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SEISMIC STRENGTHENING OF A PRECAST REINFORCED CONCRETE WALL PANEL USING NSM-CFRP

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Abstract: *The precast reinforced concrete wall panel (PRCWP) presented in this paper is part of an experimental program in which the seismic performance, weakening effects due to cut-outs, strengthening strategies and cost evaluations were investigated. The experimental specimens were 1:1.2 scaled RC as-built solid walls or as-built walls with window or door openings. The specimens were subjected to cyclic load reversals, displacement controlled. Most of the specimens were first tested unstrengthened, then after they were repaired, strengthened using FRPs and tested again. The wall panel presented here was post-damage strengthened using near surface mounted (NSM) carbon fibre reinforced polymers (CFRP). The repair and strengthening strategy steps will be presented together with the experimental results of both the unstrengthened and the post-damage strengthened specimen.*

Key words: *seismic, strengthening strategy, RC wall, NSM-CFRP.*

1. Introduction

The use of large panel structures was widely used in seismic areas, because the system composed of precast reinforced concrete panels can provide an efficient performance under earthquake conditions. After 50 years of existence, which most of them have and interventions some of them were subjected to, detailed investigation is needed. The analysed specimens meet the requirements of Eurocode 8 for walls designed to medium ductility and are referred as large lightly reinforced walls.

The application of NSM-CFRP was investigated in this paper as a retrofitting strategy, in order to increase the load bearing capacity of the specimen first tested in the unstrengthened condition. Research on NSM-FRPs studies were conducted by Sas [1], Konthesingha [2], Lee and Cheng [3], Sakar et al. [4], Stoian et al. [5], Florut et al. [6] and others.

2. Experimental Program

The experimental specimen was a 1:1.2 scaled element, namely precast reinforced concrete wall panel: PRCWP (12), designed and casted according to a Romanian Project Type 770-81 [7], [8]. PRCWP (12) specimen has an initial narrow door opening. Based on the two experimental tests performed in the unstrengthened condition and post-damage strengthened condition, important aspects related to the seismic efficiency of the strengthening system can be drawn out.

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The experimental specimen was: 2150 mm height, 2750 mm width and 100 mm in thickness. The narrow door opening was 1800 mm height and 750 mm length. The experimental specimen was set between two reinforced steel concrete composite beams, namely a top - loading beam and a bottom - foundation beam. The web panel reinforcement of the PRCWP (12) consisted of horizontal rebars, vertical bars, welded wire mesh in the right pier, a spatial reinforcement cage on the entire height of the left pier, a spatial reinforcement cage in the coupling beam, vertical bars in the coupling beam, spatial reinforcement cage at the top right corner of the door opening, and two inclined bars at the top corners of the opening. The configuration of the experimental specimen selected for investigation is presented in Fig. 1 [11].

2.1. Material Considerations

The specimen's concrete quality was C25/30 class, while the reinforcement S255 was used for the spatial reinforcement cage, S355 for horizontal, vertical and inclined steel bars, and S490 for the steel wire mesh.

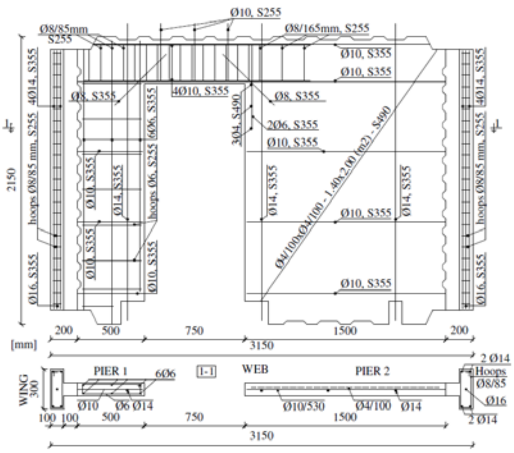


Fig. 1. *Specimen outline and reinforcement*

The steel reinforcement properties obtained experimentally were given in [9, 10]. Near surface mounted CFRP plates were used for the retrofitting of the specimen. Also, carbon fibre (CF) fabric, applied externally bonded was used to improve the confinement capacity of the specimen. Table 1 summarizes the geometrical and mechanical properties of the CFRP plates and CF fabric used. The mentioned characteristics are based on manufacturer's data. The mortar, used to replace the heavily damaged concrete was Mapegrout Easy Flow GF, having a compressive strength of 60 N/mm^2 at 28 days according to the product data sheet.

2.2. Testing Methodology and Test Set-up

Detailed data related to the tests set up and testing methodology of the precast reinforced concrete wall panel specimens were presented by Demeter [10]. A general view of the test set-up of the specimens is presented in Fig. 2.

The specimen was tested under quasi-static reversed cyclic lateral loads, displacement controlled (with two cycles per drift), of measure 0.1% drift ratio, namely 2.15 mm. Vertical loads were also applied in order to impose the gravity loading condition and to restrain the rotation of the element.

The experimental specimen was monitored during the experimental tests using pressure transducers (P), displacement transducers (D) and strain gauges applied on steel rebars, CFRP plates and CF fabric (G).

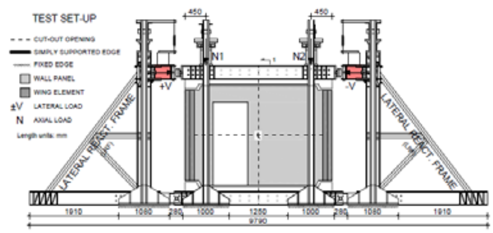


Fig. 2. *General view of the test set-up CF fabric and plate properties*

Table 1

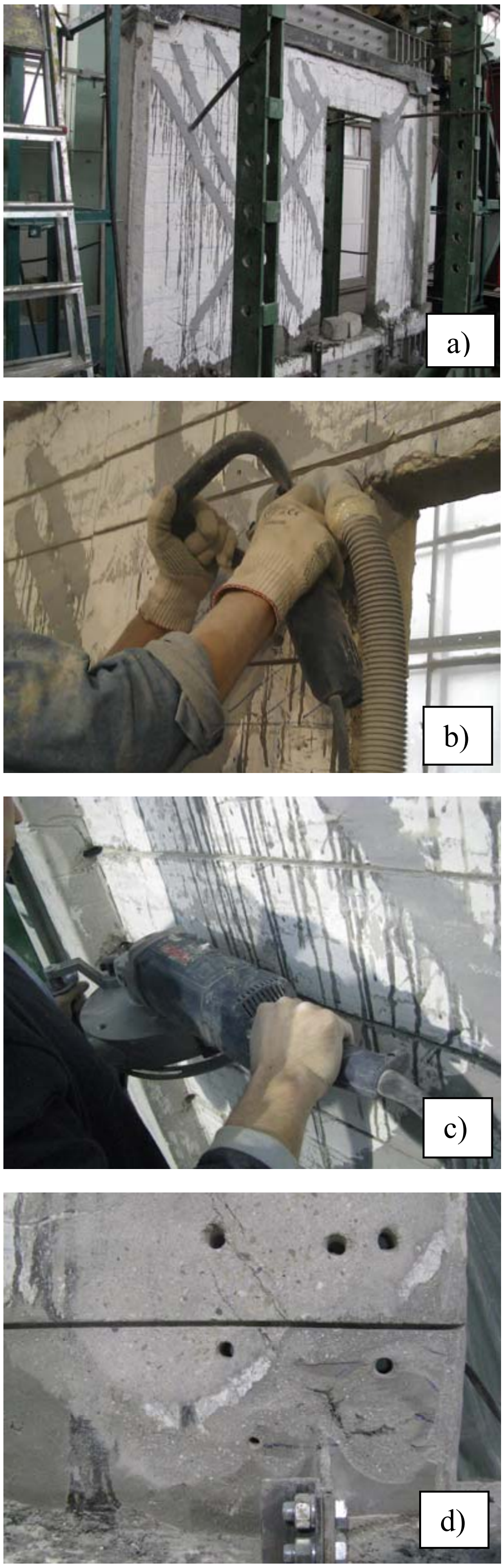
Component	carbon fibre fabric	carbon fibre plate
Product name	MapeWrap C UNI-AX	Carboplate E170/100/1.4
Thickness [mm]	0,166	1,4
Areal weight [g/m^2]	300	225 g/ml
Tensile strength [MPa]	4830	3100
Tensile modulus [GPa]	230	170
Elongation at break [%]	2,0	2,0

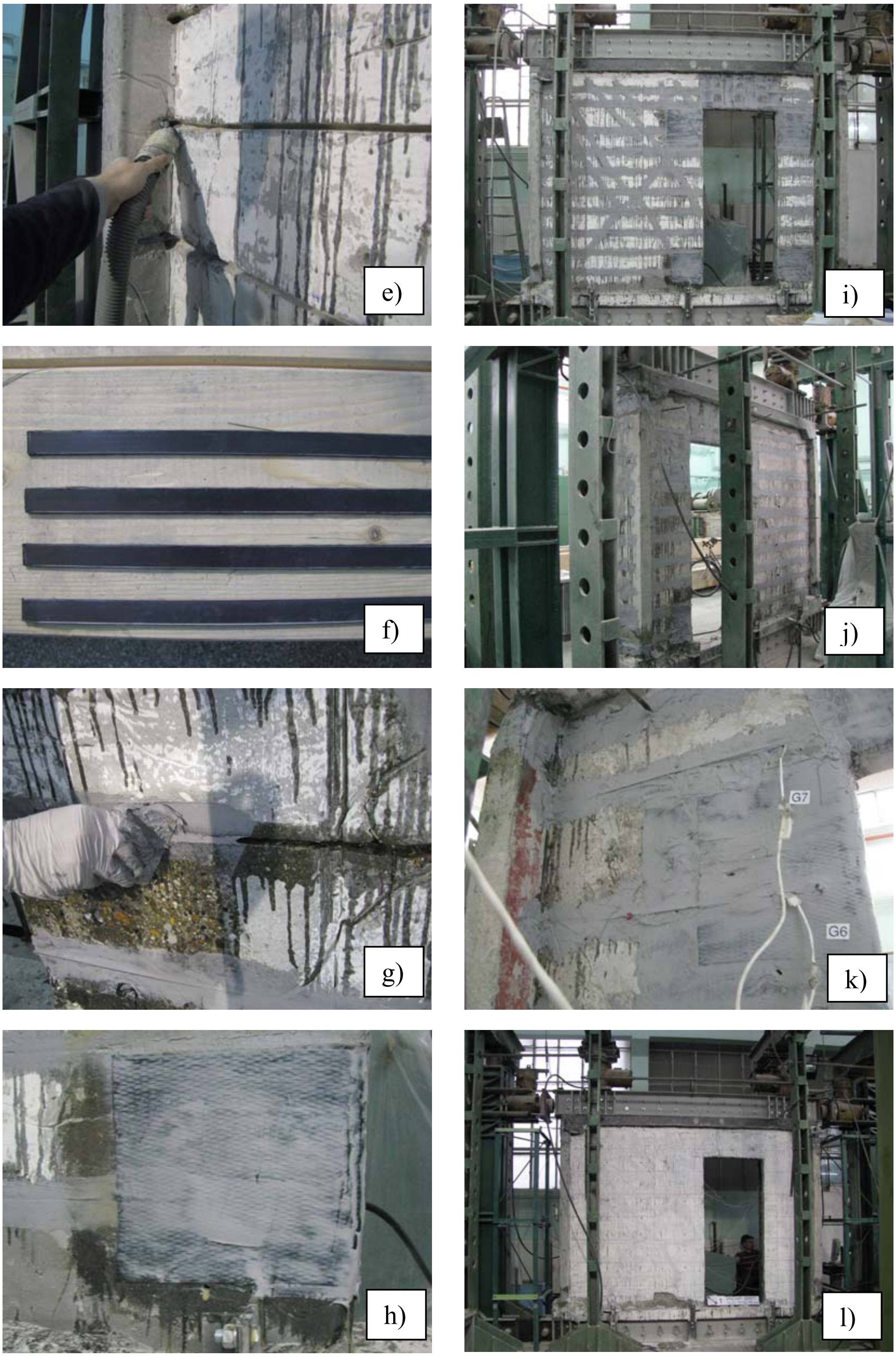
3. Repair and Strengthening of the Specimen

The retrofitting strategy adopted here intended to increase the initial load bearing capacity of the element, the solution being qualitative and based on the behaviour of the reference specimen.

The damaged specimen was first repaired by removing the crushed concrete and replacing it with a high-strength repair mortar (Fig. 3a). The wall surface was then polished locally with a special grinder (Fig. 3b) to achieve a fully smooth surface for the externally bonding application, channels were cut for the CF plates (Fig. 3c), and the concrete edges of the element were rounded at a radius of approximately 20 mm to achieve the effectiveness of the confining solution. Local holes were drilled in the panel to provide the anchors for the confinement strengthening system (Fig. 3d), and the surface of the wall was vacuum-cleaned (Fig. 3e). The cracks were cleaned and filled superficially with epoxy resin.

According to the strengthening strategy, the NSM plates (Fig. 3f) (10 mm x 1.4 mm) were mounted horizontally in the piers and in the spandrel in each side of the wall at 200 mm centres (Fig. 3g). All CF plates were anchored in the wing element. CF confinement strips (Fig. 3h) were applied at the corners of the door opening and vertical, wrapping from one face to the other of the spandrel, and at the ends of the wing walls. The completed retrofitting is shown in Fig. 3i and 3j. Fig. (3k) shows the strain gauge position on FRP plates and fabric.

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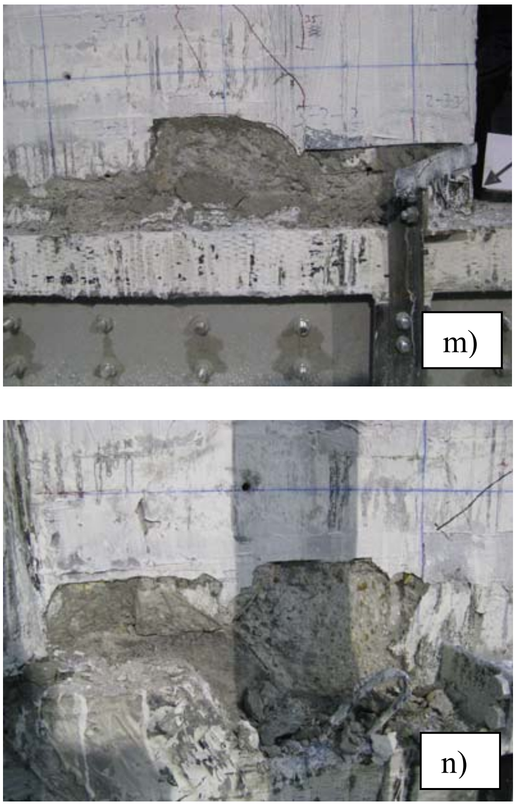


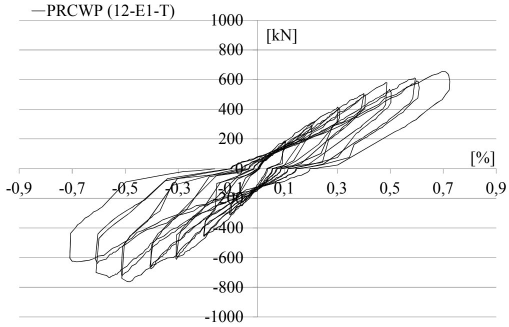
Fig. 3. *The strengthening strategy*

The failure of the post-damage strengthened specimen is presented in Fig. 3l, 3m and 3n.

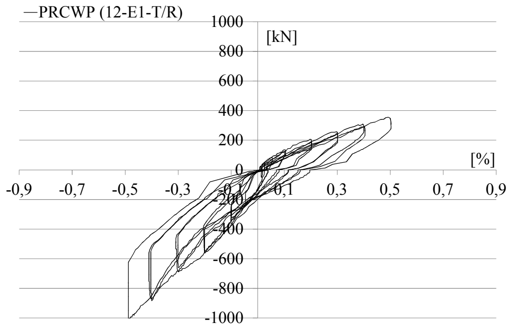
3. Experimental Results

During the experimental test of the post-damage strengthened specimen, namely PRCWP (12-E1-T/R), diagonal cracks appeared in the piers (Fig. 3l). Unfortunately, due to the capacity of the available testing facility, the specimen could not be taken to failure. The behaviour of the tested wall panel is shown in Fig. 4 as load-drift ratio response.

The load bearing capacity results show a variation of 46.5 % in the positive loading cycles and 154 % in the negative loading cycles. It is obvious that the retrofitted element, namely PRCWP (12-E1-T/R) behaved highly superior compared to the reference one, PRCWP (12-E1-T).



- *unstrengthened specimen*



- *strengthened specimen*

Fig. 4. *Load-drift ratio response*

3. Conclusions

The load bearing capacity of the specimen was increased through the retrofitting strategy, as confirmed by the load-drift ratio response of them. NSM-CFRP system can be an effective solution for strengthening elements. Further studies focused on numerical analysis, strengthening systems, openings in walls are in progress. The studies aims to establish the seismic performance of PRCWP under different parameters.

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3. MAPEI (Romania) Corporation.

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