Experimental Study on Reinforced Concrete Frame Infilled with Mud Concrete Blocks

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Abstract - *Reinforced Concrete (RC) frame buildings with masonry infill walls are built all around the world. The masonry wall panels that are built as a partition or to enclose the structure are generally considered as non-structural elements, which is a widely practised hypothesis. As a result, while designing the framed structures, the structural role of the infill panels are neglected and this hypothesis does not seem to correspond with the reality when the structure is subjected to seismic lateral loads. The aim of this study is to develop a sustainable infill material with low energy consumption at manufacturing level called Mud-Concrete block with the required strength characteristics. Mud Concrete Blocks (MCB) is a form of 'Concrete block' manufactured using soil, cement and water. In the present study, two types of infilled panel and a bare RC frame is tested under repeated lateral loads. The different types of frames include a. Bare frame (without infill wall), b. RC frame with MCB as infill wall and c. RC frame with MCB as infill with a central opening. The load verses deformation graph is obtained. The performance of infill frames were compared in terms of strength, peak to peak stiffness, cumulative energy dissipation and crack distribution.*

Key Words: Framed structures, Infill wall, Lateral load, Mud concrete block, Stiffness, Energy dissipation.

1. INTRODUCTION

In modern day construction practices, one of the most feasible choice of erecting a concrete building is to construct a framed structure as it allows to follow an easy and smooth pattern of work during the various stages of construction with appreciable economy. Frame structures are structure that are formed with a combination of beams, columns and slab to transfer the load acting on them. To separate the internal spaces from the external environment or to set partition wall, RC frames are provided with infill walls. Most widely, Reinforced concrete frame buildings with masonry infill walls are built all around the world. The masonry wall panels that are built as a partition or to enclose the structure are generally considered as non-structural elements, which is a widely practiced hypothesis. As a result, while designing the framed structures, the structural role of the infill panels are neglected and this hypothesis does not seem to correspond with the reality when the structure is subjected to seismic lateral loads. As a matter of fact, the behaviour of these framed structures is affected by these non-structural elements during an earthquake horizontal load. Hollow clay tile blocks, wooden panels and concrete blocks are commonly used as infill.

In the present scenario, materials are considered as the most unavoidable component for the construction of building. Presently in the construction industry, there is a large increase in the demand for materials which leads to significant consumption of natural resources. This has gradually led to an increase in the cost of construction materials as well as to a scarcity of resources. This situation has created a need for sustainable materials with low energy consumption and environmental impact during both the manufacturing process and at the operational level. Therefore, it is necessary to identify an alternative building material which is simpler in manufacturing and also promote sustainable & affordable construction that satisfies the current comfort standards. 'Soil' can be considered as one such sustainable raw material which has been used extensively for building construction since ancient times.

Mud Concrete Blocks (MCB) is a new concept in the construction industry. It is a form of 'Concrete block' produced using soil, cement and water. The initial concept of developing Mud-Concrete was to incorporate both the strength and durability of concrete into mud-based constructions.

2. PAST LITERATURES

Elouali. T (2012) conducted an experimental program to investigate the behaviour of frame with masonry infill panels subjected to cyclic loading. Two types of masonry materials are frequently used for testing. The effect of the infill panel on the seismic response of framed building was evaluated. The experimental results have been used to develop an analytical model for the determination of the stress-strain relationship to predict the inelastic behaviour of each type of infill.. The results obtained show that the infill has an effect on the seismic response of frame buildings and it should be considered in the analysis of such a type of structures.

Syed Azmat Ali Shah et al. (2013) studied the performance of masonry infill walls under lateral loads i.e. the application of dynamic forces. The study focuses on different modes in which the structural members fail during loads. It also involves mechanical model and material model. It was observe that the behaviour of frame structures under lateral loads is mainly dominated by the presence of columns in the structure. It can be seen that columns are the primary members of a frame structure that resists the lateral loads.

Andre Furtado et al. (2015) developed a simplified macro-model to study the out-of-plane behaviour of the Infill Masonry (IM). He also studied the interaction between in-plane (IP) and out-of-plane (OOP) behaviour of panels when subjected to lateral seismic loading. It was observed that while considering the OOP behaviour of infill, the vulnerability of the building was increased and it leads to the collapse of the most vulnerable storeys for peak ground accelerations above 0.3g. A significant difference was observed between the IP and IP- OOP numerical models, which points towards the need for considering the OP behaviour of the infill walls for proper seismic safety assessment of existing RC infilled structures.

Davorin Penava et al. (2018) studied the influence of the opening (type, size and position on the shear resistance and deformation capacity of individual components (infill and frame) in masonry infilled reinforced concrete (RC) frame structures. A numerical computational model based on the non-linear finite element (FE) method of analysis has been developed. The computational model has been validated against a series of experimental tests carried out in the laboratory. A parametric study was carried out and the influence of differences in size and location of window and door openings on the shear resistance of infilled frame was studied. From the analysis, it was found that the type of opening influences the design characteristics of the infilled RC frame. It was found that, the shear resistance of columns of the infilled RC frame with a window opening is lower than the shear resistance of the columns of the RC frame. In contrast, the shear resistance at the columns of the infilled RC frame with a door opening is higher than the shear resistance of the columns of the RC frame, and in this case the contribution of the shear capacity of the frame is underestimated.

F.R. Arooz and R.U. Halwatura (2018) studied the mix design and durability characteristic of Mud Concrete Blocks. In Mud-Concrete, the sand and coarse aggregate components of concrete are replaced by fine and coarse aggregates of soil. The percentage of gravel gravel governs the strength of Mud-Concrete. As a result, the mix proportions of the Mud-Concrete Block were finalized to have a minimum of 4% cement, fine ≤ 10% (≤ sieve size 0.425 mm), sand 55 – 60% (sieve size 0.425mm ≤ sand ≤ 4.75 mm), gravel 30–35% (sieve size 4.75mm≤gravel≤ 20 mm) with a water content of 18% to 20% from the dry mix. The achieved mix design for the Mud Concrete Block also satisfied the durability requirements up to the standard levels.

3. OBJECTIVE

i. To find appropriate mix design for Mud Concrete Blocks (MCB).
ii. To study the properties of Mud Concrete Blocks.
iii. To study the effect of mud concrete block infilled RC frame under repeated lateral loads.
iv. To compare the behaviour of RC frame infilled with and without infill wall.
v. To study the behaviour of MCB infilled wall with and without opening.

4. EXPERIMENTAL INVESTIGATION

4.1 Test Specimen

Three set of frames were taken for the study. The frames that were built for experimental investigation were scaled down model of actual frame in the ratio 1:3. The dimension of the scaled model is 1.3m×1m×0.13m. The details of specimen are given in Table-1.

Table-1 Types of Frames

Frame	Details
F1	Bare Frame
F2	Frame with MCB as infill
F3	Frame with MCB as infill and with an opening

4.2 Material Properties

i. Cement

Pozzolanic Portland cement conforming to IS 12269-1987 was used in the study.

ii. Fine aggregate (FA)

Fine aggregate are soil particles passing through 4.75 mm IS sieve. Generally river sand, crushed stone, crushed gravel, M sand etc. are used as fine aggregate. In this study, M sand conforming to Zone II is used.

iii. Coarse Aggregate (CA)

Those fractions from 20 mm to 4.75 mm are termed as coarse aggregate.

iv. Reinforcement

Fe500 steel of diameter 10 mm was used as main bars and 6 mm diameter bars were used as ties.

v. Soil

MCB block was prepared using the soil that is commonly available in Kottayam. The soil used here is lateritic soil along with small proportions of sand. The Specific gravity of soil is obtained as 2.4. The collected soil contains :

- Gravel (> 4.75mm) : 25%
- Sand (4.75< sand > 0.425mm): 60%
- Fine (< 0.425mm) : 15%

vi. Mortar Mix

Mortar mix was prepared using cement, fine aggregate and water. Different ratios of mortar mix such as 1:3, 1:4 and 1:6 are prepared and tested. Mortar mix for plastering was prepared according to IS 2250(1981). Mortar cubes of 7cm x 7cm x 7cm were prepared and tested for compressive strength. Mortar mix of 1:4 was chosen for plastering in the present study.

4.3 Mud Concrete Block

Mix Proportioning of MCB Blocks

The mix proportion of MCB Block is fixed by conducting trials. The concentration of cement is kept as 10% by weight of the block. The mix proportion of the two samples is given in Table-2. Water is added to obtain the required consistency.

Table-2: Mix Proportion of Blocks

Sample	Cement (%)	Soil (%)	Sand (%)
1	10	85	-
2	10	43	47

Casting of MCB Blocks

The required amount of soil and sand is taken and it is then thoroughly mixed. To this mixture calculated amount of cement is added. The mixture should be uniformly mixed. Water is added to obtain the required consistency. Then the mixture is the poured into the mould. The size of the block is fixed as 290 × 190× 90 mm. The mould is filled in 3 layers each layer being tamped 25 times. Surface is finished with a trowel. It should be cured for 28 days. Wet gunny bags are placed on top of blocks for curing. The compressive strength of the block specimen is found. The sample with higher compressive strength is chosen to build the infill wall.

Testing of MCB Blocks

Six blocks from each sample is tested for compressive strength. The compressive strength of sample 1 and sample 2 is obtained as 2.92 MPa and 4.21 MPa respectively. The percentage water absorbed is obtained as 7.02%. Hence the block can be used for building wall.

4.4 Casting of Frames

The frames were cast using M20 grade concrete. Before pouring the concrete into the mould, it was oiled well to allow easy demoulding of specimen and for better finish of cast surface. The reinforcements were then placed in position and cover blocks were used to keep reinforcement in position and to ensure the correct cover. The concrete was poured and tamped with rods to avoid honeycombing as shown in Fig-1. The frames and the control specimens were de-moulded after 24 hours of casting. The frames were covered with gunny bags which were wetted at regular intervals.

Fig-1 Casting of RC Frame

To cast masonry panels, the surface of solid blocks were slightly wetted to prevent the absorption of water from mortar mix. A smooth surface was prepared and mortar mix was applied in a layer of 10mm thick. Blocks were placed over the mortar layer and slightly pressed. Broken blocks were placed in alternate layers to eliminate vertical joints. Different layers were placed and joints were filled with mortar. Excess mortar was swiped off from the surface and wall is finished ensuring that the blocks were placed level. Fig-2 and Fig-3 shows frame infilled with MCB Block with and without opening respectively.

Fig- 2 Frame infilled with MCB with opening

Fig- 3 Frame infilled with MCB

4.5 Test Setup

Frames were tested in a loading frame of 50T capacity. The loading frame for testing the frames consisted of two ISMB300 sections as horizontal members and two ISMB250 sections as vertical members. The frames were placed above ISMB300 section. Fig- 4 shows a schematic diagram of test setup. A vertical restraint with roller arrangement was made at the top right corner to prevent the frames from lifting up due to the application of the lateral load. This also allows the horizontal movement of the top member of the frame when lateral load is applied. The lateral load was applied at the top right corner of the frame by a manually operating hydraulic jack of capacity 50T. This hydraulic jack is provided through a load cell of capacity 50T. Deflections at top, three-fourth height and mid height of the frame are measured.

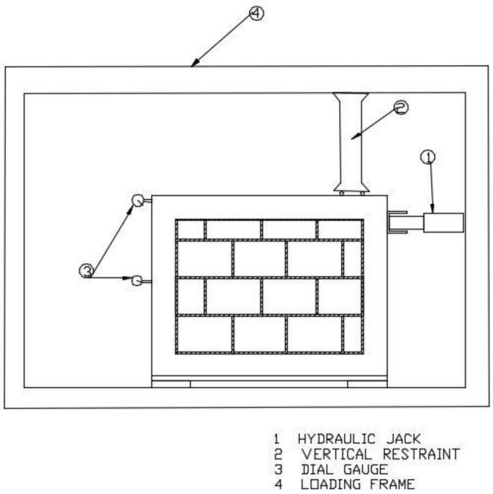

Fig- 4 Schematic Representation of Test Setup

5. RESULTS AND OBSERVATION

The loading history consists of step-wise increasing load cycles. In the initial cycle a load of 0.5kN is given. The load is increased as 1.0 kN, 1.5 kN, 3.0 kN, 6.0kN, 9.0kN up to 30.0kN is given in subsequent cycles.

The RC frame shows signs of failure in third cycle at 1.4 kN load cracks are formed in bottom left corner and top right corner. The frame fails to take further loading at 2.3 kN in forth cycle. Fig-5 shows the failure pattern. The load vs. deformation graph of frame F1 is shown in Chart-1.

Fig- 5 Crack Pattern

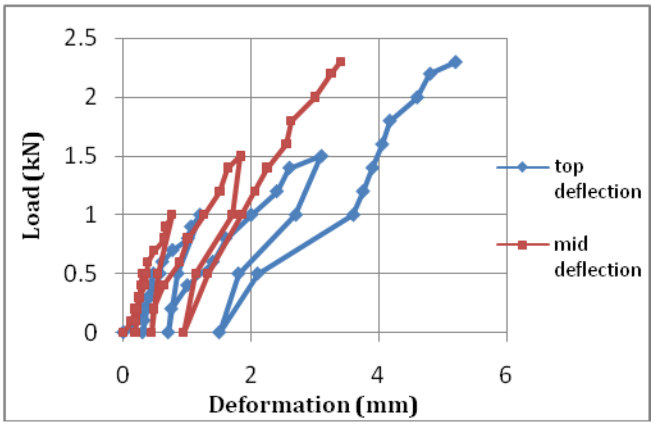

Chart-1 Load vs Deformation Graph of Frame F1

In frame F2, it shows sign of failure at 5th cycle at a load of 5.5kN, first cracks were observed on the junction of frame top right and bottom left corner. When the load reached 8.0kN in the 7th cycle, the mortar layer started to detach from the infill and frame. When the load has reached 15.7 kN the frame fails to take further loading after the 8th cycle. Fig-6 shows the failure pattern. The load vs deformation graph of frame F2 is shown in Chart-2.

Fig-6 Crack Pattern

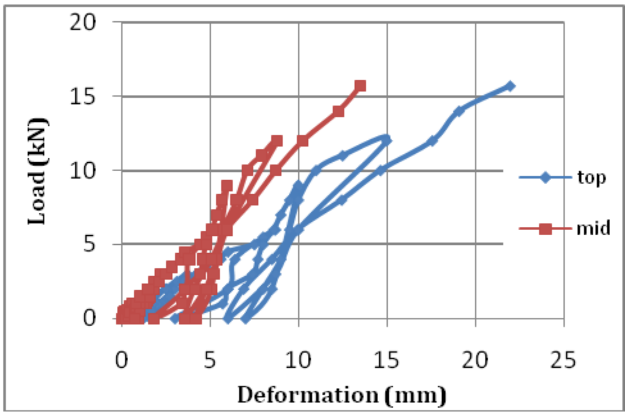

Chart-2 Load Vs Deformation Graph of Frame F2

The frame F3, shows sign of failure at 5th cycle at a load of 6.0kN, first cracks are observed on the junction of frame top left and bottom right corner. When the load has reached 7.5 kN in the 6th cycle mortar layer start detaching from the infill and frame. Flexural cracks are observed on the vertical members due to cantilever action. When the load has reached 14.3 kN in 8th cycle the frame fails to take further loading. Fig-7 shows the failure pattern. The load vs deformation graph of frame F3 is shown in Chart-3

Fig-7 Crack Pattern

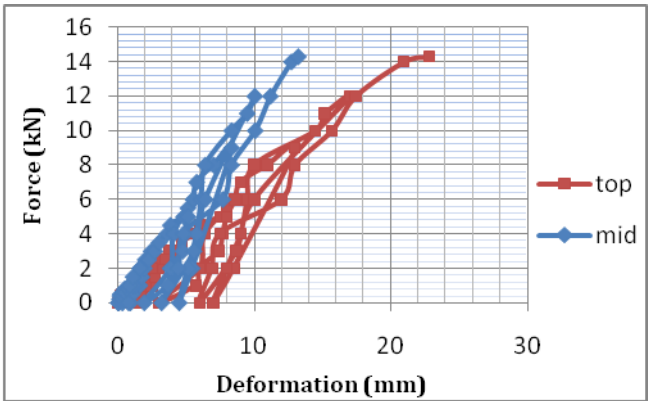

Chart-3 Load vs Deformation Graph of F3

5.1 Comparison of Results- Load vs. Deformation Graph

The ultimate load carrying capacity of bare frame was found to be 2.3 kN, which is 85.35% less than the ultimate load carrying capacity of infill frame F2. The load carrying capacity of MCB with opening is less than load carrying capacity of infill panel without opening by 9.79%. Chart-4 shows comparison of the load vs deformation graph of the 3 frames in first 4 cycles.

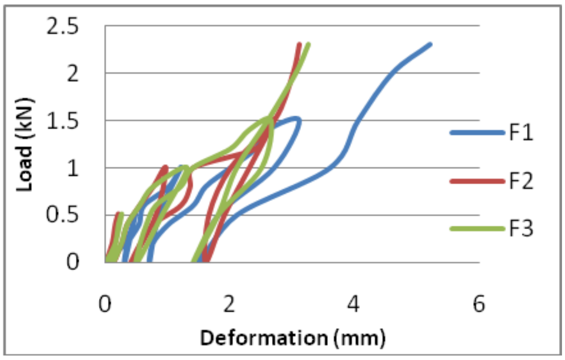

Chart-4 Comparison of the Load Vs Deformation Graph

5.2 Stiffness Degradation

The stiffness in a particular cycle was calculated from the slope of the line joining peak values of base shear in each half cycle. The comparison of stiffness degradation of infill frames is made corresponding to top deflection is given in Chart-5.

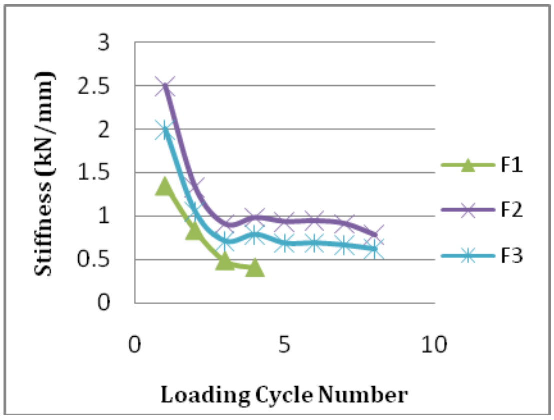

Chart-5 Comparison of Stiffness Degradation of The Frames F1, F2 and F3,

It can be observed that all graphs follow same trend. Degradation of stiffness takes place after each cycle of loading. The frame F3 was observed to have higher stiffness degradation compared to frame F2 by 6.684%. The stiffness of frame F2 is higher than F1 by 48.48%.

5.2 Energy Dissipation Capacity

The energy dissipation capacity of a structure is a very important index that indicates the structural performance in energy based seismic design (yujiao, 2011). This index depends greatly on the structural components that form the whole system. The energy dissipation capacity of a structure under loading is equal to work done in straining or deforming the structure up to limit of useful deflection i.e., numerically equal to area under load deflection curve. The comparison of cumulative energy dissipation capacity of infill frames is made corresponding to top deflection is given in Chart-6.

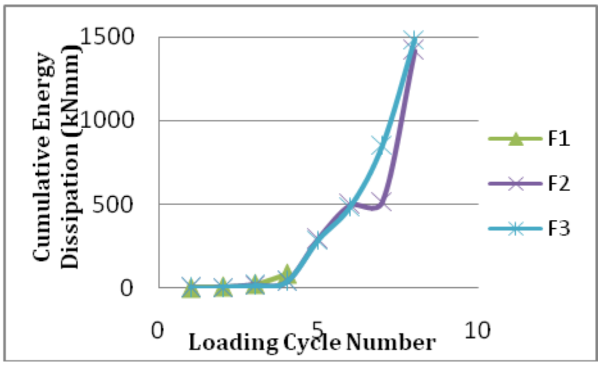

Chart-6 Comparison of Cumulative Energy Dissipation Capacity of the Frames F1, F2 and F3

The energy dissipation is getting increased after each cycle of loading. The cumulative energy dissipation capacity of frame F3 is 8.2% higher than that of the F2, which is about 15 times higher than the bare frame (BF).

6. CONCLUSIONS

The specimens were tested under repeated lateral load and the following conclusions were obtained.

- The ultimate load carrying capacity of RC can be improved by the incorporation of infill wall.
- The ultimate load carrying capacity of F2 is higher than F1 by 85.35%.
- Presence of infill panel reduces the lateral displacement of frame.
- The presence of opening reduces the load carrying capacity of frame.
- The ultimate load carrying capacity of F3 is less than F2 by 8.91%.
- With the incorporation of infill wall the stiffness of the frame was increased by 1.9 times.
- The cumulative energy dissipation capacity of the RC frame was increased by 15 times with the incorporation of infill wall.

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