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Behaviour of concrete Brick and flyash Brick on infilled frame under cyclic loading

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ABSTRACT

Masonry walls are used extensively as exterior walls to form part of the building envelope and as interior partition in steel or concrete structures. Due to Complexity in analysis and insufficient design information it is not accounted for in current design practices, however only few studies were conducted to comprehend the behavior of masonary wall. In this study a finite element technique was used to model masonry infilled RC frame using concrete brick and flyash brick under cyclic loading using the simplified three-dimensional micro-modeling approach in commercially available FE software ABAQUS. The inelastic behavior of concrete and steel reinforcement bar has been incorporated through concrete damage plasticity model and Johnson-Cook models available in ABAQUS. The simulations were carried on the infilled frame against cyclic loading which was proximity of experimental tests conditions and geometry available in the literature. The simulated and experimental results were compared and found to be in good agreement with each other. Thus, from the results it can be inferred that infilled wall with concrete brick masonry assemblage performed better than flyash based infilled wall system.

Key words : *Masonry wall, CDP model, Finite element modelling, Cyclic loading, Concrete brick, Flyash brick*

Introduction

Masonry walls are extensively employed as outer walls to form part of building envelope and as partition wall in steel/concrete frame structures. The impact of masonry infill wall to resist lateral loads can be neglected by Engineers due to lack of sufficient design knowledge and intricaciesin analysis of that design. Infill walls can greatly provide strength to flexible frames and significantly resist the lateral load. During the 1990, Manjil earthquake in Iran, several buildings did not collapse although they were not appropriately designed to resist earthquake loads because of the presence of the masonry infill walls. The presence of masonry infill walls contributed to resist the lateral load (Mallick *et al.*, 1971) and the shear connector is one the key factor (Liauw, 1979). Moreover, most of the damage took place in the masonry infill walls and not the frame. Also, it was observed that the increase in the opening percentage lead to a decrease in the frame's stiffness and remained constant beyond opening percentages of 50% (Asteris, 2003). Under such circumstances, the effect of inll may be ignored if the area of opening exceeds 40% of the area of the inll panel (MondalandJain, 2008; Eshghi and Pourazin, 2009). In the infilled frame, the interface pattern also affects the structural system significantly when the lateral load increased (Senthil, 2010; Senthil and Satyanarayanan, 2016; Senthil *et al.*, 2018). Based on the detailed literature, it has been observed that the behavior of infilled frame with flyash based brick masonry and concrete brick masonry was found to be limited and the infilled frame under cyclic load-

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ing is not completely explored heretofore. Therefore, present study was motivated and focused to understand the constitutive behavior of brick made by flyash and cement and application of these bricks in the structural systems in order to understand the capacity of building under cyclic loading. Therefore, a simplified three dimensional macro model approach was employed in order to understand the infilled frame subjected to cyclic loading. The finite element model includes material parameters such as elastic and inelastic property, stress–strain, failure and yield criteria for masonry, concrete and steel. The numerical results thus obtained were compared with the experimental results available in literature. Finally, the response of bare frame, infilled frame with flyash and concrete bricks were compared in terms net displacement of the systems.

Constitutive Modelling

The constitutive behavior of concrete, steel reinforcement and brick masonry was modelled using Concrete damage plasticity model, Johnson-Cook Model and cohesive model, respectively. The basic idea about this model is discussed briefly in this Section.

Concrete damage plasticity - Concrete

The stress-strain relationship of concrete in the software was modeled as concrete damage plasticity modeled. CDP model which readily available in ABAQUS (Abaqus User Manual, 2013) which has been developed to predict the behaviour of concrete and other quasi-brittle materials such as rock and mortar under cyclic loading. Cracks in tension or crushing in compression are the main failure modes of this model.

Johnson-cook model –Steel reinforcement bar

The elastic and plastic behavior of steel reinforcement bar has been incorporated using the Johnson-Cook model includes the effect of stress state, temperature and rate of strain. The material behavior of the steel reinforcement was incorporated using the well-known Johnson–Cook (Johnson and Cook, 1985) elastoviscoplastic material model, that is capable of predicting the flow and fracture behavior of the ductile materials. It includes the effect of linear thermo-elasticity, yielding, plastic flow, isotropic strain hardening, strain rate hardening, softening due to adiabatic heating and damage and the material parameters for steel is available in (Børvik *et al.*, 2005).

FE Modeling

Modelling of frames

In this study, the samples used for the modeling are of the experiments carried out by (Basha and Kaushik, 2016). Samples tested in this study is half-scale models of an exterior ground-story frame which are connected to a rigid foundation beam to provide fixity at the base of column. The specimen considered was 1.5 m long and 1.5 m high and 115mm thick fly ash brick wall. Hence, the bounding frame was ordinary moment resisting frame with beam and column dimensions of 115 mm × 175 mm using 12 mm, 10 mm, 8mm and 6 mm Fe500 steel bars for longitudinal and transverse reinforcements respectively. For modeling of Concrete, 8-node three-Dimensional element with Reduced integration (C3D8R) was used. The type of element used for reinforcement was B31, which is a type of elements of a 3 dimensional beam with a linear (first degree) function and the stirrups were modeled as a rectangular shape with bending performance. For masonry materials, the element used for concrete modeling, namely C3D8R was selected. The embedded region was used to model interaction between concrete and rebar. In addition, the masonry infill and RC frame were considered as solid element and the interaction between them is defined as surface to surface interaction and the RC frame is applied master and masonry infill is slave. In the present study static analysis has been performed for both bare and infill frame under cyclic loading provided to the reinforced concrete frame.

Application of Loading

The cyclic in-plane loading was applied as per ACI 318 (Basha and Kaushik, 2016)] which is similar to that of experimental tests. FEM analysis were carried out using ABAQUS/standard software and type of analysis chosen for performing the simulations was static (ABAQUS, 2017). The systems were tested in lateral directions and their self-weight was also considered in the analysis. The axial load equal to 0.056 MPa, which is calculated as 1% of $P/(f_{ck}{*}A_g)$, on each column was applied over the model. The bottom face of the columns was assumed to be fixed using the ENCASTRE boundary condition. The in-plane cyclic displacement controlled loading was applied at the end face of the top beam. Lateral loading applies is a type of slow cyclic displacement control loading that is the same for both frames and it starts from 0 to 75 mm with the time from 0 to 213 Sec.

Mesh convergence and Validation Study

In the present study, mesh convergence study of bare frame has been performed to observe the influence of mesh size on results. The mesh size of steel reinforcement used in frame has been kept as 5mm for all the simulations whereas concrete mesh size has been varied from 15 to 50 mm. The behaviour of bare frame was measured through the experiemnts by Basha and Kaushik (ACI 318, 2007) and the same was verified through the simulation, see Table 1. As the mesh size of concrete frame was reducing the input displacement at a particular time has been obtained more closely. During the simulation, on reducing the mesh size of concrete frame after 40mm due to technical issue with the software full simulation result has not been obtained, so upto 86 frame from a total of 216 frame the input displacement controlled result has been compared Table 1. Finally the conclusion comes out from the mesh convergence study was that 20 mm mesh size of concrete frame and 5 mm mesh size for steel reinforcement giving the most accurate results.

Influence of Concrete Brick and flyash Brick Masonry on Infilled RC frame

In the present study, the bare frame was infilled with concrete masonry assemblage and the result obtained is compared with ductile bare frame. The result compared between bare frame and concrete infill masonry in terms of displacement and reaction forces as shown in Table 2. From displacement data, drift of frame has been calculated and compared in Fig 1.

The lateral force in push and pull condition was measured at the face of top beam of RC frame and ultimate displacement has been obtained at a distance of 1260 mm from the bottom face of column as the prximity of the experimental test. The lateral force obtained by adding the forces on all the nodes of the face of top beam where the displacement has provided in the numerical simulation. The displacement has been taken by taking a node at a distance of 1260 mm from the base of the column.the hysterisis curve of experimental observation has been compared from numerical simulation.

The response of bare frame, infilled frame with flyash masonry assemblage and infilled frame with concrete masonry assemblage were compared in terms of displacement, see Table 2. It was observed that resistance of both of the infilled frame found increased significantly as compared to the bare

Table 1. Mesh convergence study on bare frame

Mesh Size (mm)		50	40	25	20	15	Experimental Results (Basha and Kaushik, 2016)
No. of frame		86	86	86	86	86	-
Stress in concrete (MPa)		26	28	38	34	44	-
Stress in steel (MPa)		580	615	629	565	585	-
Lateralforce (kN)	Push (+)	10	8.1	9.13	4.63	3.19	7.13
	Pull (-)	-18	-15	-13.68	-7.91	-5.11	-8.12
Net displacement (mm)		5.3	5.83	9.12	11.07	11.25	11.00

Table 2. Comparison of bare frame, fly ash in masonry infilled frame and concrete masonry infilled frame

Infill cases		Bare Frame Masonry infilled frame	Flyash Brick Masonry infilled frame	Concrete Brick
No. of frame		216.0	216	216.0
Stress in concrete (MPa)		39.8	30.86	29.9
Stress in steel (MPa)		944.7	878.1	842.6
Lateral Force (kN)	Push	+71.75	+71.75	80.7
	Pull	-63.59	-63.59	-73.1
Net Displacement (mm)		60.0	62	62.0
Drift (%)		3.9	4.133	4.1

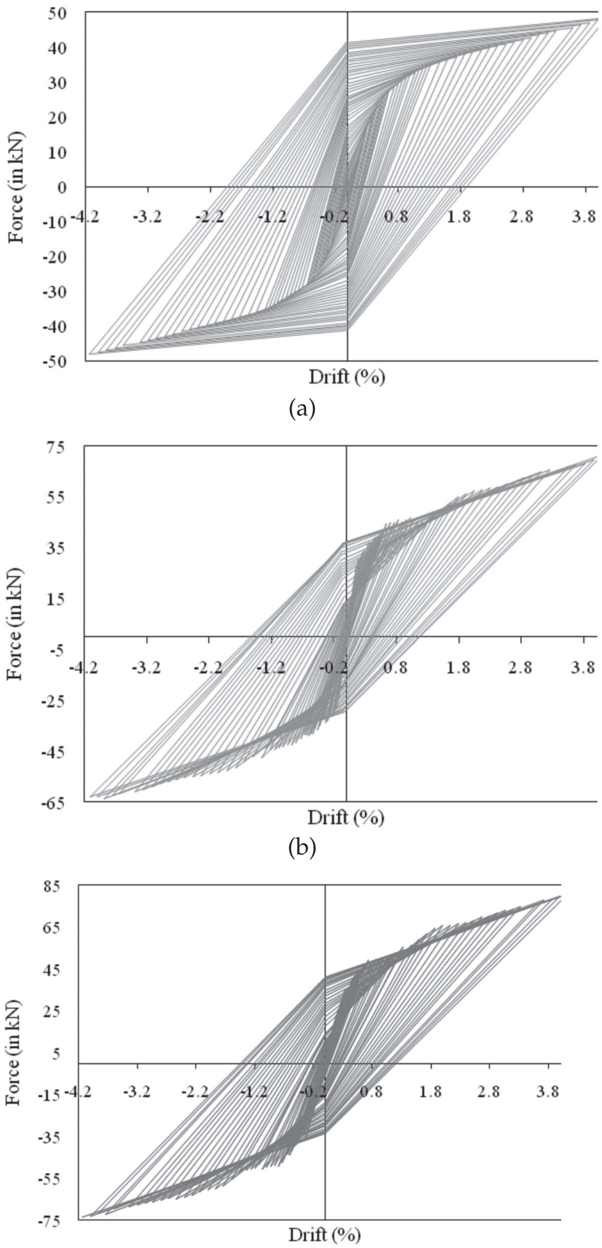

Fig. 1. Hysteris Curve Comparison for (a) bare frame (b) infilled frame with flyash bricks and (c) infilled frame with concrete bricks of Numerical results

frame. Also, it was observed that the resistance of the infilled frame with concrete masonry assemblage was more (10%) than the infilled frame with flyash masonry wall. However, the net displacement in the given chosen cases was found to be almost same. Therefore, it is concluded that the performance of infilled frame with concrete brick masonry assemblage was better than the flyash based infilled wall systems.

Conclusion

The response of infill frames with concrete and flyash brick masonry were studied in terms of displacement and lateral load resisting capacity. The inelastic behavior of concrete and steel reinforcement bar has been incorporated through concrete damage plasticity model and Johnson-Cook models available in ABAQUS. The Surface-based cohesive behavior model has been used in order to model the damage behavior of masonry unit. The simulations were carried on the infilled frame against cyclic loading which was proximity of experimental testsavailable in literature si compared. Based on detailed numerical study, following conclusion were drawn:

- Lateral load resisting capacity of concrete bricks infill frame found to be on the higher side as compared to the fly ash bricks infilled frame whereas, the lateral load carrying capacity of bare frame is significantly low, i.e. 40% less than the concrete bricks infilled frame.
- Therefore, it is concluded that the performance of infilled frame with concrete brick masonry assemblage was better than the flyash based infilled wall systems.

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