Precast RC Wall Panels with Cut-out Openings Retrofitted by FRP Composites

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Summary

In this paper studies made on seismic retrofitting of reinforced concrete large panels with cut-out openings are presented. There are described the horizontal and vertical loading strategies, the strengthening procedures and the experimental results of the elements strengthened in both prior-to-damage and post-damage states.

Keywords: RC precast wall panels; cut-out openings; FRP strengthening; seismic retrofit; shear; quasi-static cyclic loading.

1. Introduction

The structural system of Precast Reinforced Concrete Wall Panels (PRCWP) was extensively used in Romania, from 50's to the 90's, for housing buildings with 5and 9 stories. Cut-out openings are often required to facilitate direct access from outside or between adjacent apartments, predominantly at the ground floor, where both gravity and seismic capacity demand is maximum. However, cut-out openings performed in structural walls results in the modification of the internal force flow paths, loss of load bearing capacity and reduced structural safety.

The present study was performed in order to investigate the shear behaviour of the PRCWPs with cut-out openings subjected to in-plane seismic loading conditions and to assess the increase of the shear capacity obtained after strengthening with Fibre Reinforced Polymer (FRP) composites.

2. Experimental program

In the experimental part of the program a series of eight, 1:1.2 scaled wall specimens were constructed. The geometric dimensions, reinforcement arrangement and material properties of the wall panels resulted from an actual precast RC large panel (PRCLP) building, according to a typical plan. The experimental variables were represented by the opening type (without opening, i.e. solid wall, narrow door, and wide door), the opening nature (as-built and cut-out) and the strengthening state (not strengthened, post-damage, and prior-to damage). In this paper test results on two double tested elements are presented.

Both experimental specimens were obtained from a solid wall (S), by cutting out a narrow door (E1) for element no. 3, and a wide door (E3) for element no. 5, respectively. In order to ensure the out-of-plane stability, the wall panels were built with wing elements along the vertical edges. The experimental elements were tested twice: first the RC wall panels were damaged, served as reference specimens, thereafter were repaired, strengthened and then retested.

The test set-up was designed to reproduce the in-situ boundary and seismic loading conditions of a wall panel at the ground floor of an actual PRCLP building. As force transmitter (upper part) and as foundation (lower part) element two composite steel-concrete beams were used. The horizontal joint gap between the beams and the wall specimen was filled with high-strength mortar. The

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vertical (gravity) and in-plane horizontal (seismic) forces were induced by four hydraulic cylinders supported by reaction frames.

The experimental elements were subjected to pseudo-constant axial and in-plane reversed cyclic lateral forces, simulating the seismic loading conditions at a quasi-static rate. The initial axial loads were computed considering a normalized axial stress of 0.056. The lateral loading history was defined in terms of constant displacement increment of 2.15 mm (corresponds to 0.001 rad storey drift angle) and two cycles on each displacement level. The rocking rotation of the wall panels was restrained by the displacement control of the two vertical hydraulic cylinders, at a rate of 100 kN/mm. The failure criterion was assigned to the displacement level, where a 20% lateral load capacity drop was observed.

Strengthening of the walls was carried out with CFRP fabrics, using the Externally Bonded Reinforcement (EBR) technique. For the reference walls, before retrofitting, the crushed concrete was replaced by high-strength mortar. The aim of the strengthening strategy was: to provide confinement effect at the cut-out opening corners; to increase the shear capacity of the sleeve walls and to offer flexural capacity along the vertical and horizontal edges of the cut-out opening. The strengthening was carried out symmetrically on both faces of the walls.

The instrumentation for the experiments consisted of displacement transducers and strain gages attached to the steel reinforcements and FRP composites.

3. Test results and conclusions

The characteristic shear behaviour mode of the wall panels was exhibited by the pinched hysteresis loops. As the displacement level was increased, the stiffness gradually decreased, but more significantly around the zero displacement value and less at the peak displacement.

Increasing the cut-out opening width from 75 cm (S/E1) to 175 cm (S/E3) a significant reduction of the lateral load bearing capacity was observed. By strengthening of the damaged wall panels with FRP composites the load bearing capacity increased with 6% for element 3-S/E1-T/R and 43% for element 5-S/E3-T/R, while the displacement capacity gain was 57% and 90%, respectively.

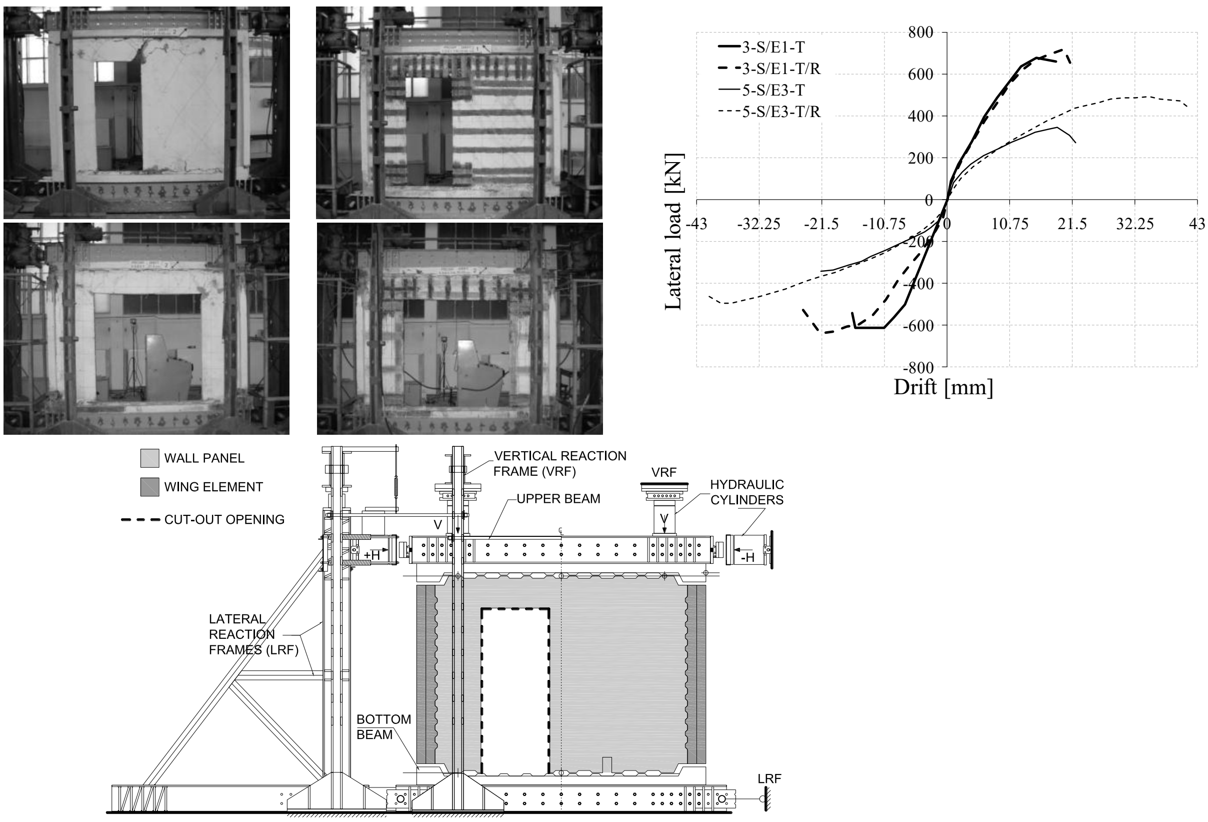

Fig. 1: Test set-up and the load-displacement envelope curves