

Experimental Study of Flexural Behaviour of Reinforced Baked Clay Beams under Impact Loading

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Abstract

This paper presents behaviour of Reinforced Baked Clay (RBC) beams under drop weight impact loading. The beams were made of two different grades of baked clay with cube crushing strength of 20 MPa and 30 MPa, respectively. The RBC beams were subjected to repeated drop weight loading by a hammer of weight equal to that of the specimen being tested. The results showed that the impact resistance of the RBC beams was governed by the compressive strength of the baked clay. Failure of grade 20 beams occurred due to irregular cracks and the beams of grade 30 failed by opening of a single crack at mid span. It was observed that the beams of grade 30 had sustained about 1.5 times more number of impacts until steel in tension zone yielded and failed completely after necking.

Keywords

Baked Clay, Impact Loading, Cracks, Deflection, Compressive Strength, Reinforcement

1. Introduction

Clay is being used, since ancient time, in unbaked and baked states for the construction of houses [1]-[3]. Sun baked and fired bricks are being used for the erection of buildings since the dawn of civilizations in various parts of the world, e.g. in Greece, Mesopotamia and Indus valley [4]-[6]. The buildings constructed of fired bricks are still in existence after hundreds of years. The bricks cast and fired in same manner today have average compressive strength of about 12 MPa [7]. If the clay bricks are compacted mechanically at higher degree of density and fired at standard temperature, they may give higher degree of compressive strength.

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Structural members such as beams, columns and slabs may be subjected to dynamic loads besides compressive, shear, tensile and flexural loads. The dynamic loads on buildings are in general due to extreme wind and seismic vibrations [8]. To determine the effect of such impact loads on a structural member, various types of impact and impulsive tests are conducted such as: 1) falling mass, 2) air ballast, 3) spring loads, 4) deformation controlled impact and 5) pendulum loading [9].

Currently, due to terrorist activities, highly explosive attacks are common everywhere [10]-[12]. Thus, it is imperative to design buildings which may remain safe in such dynamic loading conditions. This necessitates to investigate the impact resistance of other low cost materials such as baked clay.

Reinforced Baked Clay (RBC) is a light weight, heat and fire resistant material having compressive strength equal to that of normal weight concrete [13]. Previous studies suggest that RBC is a potential construction material as a replacement of reinforced cement concrete in order to erect low cost houses [14]-[16]. However, the behaviour of RBC under impact load is not yet conducted. The object of this study is to investigate behaviour of RBC beams under impact loading. For this purpose, guidelines for testing reinforced concrete beams under impact loads were followed to specify the size of specimen, weight of hammer and the drop height, see, e.g. [17]-[20].

2. Materials and Methods

2.1. Casting of Beams

Local clay was excavated in vicinity of Nawabshah city at a depth of 1200 mm in order to decrease possibility of mixing of aggregates and organic matter in the quarry. The excavated clay was initially dried and then pulverized. The clay was mixed with pit sand by weight in a ratio of 70:30. This proportion of clay and pit sand was adopted from another study [13] which suggested that addition of pit sand was helpful in increasing compressive strength and minimizing shrinkage and cracks of clay beams. The mixture was put in a pan mixer and 22% of water was added. This much quantity of water was required in order to achieve workability and proper bond between the layers of clay beams. The mixing was carried out for 15 minutes. The clay and sand mixture was put in layers in steel mould (Figure 1) of the Mechanized System [21] to cast and compact the clay beams. Two batches of clay beams were cast. Each batch consisted of three beams. During casting process, the clay beams were compacted with the help of wooden plunger (Figure 2). First batch of beams was compacted at a pressure of 1.94 MPa and the other batch was compacted at 6 MPa. Both batches of clay beams were dried in shade and then baked in a kiln at a temperature of 1000°C. Cubes of size 150 mm were cut from the baked clay beams and were tested in Universal Testing Machine.

Average compressive strength of the cubes was found to be 20 MPa, and 30 MPa, for both batches, respectively. Beams of 150 mm × 150 mm × 500 mm were cut from both batches. The baked clay beams were under



Figure 1. Mould utilized for casting of clay beams.

reinforced with a single 6 mm steel bar in both compression and tension (**Figure 3**). The RBC beams were tested in drop weight impact loading machine designed for this purpose.

2.2. Drop Weight Impact Load Testing Machine

A drop weight impact testing machine was designed and fabricated to test RBC beams (**Figure 4**). This testing machine is composed of: 1) a pair of truss section, 2) a pair of double vertical post channel sections, 3) four tension stiffening steel plates, 4) two 2130 mm long steel pipes, 5) hammer and tup assembly.

The truss frames are welded to each other so that they form a stiff frame for supporting the beam. This frame is 2300 mm long and 450 mm high. A vertical frame composed of two pairs of 2130 mm long channel section, were welded to each other. The hammer assembly is composed of a steel box. The box is so designed that two 20 kg standard weights can be accommodated. A 150 mm long semicircular tup was welded with the hammer

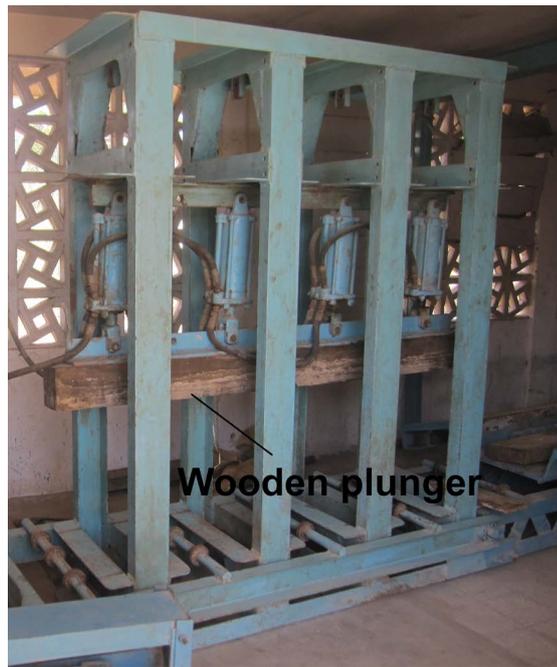


Figure 2. Wooden plunger used to compress clay beams in mechanized system.

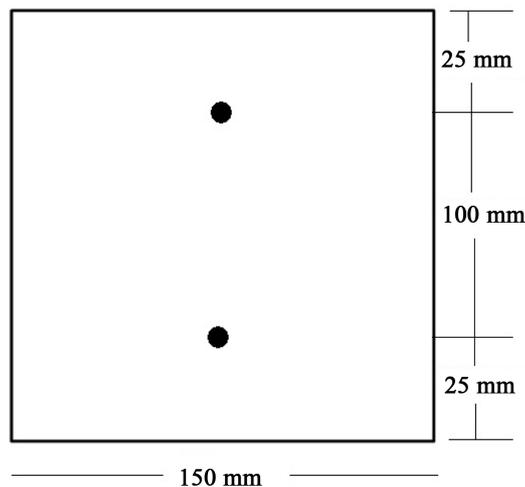


Figure 3. Cross section of reinforced baked clay beam.

assembly which can smoothly slide between vertical posts. Two 152 mm steel pipes were welded vertically at their ends in the system so that the hammer slides along those pipes and has only small allowance of lateral movement of only 2 mm. The hammer can be raised manually up to a height of more than 1500 mm.

3. Results and Discussion

Deflection Behaviour under Impact Loading

The RBC beams of grade 20 got cracked on application of first impact applied at mid span. On application of further impacts, a number of irregular cracks of different sizes occurred and the beams failed completely (Figure 5). The RBC beams of grade 30 got cracked at the impact of first blow of hammer at mid span in tension zone. On application of further impacts, the beams failed by developing shear plug below the point of impact in tension zone and yielding of a reinforcing bar (Figure 6).

It is interesting to investigate in detail the effect of compressive strength (*i.e.* grade 20, and grade 30) of baked clay on deflection behaviour by keeping the area of reinforcement as constant. For this purpose, the deflection response of the beams of grade 20 was compared with those of grade 30. Figure 7 presents comparison of impact response of the beams of grade 20 and 30. It can be observed that grade 30 beams showed 1.5 times more

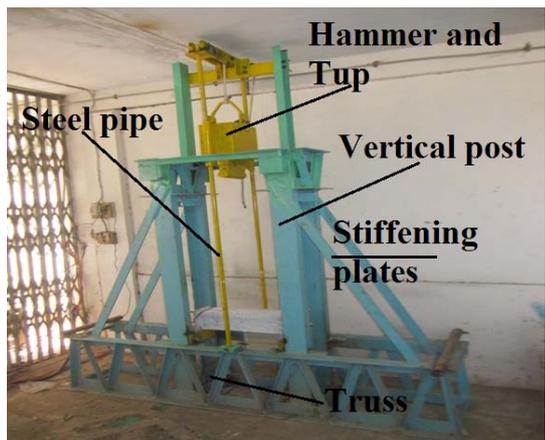


Figure 4. Drop weight impact testing machine.



Figure 5. Failure behaviour of reinforced baked clay beam of grade 20 under impact load.



Figure 6. Failure behaviour of reinforced baked clay beam of grade 30 under impact load.

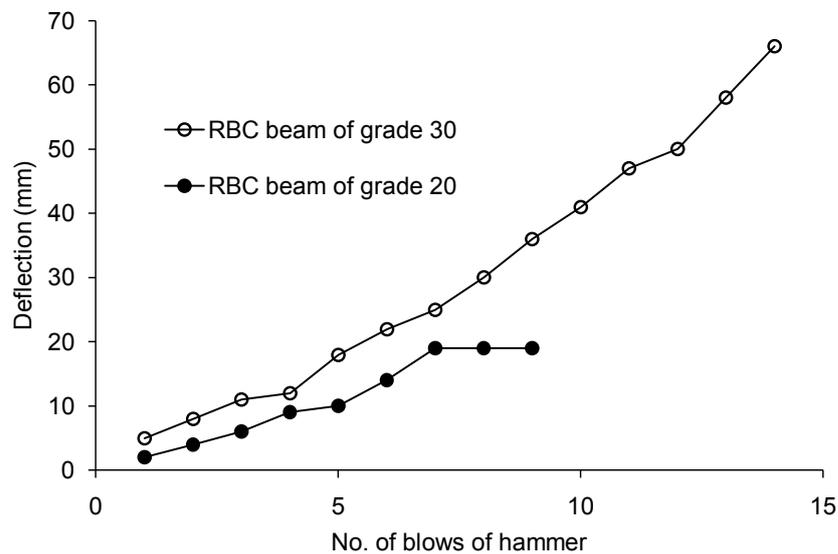


Figure 7. Comparison of impact resistance of reinforced baked clay beams of grade 20 and 30.

impact resistance as compared to the grade 20 beams. This is because, 1) the beam of grade 30 failed due to yielding of a steel bar followed by crushing of baked clay, and 2) the beams of grade 20 failed due to crushing of baked clay material. This behaviour of the RBC beams is consistent with that of RCC beams, see e.g. Khan [22].

4. Conclusions

In this study, effect of cube crushing strength on impact resistance and deflection behaviour of Reinforced Baked Clay (RBC) beams under drop weight impact loading were investigated. The experimental programme has led to the following conclusions:

- 1) Cube crushing strength of RBC is directly related to resistance to impact loading; the larger the cube crushing strength is, the higher the resistance to impact loading of RBC beams is.
- 2) The RBC beams of grade 20 showed global failure by developing a number of irregular cracks both in the compression and tension zones.
- 3) The RBC beams of grade 30 exhibited a single crack in tension zone below the point of impact and failed by yielding of a steel bar in tension zone.

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