STIFFNESS DEGRADATION BEHAVIOR OF RETROFITTED RC INFILLED FRAME UNDER CYCLIC LOADING

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Abstract

The present study was to evaluate the load carrying capacity of retrofitted 3-bay 4-storey brick infill R.C frame using Ferro cement under cyclic loading. Generally bricks will not be considered as a structural element, but by an effective strengthening technique infill walls and RC frame elements can be kept together and forcing them to work as a whole until the end of the ground motion. The effectiveness of the retrofitted frame under cyclic load was investigated in terms of displacement, stiffness and load carrying capacity.

Keywords: *Retrofit, Ferro cement, R.C frame, brick infill, cyclic loading, stiffness degradation*

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1. INTRODUCTION

Retrofitting of existing buildings or damaged structures during earthquake are not received proper attention in India. There is no code or guidelines available to deal with the different type of retrofitting techniques. The basic concept of retrofitting techniques is to upgrade the lateral strength or stiffness and displacement depending on the importance of the structure and availability of funds. Govindan [1] compared the experimental behavior of a quarter size seven-storey infilled reinforced concrete frame with that of a reinforced concrete frame without infill subject to lateral loads, and assessed the failure mode of the brick infilled frame. Dubey et al [2] conducted experimental studies on the effect of reinforcement on ultimate strength of infilled frames under lateral loads. Mehrabi Armin et al [3] reported the effect of masonry infills on the performance of RC frames which were designed as per current codal requirement. S. Z. Korkmaz [4] conducted test on one bay two storey RC frame specimens with existing brick infill walls and strengthened with the application of ferro cement under reversed cyclic loading. He concluded that, at lesser lateral forces, the frame and infill wall behaved monolithically but the frame deformed in a flexural mode and the infill corners damaged at the later stage while increasing load. Achintya et al [5] assessed the behavior of brick in filled reinforced concrete frames under lateral loading, through experiment and reported that the stiffness of the in filled frame decreased very rapidly after the formation of initial crack. Costas P. Antonopoulos et al [6] demonstrated that externally bonded FRP reinforcement was able to enhance the strength, energy dissipation and stiffness characteristics of RC joints under lateral loads. Mihail Garevski et.al [7] reported that the CFRP strips put on the infill walls could improve the behavior of RC frame significantly under strong ground motion. Ferro cement is one of the cost effective and less skilled methods to meet out the above requirement.

1.1 Objective

The objective of this investigation was to quantify the behavior in terms of load-displacement and stiffness of one quarter size three bay four storey R.C frame with central bay stiffened brick infill after retrofitting by Ferro cement. The middle bay of the frame is brick in-filled in which the reinforcement strip extended from the frame and embedded in 20mm thick concrete in between two layers of brickwork. The frame was subjected to static cyclic loading, simulating earthquake effects. This paper presented the research work on the structural behavior of three bays four storey retrofitted with Ferro-cement, R.C in filled frame with reinforcement concrete in between the brick layer.

2. EXPERIMENTAL INVESTIGATION

2.1. Materials

Ordinary Portland cement of 53 grade which was tested and found to be in accordance with IS: 4031-1988 and confirming to prescribed specifications in IS: 12269-1987 and its specific gravity was 3.0. For infilling the central bay of the frame with brick masonry, cement mortar 1:4 was used. The thickness of the brick masonry panel was 100mm. The angular granite chips of size 12 mm and specific gravity of 2.71 was used as coarse aggregate for the preparation of concrete mix. Regular water sand affirming to IS-383 zone II with a specific gravity of 2.60 was used as fine aggregate. Locally accessible consumable water in accordance with IS 456 was utilized in the mixing of concrete Mix design for M30 concrete was done as per IS 10262 [2009].

2.2. Frame Sections and Dimensions

The cross section of the beam and column in the frame is taken as 150x100 mm.

Frame along X axis : 3m
Frame along Y axis : 2.8m
No of storey : 4

Height of each storey : 0.7m
No of bays : 3
Width of each bay : 1m
Mix ratio : 1:1.7:2.72
The schematic diagram of frame was shown in Fig.1.

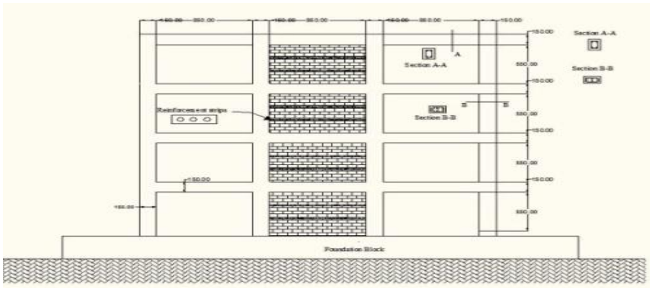

Figure- 1: Schematic diagram of Frame

2.3 Test Set Up

The frame was erected on the test floor. Loads were applied at top and middle floor levels using hydraulic jacks and load cells. LVDTs were fixed in 2^{nd} and 4^{th} floors of lee-ward side to measure displacements of frame. For each loading the readings were taken in LVDTs and strain gauge readings were taken on both concrete and steel. Concrete strains were noted till the initial failure of concrete and steel strains were noted for the zero reading and up to ultimate load. Dial gauges were fixed on the two sides of foundation blocks to check the foundation movements.

3. TESTING

Cyclic loading was applied on the frame with the help of load cells till the frame got failed. For each loading the readings were noted in LVDTs and dial gauges and strain readings were also taken on both concrete and steel. Concrete strains were noted till the initial failure of concrete and steel strains were noted for the zero reading and up to the final cycle. The frame was tested in the loading frame under cyclic load until the partial failure which was at the loading of 130kN and retrofitting was done by Ferro cement.

3.1. Retrofitting

The partially collapsed frame was taken back from the test bed for retrofitting. The loose materials were removed from the frame. Weld mesh of ½ inch spacing with 0.4mm thickness was wrapped over the frame where it got split and cement mortar 1:1.5 mix, w/c of o.4 and coarse aggregate of 5mm or less was applied properly on the mesh. The thickness of Ferro cement application was 15mm. The frame was erected on the testing platform and 100mm thick brickwork was done on the middle bay. 20 mm thick concrete was laid on the reinforcement strip in between the two layers of brickwork.

3.2. Grouting

Grouting is one of the strengthening techniques, and it is not altering the originality of the existing buildings. The purpose of this technique is to fill the minor voids and cracks of the retrofitted frame, which are present due to the partial collapse. The grouting played major role in the merit of the retrofitting using ferro cement approach.

Figure- 2: Grouting of retrofitted frame

The performance of grouting depended on the mechanical, physical, and chemical properties of the mix and its interactions with the frame to be retrofitted. In this study, expansive cement and epoxy resin were mixed and injected for minor cracks of less than 2 mm [Fig 2].

3.3. Retesting

The retrofitted frame was tested in the loading frame under cyclic load. Cyclic loading was applied on the frame with the help of load cells till the frame got failed. For each loading the readings were noted in LVDTs and dial gauges and strain readings were also taken on both concrete and steel. Concrete strains were noted till the initial failure of concrete and steel strains were noted for the zero reading and up to ultimate load. The failure of the retrofitted frame was shown in fig 3.

Figure- 3: Failure of retrofitted frame

4. RESULTS AND DISCUSSION

4.1 Load Vs Deflection

The load – displacement behavior of the frame was as shown in fig 4. It was observed that until 180kN the displacement was proportional and increased to 155mm at the collapse load of 230kN.Attempt of three post cycle was possible and at the end of 230mm displacement, load was 50kN and the structure did not regain any displacement. This showed that the retrofitted frame was having good ductility property. Further more because of the proper interfacing, the spalling of infill did not occur and hence the adverse effect of infill was nullified. The load Vs deflection curve was shown in fig 4.

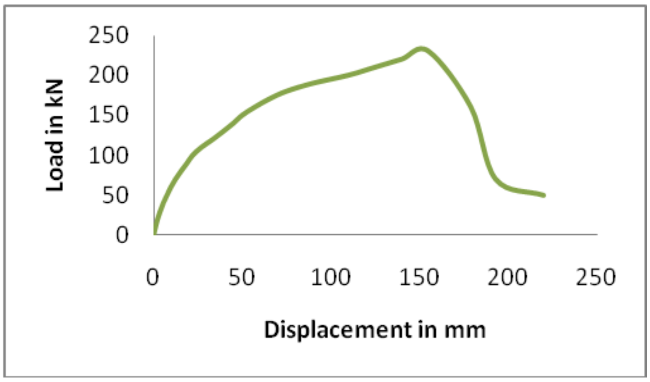

Figure- 4: Load vs Displacement

4.3 Stiffness Degradation

The stiffness degradation at the initial stage was steep and after 18th cycle, the stiffness degradation was gradual. It was attributed to the transfer of load to frame and the RC strip after the bond failure in brick layers and yielding of reinforcement. The stiffness Vs load cycle curve was shown in fig 5.

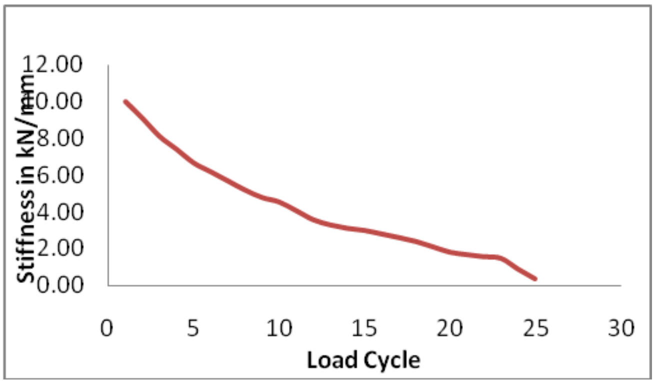

Figure- 8: Load Cycle vs Stiffness

5. CONCLUSION

Frames damaged due to earthquake would be retrofitted effectively by the application of Ferro cement with cement mortar grouting and the retrofitted frame was capable of taking 30% extra load over the virgin frame. It was to be noted that the brickwork got cracked and did not fall due to the proper interfacing between the frame and infill and adverse effect of infill was nullified. The application of Ferro cement technique was a cost effective one and could be executed with less skilled labor

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BIOGRAPHIES

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