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Effect of Reinforcement on Deflection and Cracks in Baked Clay Beams Subjected to Impact Loading

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Abstract

Attempts are being made to utilize Reinforced Baked Clay (RBC) as a substitute of Reinforced Cement Concrete (RCC) for construction of low cost houses in plains of Pakistan. Since baked clay is considered to be more brittle as compared to concrete. Therefore, it is necessary to investigate how deflection and crack width of RBC beams subjected to impact loading are governed by amount of reinforcement. This paper presents the behaviour of RBC beams under drop weight impact loading. The beams were reinforced with two steel bars, one in compression zone and the other in tension zone. In group A beams, the diameter of steel bars was 12.7 mm, while the beams of group B were reinforced with steel bars of 15.8 mm diameter. The RBC beams were subjected to repeated impacts of a hammer of mass 21 kg falling from a height of 1000 mm. The results show that 1) three times reduction in deflection, and 2) 2.5 times decrease in crack width, were achieved in RBC beams by increasing the area of steel to 50%. In addition to this, all the RBC beams failed within nine blows of the hammer, irrespective of area of reinforcement.

Keywords

Reinforced Baked Clay, Impact Load, Deflection, Cracks, Compressive Strength

1. Introduction

Due to high cost of cement, and aggregates in plains of Pakistan, attempts are being made to search for other indigenous and low cost materials of building construction. In this regard, baked clay is considered to be a potential material for construction of low cost houses. Preliminary studies report that the compressive strength of baked clay is comparable to that of normal weight concrete [1]-[7]. Research has been carried out on flexural behaviour of laboratory size Reinforced Baked Clay (RBC) beams. The studies suggest that the load carrying capacity of RBC beams is also comparable to that of RCC

beams [8].

If a structural member is subjected to an impact load, more stresses and deformations could be developed as compared to static loads. Impact loads include shock waves and vibrations from explosions, earthquakes, nearby rail roads, or movement of heavy machinery near a structure. A structure would normally resist a static load, but if the load of same magnitude is applied as an impact load, it could cause comparatively more damage to it.

At present, public and government buildings, all over the world, are being targeted with terrorist attacks. For public safety, structural engineers are paying more attention to design buildings which could sustain impact loads caused by explosions. For this purpose, it is important to investigate the effect of impact loading on materials of building construction. Like concrete, baked clay is a brittle material, it may exhibit complex cracking behaviour when subjected to impact loading [9]. The impact loading can cause the beam to crack in tension or the failure in compression zone or both [10]. The failure of baked clay due to crushing in compression zone at the point of impact can cause brittle mode of failure, which is considered to be undesired in structures. If the impact load causes the beams to crack in tension zone, water could get access to the reinforcement, which in turn may cause rusting of steel bars and failure with time [11]. If the material of the beams is impact resistant, increase in ratio of reinforcement can increase the strength of the beams against impact loading [12]. The authors are of the view that no study regarding the effect of reinforcement on deflection and cracking behaviour of baked clay beams subjected to impact loading is reported in the literature. In this regard, an experimental programme was performed to investigate the effect of reinforcement on deflection and cracking behaviour of baked clay beams subjected to impact loading.

2. Materials and Methods

2.1. Casting of Clay Beams

Indigenous clay was pulverized and was mixed with local pit-sand. The clay and pit-sand mixture was prepared in a ratio of 70:30 by weight. The quantity of water added was 22% of the clay and pit sand. The mixing was performed in a pan mixer for fifteen minutes. This moist mixture was covered with plastic sheet and was placed for 24 hours. For convenience, from now on, the mixture is referred to as moist clay. Beams of dimensions 150 mm × 300 mm × 1980 mm were cast in Mechanized System (**Figure 1**) [13]. These moist clay beams were compacted at 3 MPa in drained state condition [6] during the process of casting. After compaction, these clay beams were dried in shade. These dried clay beams were fired in a Potter's type kiln at 1000˚C (**Figure 2**).

2.2. Testing Programme

Five cubes of 150 mm size were sawed from these baked clay beams and tested in Universal Testing Machine for compressive strength (**Figure 3**). The compressive strength test was performed in accordance with British Standard BS EN 12390-3 [14]. Six beam

Figure 1. A clay beam is being cast and compacted in mechanized system.

Figure 2. A view of a baked clay beam after firing in Potter's type kiln.

Figure 3. Determination of compressive strength of a baked clay cube in Universal Testing Machine.

prisms of 150 mm square in cross section and 500 mm long were sawed from these baked clay beams. The baked clay beam prisms were reinforced using two steel bars, one in compression zone and other in tension zone. The baked clay beam prisms were divided into two groups based on diameter of steel reinforcement. Group A beams were reinforced with two steel bars each of diameter 12.7 mm. The beams of group B were reinforced with two steel bars each of diameter 15.8 mm. These beam prims were tested under drop weight impact loading. For this purpose, drop weight impact load testing machine, designed and fabricated by the authors, was utilized (Figure 4). In this test, a hammer of mass 21 kg was used. The hammer was dropped manually from a height of 1000 mm.

3. Results and Discussions

Reinforced baked clay beam prisms belonging to group A (reinforced with two steel bars each of diameter 12.7 mm) and group B (reinforced with two steel bars each of diameter 15.8 mm) were tested under drop weight impact loading.

3.1. Cube Crushing Strength of Baked Clay

Five cubes of 150 mm size were cut from baked clay beams and tested in Universal Testing Machine. Average compressive strength of the cubes was found to be 20 MPa. It may be noted that compressive strength of normal weight concrete is generally considered as 20 MPa. This implies that the compressive strength of baked clay can be achieved comparable to that of normal weight concrete.

3.2. Load Deflection and Cracking Behaviour of Reinforced Baked Clay Beams Subjected to Impact Loading

Three beams from each group were tested. The beams of each group showed similar

Figure 4. A reinforced baked clay beam of dimensions 150 mm × 150 mm × 500 mm is being tested for drop weight impact loading.

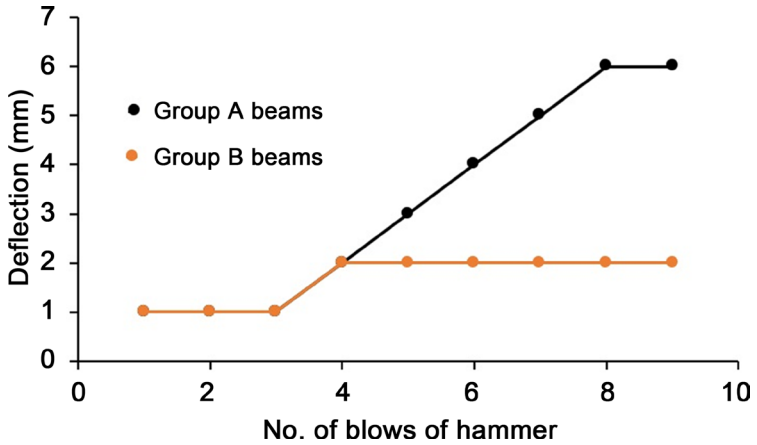

Figure 5. Impact load versus deflection response of RBC beams of group A (with two 12.7 mm diameter steel bars) and group B (with two 15.8 mm diameter steel bars).

load deflection behaviour. For convenience of presentation, the results of a representative beam from each group are described. Figure 5 shows load deflection behaviour of RBC beams of group A and B. It can be observed that the deflection was reduced to three times by increasing the area of steel by 50%. It was also observed that the crack width of beams was decreased to 2.5 times by increasing the area of steel by 50%. All reinforced baked clay beams failed completely within nine blows of drop weight hammer, irrespective of area of reinforcement.

Figure 5 shows that during initial part of impact loading of RBC beams of group A and B, the values of deflection are same irrespective of ratio of reinforcement. This is due to same magnitude of compressive strength of both of these groups of beams. The effect of further impact loading was then transferred to reinforcement. This implies that more the area of reinforcement, less the deflection caused by impact loading.

4. Conclusions

In this paper, effect of reinforcement on deflection and cracking behaviour of reinforced baked clay beams, subjected to drop weight impact load, was investigated. Following conclusions were drawn:

1) Deflection was decreased to three times when the area of steel was increased to 50% in RBC beams.

2) Crack width of the RBC beams was decreased to about 2.5 times by increasing 50% of area of reinforcement.

3) Irrespective of area of steel, failure of all the RBC beams occurred within nine blows of hammer.

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