Influence on the bearing capacity of a large door and window cut-out opening in Precast Reinforced Concrete Wall Panel

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Abstract: - The authors of this paper are presenting an experimental study regarding the influence on the seismic behavior of a large door and window cut-out opening (EL2) in a Precast Reinforced Concrete Wall Panel (PRCWP). The experimental specimen was subjected to in-plane cyclic loading in order to simulate the shear behavior and not the flexural one. The lateral loads will be applied in displacement control while two vertical loads simulating the load of a five story building will prevent the rocking effect of the test specimen. The measurement will include the lateral force, the drift and the efforts in the reinforcement up until failure. The primary goals were to provide information about the shear behavior of Precast Reinforced Wall Panels (PRCWP) weakened by a large door and window cut-out opening and to compare the results with a solid element tested in a previous campaign to see how much of the initial bearing capacity is lost due to the cut- out opening.

Key-Words: - Experimental test, precast, cut-out, concrete walls, seismic loading, diagram.

1 Introduction

Due to the fact that in the past 50 years in Romania the vast majority of new apartment buildings were made using Precast Reinforced Concrete Large Panels (PRCLP) as structural system and that a staggering large portion of this buildings were made over 30 years ago it is necessary to study the behavior of this panels under seismic loading.

In a modern and developing country like Romania owners of apartments in this old buildings started to feel the need of a better space distribution so they proceeded to cut-out openings in this large reinforced concrete panels to better facilitate the access from one room to another or to create entrances at the base floor of the buildings for commercial spaces.

The porpoise of this paper is to determine the loss of load bearing capacity, modification of internal force flow path of one Precast Reinforced Concrete Wall Panel (PRCWP) with a large door and window (EL2) cut-out opening made at the ground floor of a five story building, were most of this interventions are made and were both the gravity and seismic capacity demands are maximum.

The maximum load bearing capacity from the weakened reinforced concrete wall panel will be compared to that of a solid unmodified precast panel tested in a previous campaign [1]

2 Experimental Program

2.1 Test Specimen Description

The experimental test specimen's features like dimensions, reinforcement details and material properties are all taken from an existing building which was build according to a 1982 typical plan. In Fig.1 the dimensions and reinforcement details are presented.

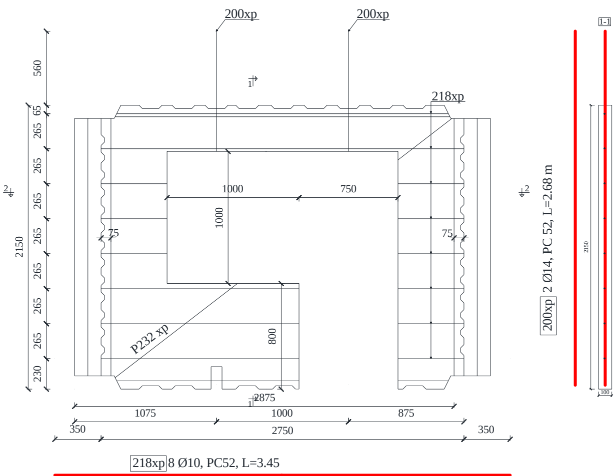

Fig.1 Dimensions and reinforcement details

The wall specimen was scaled down by a factor of 1:1.2 due to limitations imposed by the laboratory testing and handling facilities. To ensure the out-ofplane stability the wall panel has two wing elements along the vertical sides having the following dimensions: 10 cm length, 30 cm width and 215 cm height. These elements are reinforced having 4 Φ14 mm and 1Φ16 mm longitudinal bars and Φ8 stirrups at 85 mm spacing.

The opening of 75 cm by 180 cm for the door and 100 cm by 100 cm for the window were cut-out in a solid wall panel having 275 cm length and 215 cm height. In Fig.2, Fig.3, Fig.4 and Fig.5 the cutting of the opening is presented.

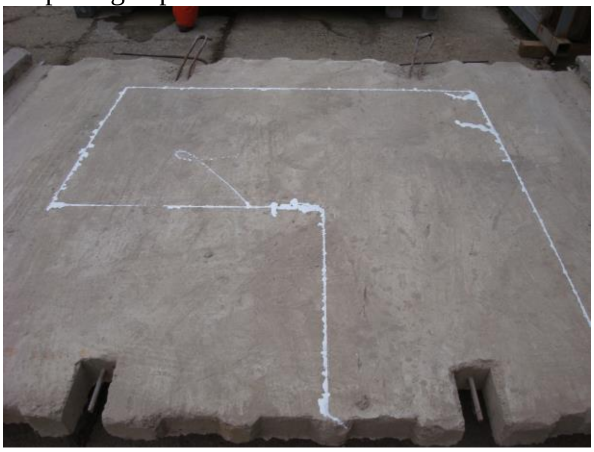

Fig.2 Contour of the opening

Fig3 Cutting of the opening

Fig.4 Opening completely cut-out

Fig.5 Specimen mounted and ready for testing

2.2 Experimental stand and instrumentation

For this experiment the test set up was conceived in order to simulate the seismic behavior of the tested specimen. So as to achieve this we needed to reproduce the shear behavior and not the flexural one. The Precast Reinforced Concrete Wall Panel (PRCWP) was cyclic loaded so the experimental stand consisted of a total of four reaction frames, two reaction frames for the lateral (seismic) forces and two for the vertical (gravity) forces, also we had four hydraulic jacks with which we induced these forces. In Fig.6 the experimental stand can be seen with all of its elements. The forces were transmitted through one composite steel-concrete beam (cap beam) and another one was used as foundation (base beam) element.

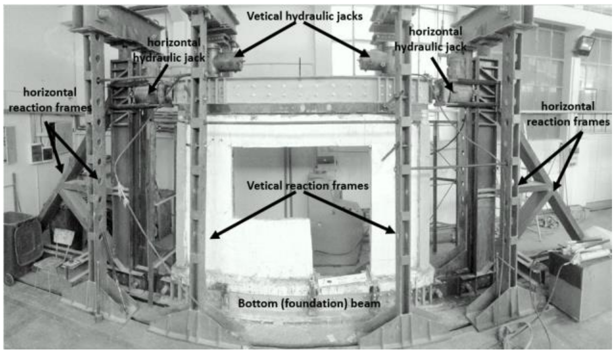

Fig.6 Experimental stand

The gap between the test specimen and the beams was filled with high strength mortar [2].

The tested specimen was subjected to quasi-static in-plane cyclic loading and pseudo-constant axial loads. The axial loads were kept constant at 220 kN to simulate the real building loading and were only increased to counter the element’s rocking rotation tendency, for each step of the loading strategy the axial load was increased by 100 kN if the element

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had a 1 mm vertical displacement. The lateral (seismic) loading strategy was defined in terms of constant displacement control of 0.1 % drift ratio, the specimen having a 2150 mm height the displacement control was in increments on 2.15 mm. Therefor the displacement levels were as follows: 2.15 mm, 4.3 mm, 6.45 mm, 8.6 mm, etc. respectively 0.1%, 0.2%, 0.3%, 0.4%, etc. For each displacement level two cycles were made, when the specimen had a 20% drop in lateral load bearing capacity the failure criteria was fulfilled.

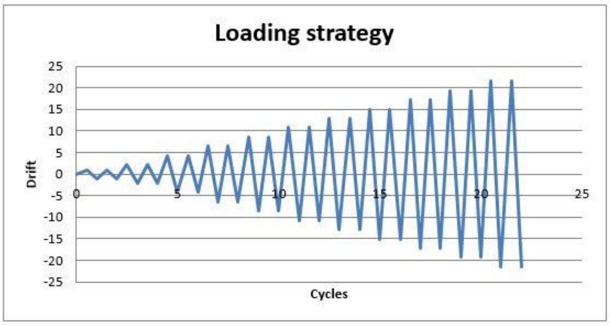

Fig.7 Loading strategy

For the monitoring of the behavior of the specimen a number of 10 displacement transducer were used, 3 pressure transducers and 3 strain gauge's mounted on the reinforcement bars. The position and distribution of the instrumentation can be seen in Fig.8.

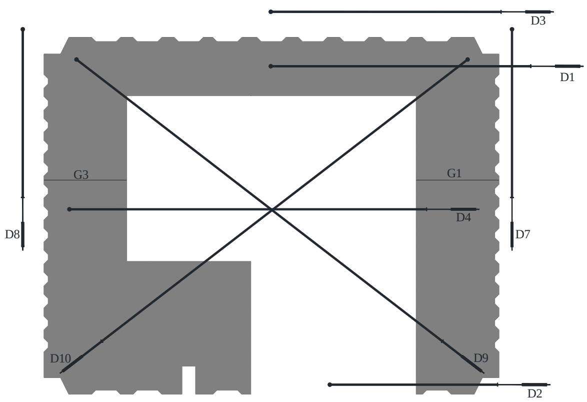

Fig.8 Instrumentation distribution

3 Behavior and Results

In order to better track the cracks appearance we made an orthogonal grind on the wall surface. The Precast Reinforce Concrete Wall Panel (PRCWP) was subjected co constant vertical loads N1=N2=210 kN. In the first part of the test (0.1% to 0.5% and 2.15 mm to 10.75 mm respectively) the specimen's behavior was characterized by the appearance of cracks, mainly in the top corners of the opening and in the left pier. In the second part of the experiment the reinforcement started yielding at 19.35 mm with a horizontal force of 251.5 kN and vertical loads N1left=433 kN and N2right=260 kN and large diagonal crack appeared in the left pier. The element had a ductile behavior losing more than 20% of its horizontal (seismic) load bearing capacity at 19.35 mm (0.9%) drift. In Fig.10, Fig11, Fig.12 the details regarding the failure of the specimen are presented and Fig.9 shows the element after testing. It can be seen that the concrete crushed at the top right corner of the door opening and at the bottom left corner of the window opening.

In the top left corner of the widow opening a large crack can be observed extending up to the top of the tested specimen and also in left pier the large diagonal crack extending from the top left corner and slicing through the entire left pier all the way to the bottom end of the element is visible. This large diagonal crack lead to the loss of the bearing capacity and inevitably to the failure of the specimen.

Fig.9 Tested element

Fig.10 Right corner of the opening failure detail

Fig.11 Diagonal crack that lead to failure

Fig.12 Top left corner of the opening detail

The tested element reached a maximum horizontal (seismic) force of 335 kN at a drift level of 17.2 mm in the first cycle corresponding to 0.8% while the vertical (gravitational) loads were N1left=453 kN and N2right=340 kN. After reaching its peak load bearing capacity the specimen lost 15% of its load bearing capacity reaching a maximum horizontal (seismic) load of 285 kN at 19.35 mm (0.9%) in the first cycle, but the failure criteria was still not met, therefor we went further with the testing and in the second cycle at the same above mentioned drift level the element only managed to reach a horizontal (seismic) load of 220 kN and the vertical (gravitational) loads were N1left=400 and N2right=304 Kn meaning a loss of 35% of its load bearing capacity. In Fig.13 the force displacement diagram is presented while in Fig.14 the strain displacement diagram for the strain gauge placed on the reinforcement. We observed that only one of the monitored reinforcements reached its yielding limit.

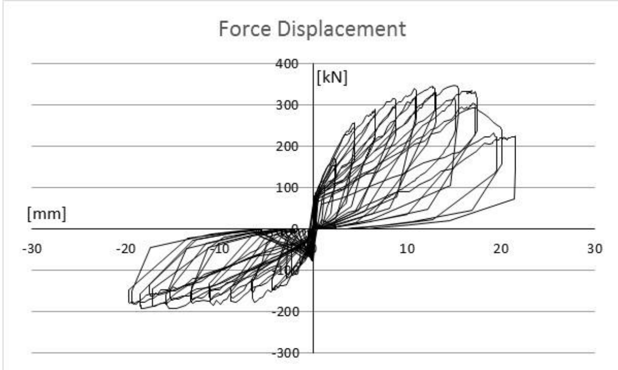

Fig.13 Force displacement diagram

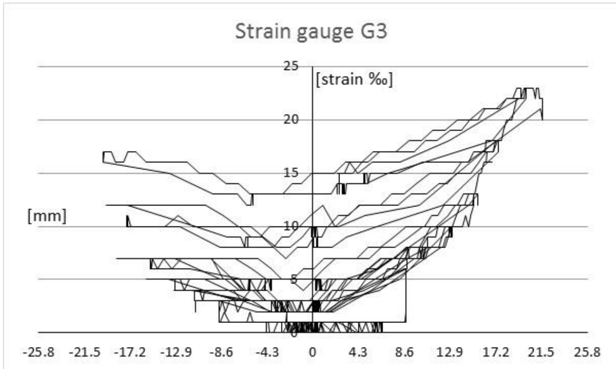

Fig.14 Strain gauge G3 placed on reinforcement

The below two diagrams depicted in Fig.15 and Fig.16 present the force displacement diagrams for the two vertical (gravitational) left and right forces and the drift. The maximum value for the right force was 361 kN obtained on negative drift and for the left force was 452 kN obtained on positive drift.

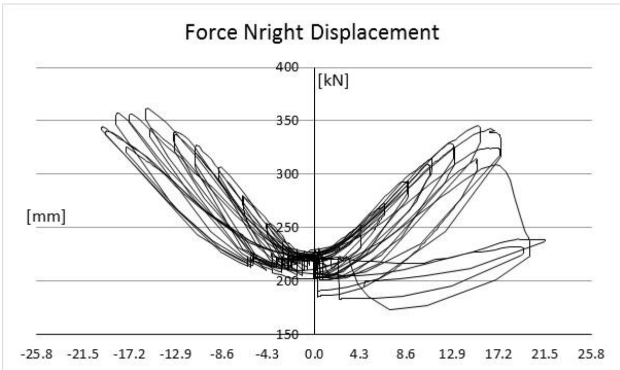

Fig.15 Force displacement diagram for the right vertical force

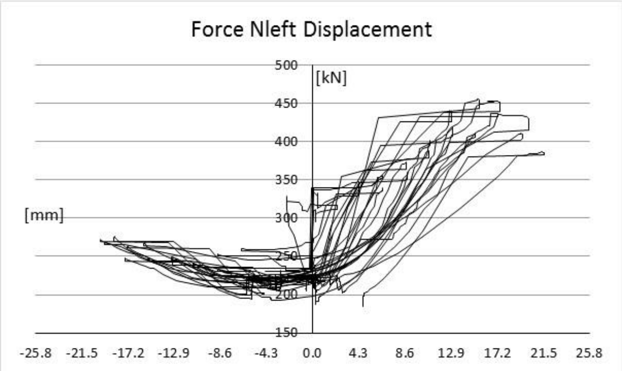

Fig.16 Force displacement diagram for the left vertical force

4 Comparison Results and Conclusions

The porpoise of this paper was to observe the effects of a large door and window cut-out opening in a Precast Reinforced Concrete Wall Panel (PRCWP). The solid specimen tested in a previous campaign [1] had a maximum unexpected later load resistance that exceeded the capacity of the hydraulic equipment so the solid wall was not loaded beyond 1210 kN and 0.6% drift ratio. In Fig.17 the difference between the two walls bearing capacity is presented and it can be clearly seen that the tested specimen with the large door and window opening cut-out had under 28% of the solid wall bearing capacity. The maximum drift ratio achieved by the PRCWP S/EL2 was increased by 50% as shown in Fig.18

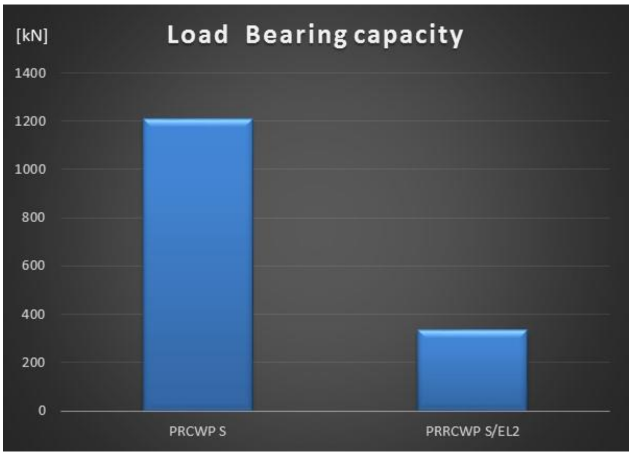

Fig.17 Difference in load bearing capacity

Fig.18 Difference in drift level

In conclusion it can be said that the implications of cutting out a large door and window opening into a solid Precast reinforced Concrete Wall Panel (PRCWP) are very severe, the behavior of the two elements are different because of the large difference in rigidity. The specimen with the opening cut-out had a much higher drift ratio making it more ductile then the solid element. Such a procedure on a PRCWP can only be made if proper retrofitting measurements are applied on the element after the cut-out of the opening.

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