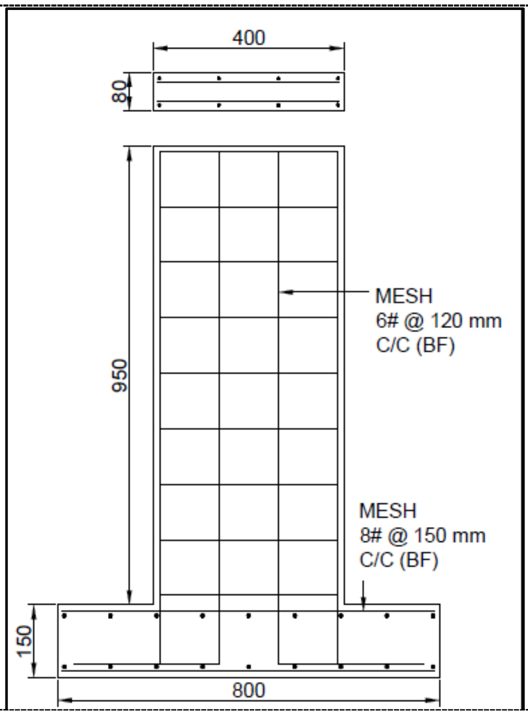

Figure 1. Monolithic wall - details

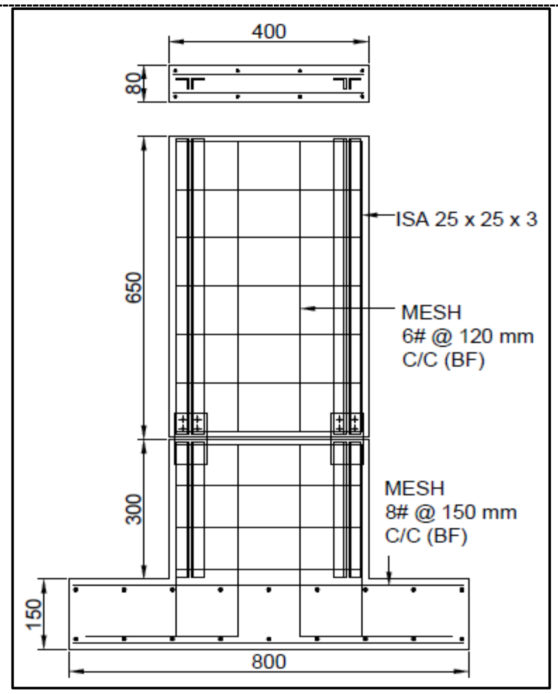

Figure 2. Hybrid wall 1 - details

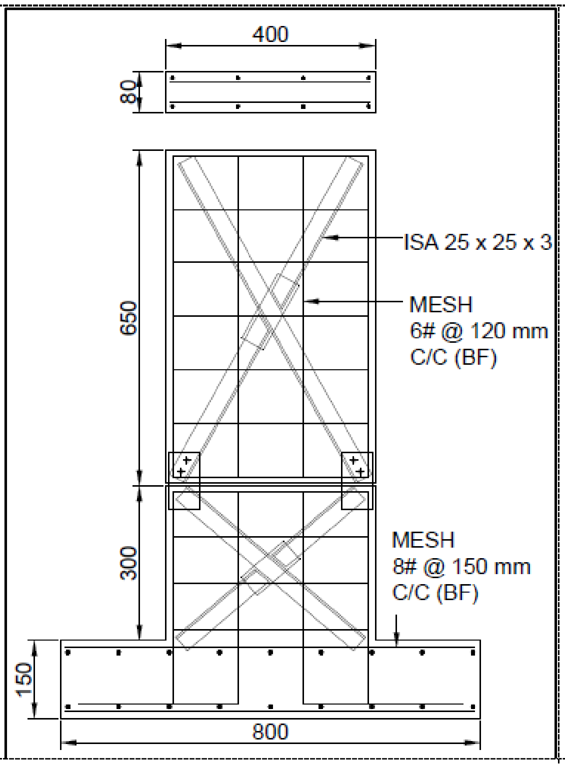

Figure 3. Hybrid wall 2 – details

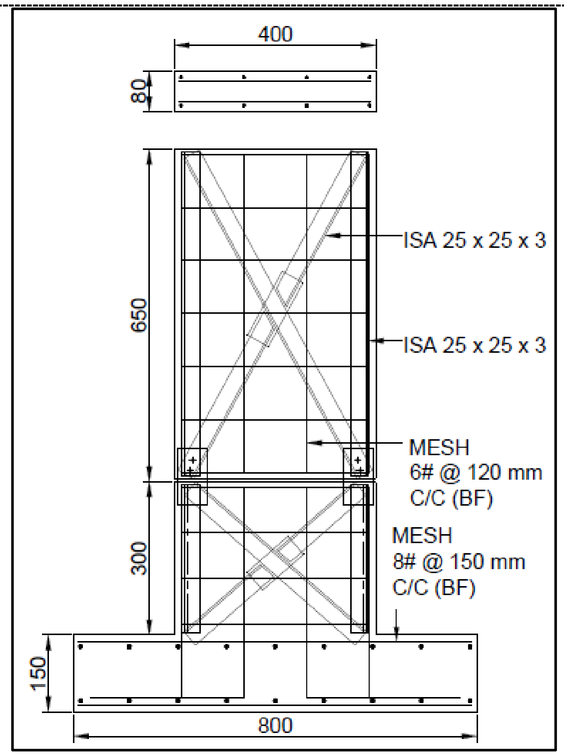

Figure 4. Hybrid wall 3 - details

2.3 Testing

For testing a static lateral load was applied to the wall specimen using a hydraulic jack-collar setup which was connected to a pumping jack that has the load reversal technique for applying load in both the lateral direction. LVDT fixed to the collar measures the lateral displacement of the wall specimen. The data was used to plot the load v/s displacement curve for all the wall specimens. The loads were increased till the failure of the structural components and the crack of the specimen was viewed for analyzing the performance of the wall under loading similar to the seismic loading. Monolithic wall was also tested in a similar way and the test results were compared with the precast walls for performance comparison. The test setup is shown in Figure 5.


Figure 5. Test setup

3. Results and discussion

3.1Crack Pattern

The cracks were found the junction of wall and footing slab in monolithic specimen. No cracks were found on the wall. The behavior was a typical cantilever action. All the precast walls had developed cracks at the joint of the wall panels. The grouted panel joints cracked. Inclined hair line cracks were also observed near the ends of the wall panels indicating crushing of toe concrete at those locations. The thickness of crack width was significant in all the precast walls. The cracking pattern is shown in Figure6 - 9.

Figure 6. Crack Pattern – MW

Figure 7. Crack Pattern – HW1

Figure 8. Crack Pattern – HW2

Figure 9. Crack Pattern – HW3

3.2 Load vs. displacement

The load vs. displacement cracks are shown in Figure 10 – 13. From the above graphs it is evident that all the walls follow the same pattern. The graphs pattern is like it follows a linear pattern till the failure load and takes a deviation downwards from the cracking load point. The lateral displacement and the corresponding failure load were being noted for all the wall specimens at the peak point. For monolithic wall the data set is (3.4mm,77.1KN), for HW1 it is (8mm,52.9KN), for HW2 it is (35.2mm,79.7KN) and for HW3 the data set is (26mm,115.7KN). Monolithic wall behaved essentially as a rigid body showing minimum lateral deflection and a medium width crack generation along the wall foundation joint which is a good result as the seismic performance point of view. HW1 wall showed some premature cracking at a lower level of failure load which was the result of poor placement of the structural members and the lateral displacement was little higher compared to the failure load. HW3 and HW2 performed well than the monolithic wall in terms of the seismic performance point of view. HW3 and HW2 walls failed at higher loads than the monolithic wall even though the corresponding lateral displacements were higher. This shows that the truss action and be-truss action placement of structural members is an excellent way for providing good seismic performance for the walls which is to be used in seismic regions. All hybrid precast walls showed high lateral displacement exhibiting ductility.

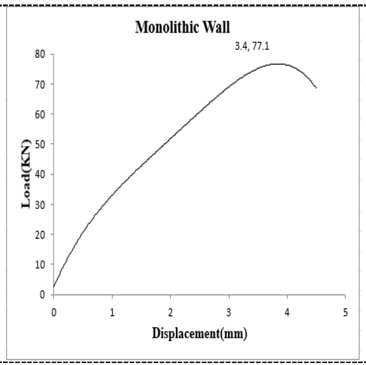

Figure 10. Load vs. deflection – MW

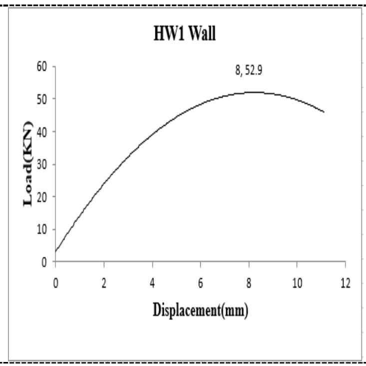

Figure 11. Load vs. deflection – HW1

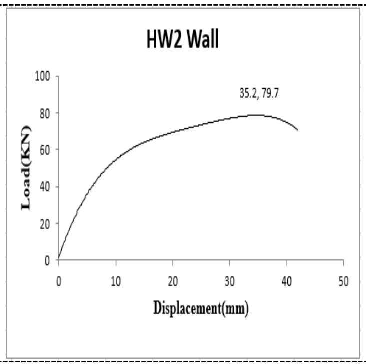

Figure 12. Load vs. deflection – HW2

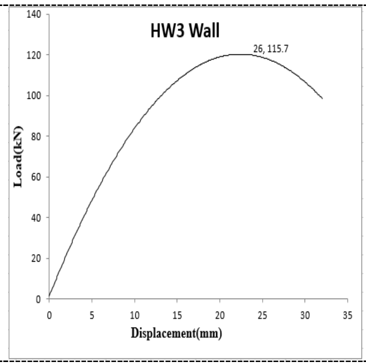

Figure 13. Load vs. deflection – HW3

4. Conclusion

The following conclusion can be made from the above study,

- All hybrid wall specimens showed less crack width than the monolithic wall which shows that the re-centering capability of the high strength angles gives an advantage for the hybrid walls over the monolithic wall in case of the cyclic lateral load applied
- The cracking load of all the hybrid walls HW2 and HW3 were more than the monolithic wall which again shows that the high strength angles along with the reinforcement mesh wrapping can sustain higher seismic load than the monolithic wall
- HW1 exhibited premature cracking at lower loads than the monolithic wall due to poor structural member placements
- Structural member placement influence the seismic performance of the hybrid walls to a larger extend
- All the test results show that the hybrid walls with correct structural member placement can be high end alternative for the normal monolithic wall in seismic regions having more chances of seismic load acting on the structures
- As the hybrid walls performs well than monolithic wall in every aspect the structural codes of all countries should include design guidelines and specifications for usage of such kind of walls in seismic region during the next revisal stage

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