Lateral Cyclic Load Test of Masonry Infilled RC Frames Strengthened with Ultra-High Performance Concrete Diagonal Strips

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ABSTRACT An experimental program was undertaken to investigate the lateral cyclic behavior of masonry infilled RC frames strengthened with Ultra-High Performance Concrete (UHPC) precast plates, bonded onto the masonry substrate by means of high strength epoxy mortar. Four ½ scale one-bay, one-storey masonry infilled RC frames were constructed. Of these specimens, one frame was tested as-built with infill, one was infilled and strengthened using 300 mm wide diagonal CFRP strips, and the remaining two were infilled and strengthened using 355 mm wide diagonal UHPC strips. The main test variable was the thickness of the bonded UHPC plates. Test results showed that the proposed UHPC retrofit technique can be successfully used an occupant friendly method in order to improve the overall seismic behavior of masonry infilled RC frames.

Keywords: Rc Frame, Strengthening, Seismic, Uhpc

I. INTRODUCTION

Infilled frame structures have been a common form of construction in many of the Latin American, Mediterranean as well as Asian countries (Pallares et al., 2021). However, aftermath observations has highlighted the vulnerability of this building typology (Fikri et al., 2018). Even in the event of lower intensity earthquakes, damage to infilled frames may lead to high economic losses and loss of life (De Luca et al., 2014). Over the past two decades several innovative techniques, such as the use of FRP (Akın et al., 2015), TRM (Ismail et al., 2018), and ECC (Dehghani at al. 2015) have been developed to strengthen masonry infilled RC frames, in order to improve the seismic response of existing building. Ultra-High Performance Concrete (UHPC) stands as a novel construction material which exhibits excellent durability and mechanical performance with very high compressive strength and non-brittle behavior which has been used lately for the rehabilitation of existing RC members (Al Osta, 2018). However, and to the knowledge of the authors, up till now no study has been conducted to examine the seismic response of masonry infilled RC frames retrofitted with this material.

II. MATERIALS

Ready mix concrete having an $f'_c = 50$ MPa was used to cast the frames. Top beam (150 mm x 250 mm) and columns (150 mm x 200 mm) were each reinforced with 4T12 longitudinal deformed bars and had 2 legs of 6 mm diameter smooth transverse bars spaced at 150 mm. Steel bars had an f_{yk}= 500 MPa. The foundation beam (450 mm x 550 mm) was purposely over-reinforced to avoid any damage. Masonry had a net compression strength f'_m= 9.5 MPa. UHPC was prepared using a reactive powder concrete that is marketed under the name VICAT and had 2% steel fibers by volume. It had a characteristic f'_c= 200 MPa (C.O.V. 5.30%) and f_r= 31 MPa (C.O.V. 7.11%) at 28 days. Sikadur-31 CF was utilized to bond the UHPC plates to the masonry. CFRP branded under the name "FOREVA TFC" and commercialized by FREYSSINET were also utilized in this study. The CFRP sheets were 0.48 mm, had a tensile Elastic modus of 230000 MPa and ultimate tensile strain of 2.1%. The CFRP strips were glued to the masonry using a bi-component TFC epoxy resin "Eponal Résine" & "Eponal Durcisseur" (Resin + hardener). It is important to note that the strengthening procedure started 28 days after the construction of the masonry infill and retrofitted specimens were left in place for at least 3 days prior to testing.

III. EXPERIMENTAL PROGRAM

A. Description of Test Specimens

Four 1/2 scale one-bay, one-storey RC frames were constructed. One of the specimens, labeled INF-REF, was tested as-built with infill, as a lower bound reference. The second and third infilled frames, labeled INF-UHPC10 and INF-UHPC20, were strengthened using 10 mm and 20 mm thick UHPC plates, respectively. The UHPC plates were 355 mm wide and were diagonally one-side bonded onto the masonry wall by means of high strength epoxy mortar. Additionally, corner UHPC plates were bonded on the back side of the infill wall. Corner plates on both sides of the infill were transversely connected using $\phi 6$ diameter threaded steel rods. The threaded rods were tightened using nuts and washers to provide additional confinement to the infill panel at four corners. The fourth infilled frame, labeled INF-FRP, was one-side strengthened using 300 mm wide diagonal CFRP sheets, it served as an upper bound reference. The CFRP sheets were anchored into the surrounding frame elements using CFRP anchors. Additionally, single side 300 mm x 300 mm corner gusset CFRP sheets were also provided. UHPC and CFRP strengthened specimens are photographically illustrated in Figures 1.

B. Test Set-up

In order to simulate earthquake effects, the specimens were subjected to quasi-static reversed cyclic sinusoidal displacement controlled lateral loading history. It was applied to central axis of the top beam using a servo controlled hydraulic horizontal actuator having 500 kN push/pull capacity and ±50 mm stroke. The frequency was set to 0.05/amplitude to maintain a loading rate of approximately 0.05 mm/sec. The amplitude of the displacement controlled loading was increased as a percentage of drift until the post peak strength dropped to 80%. For each displacement level, three consecutive cycles were repeated. An axial force having a constant magnitude of 77 kN, equivalent to 10% of column's nominal axial load capacity ϕP_n, was applied at the top of each column using vertical hydraulic jacks. Details of the test set-up are shown in Figure 2.

FIGURE 1. Photographical Illustration of Retrofitted Specimens

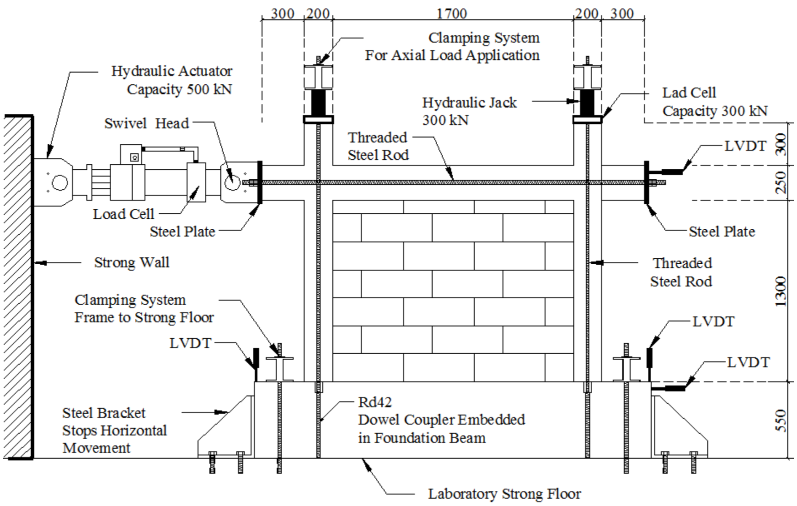

FIGURE 2. Details of Cyclic Load test Set-up (Units in mm)

B. Results

The cyclic envelope curves of the tested specimens are shown in Figure 3. These backbone curves are useful in the evaluation of the strength, stiffness and the general behavior of the specimens. The peak lateral strength of INF-REF and INF-FRP was 139.4 kN and 222.2 kN and was reached at storey drifts δ= 0.39% and δ= 0.55%, respectively. Response envelop curves clearly show the contribution of the UHPC retrofit technique, yet they reveal that doubling the thickness of the UHPC retrofit had only marginal effect towards the lateral strength gain. INF-UHPC10 and INF-UHPC20 reached a peak strength of 275.8 kN and 285.75 kN, respectively, both at δ= 0.62%. Moreover, both UHPC strengthened specimens behaved almost similarly up until peak strength has been reach, afterwards INF-UHPC20 exhibited a sudden drop of the lateral load carrying capacity as opposed to a smoother strength decay for INF-UHPC10 as a result of a more ductile behavior. Regarding the lateral stiffness, strengthened specimens had significantly stiffer response than INF-REF specimen. However, it is worth noting that INF-UHPC10, INF-UHPC20 and INF-REF specimens had comparable initial stiffness values, 93.5 kN/mm, 95.2 kN/mm and 92.8 kN/mm, respectively, as compared to 54.4

kN/mm for INF-REF. to conclude, test results showed that the proposed strengthening technique can be successfully used an occupant friendly method in order to improve the overall seismic behavior of masonry infilled RC frames.

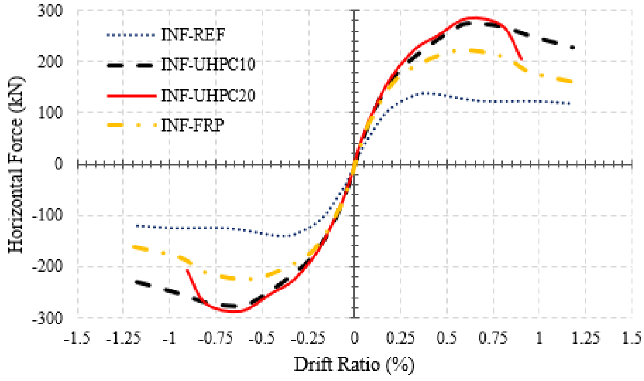

FIGURE 3. Backbone Curves of Tested Specimens

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