BAKED CLAY AS REPLACEMENT OF REINFORCED CONCRETE

Abdul Aziz Ansari 1, Mahmood Memon 2
1 Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering Science & Technology, [QUEST], Nawabshah, (Sindh), Pakistan. E.mail: bdizz_ansari@yahoo.com
2 Professor & Dean QEC, Quaid-e-Awam University of Engineering Science & Technology, [QUEST], Nawabshah, (Sindh), Pakistan. E.mail: dccquest@yahoo.com

ABSTRACT
Previously tests were conducted on beam panels with tensile reinforcement only, by applying both point load at the centre and Uniformly Distributed Load, with roller and plate supports. But here behaviour of baked clay beams with both top and bottom reinforcement as well as vertical steel bars as shear reinforcement have been included. The results show that improvement of strength is considerable and there is sufficient evidence that this material could successfully be used as a replacement of reinforced concrete with relatively lower cost without sacrificing the strength, durability and aesthetics. It appears that the top steel placed in the compression zone worked well by improving the performance of the baked clay beams but the vertical steel used as shear reinforcement needs to be rearranged so that it could play its role more effectively for enhancement of load carrying capacity leading to the behaviour which is to be expected when such reinforcement is present. Infact vertical cracks appeared only in those beams which contained shear reinforcement; exactly at the locations where vertical bars were embedded.

KEYWORDS

INTRODUCTION
Clay has been used as chief material of construction since the times immemorial. Often straw or grass were mixed with clay by hand to make it more suitable for construction. Even today 30 percent of the world population lives in a home of unbaked earth. Now a days stabilization techniques are being employed to improve the performance of clay as structural material using mechanical, physical and chemical processes (Houben et al 1994). Clay is a beautiful binder till such time that the water does not interferre.
Now-a-days clay is being industrially processed for various purposes. Polymer clay has been in use as man-made modeling material just like ceramics (Garic 1996). It may be mentioned here that the first Latin-American Clay conference (LACC) was held in Funchal, Madeira, in the year 2000 (Klaus and Gerhard 1996).
Latest technology is being employed to prepare solid mass earth blocks known as EarthZyme means earth enzymes. A new material of construction called Grancrete is being developed by scientists at Argonne and Casa Grande, which may lead to affordable housing for the world’s poorest (Grande and Paul 1996).
Ceramic houses are also being built in USA. Since 1975 Nader Khalili a resident of California has remained continuously involved in the Geltaftan Earth-and Fire System known as Ceramic House, and of the Super block construction system. He is a U.N. (UNIDO) consultant for Earth Architecture (Khalili 1987). The latest term coined is papercrete. This is being claimed to be an innovative material of construction for low-cost housing (Kennedy 2002)
Based on the literature review it was revealed that although a lot of work has been done on various aspects for the use of clay as major material of construction and different forms of industrially processed clay have been brought to the market, no attempt has yet been made to mould the panels of different structural components, which could be baked, post-reinforced and then directly used as pre-cast panels for rapid erection of buildings at relatively lower cost than concrete with all the qualities which are required by any Standards of Codal and other manifestation. The detail of experimental studies conducted by the authors before this work is presented in reference (Memon et al 1999).
DETAILS OF EXPERIMENTAL STUDY

This paper presents the details of phase-III of experimental study where the behaviour of baked clay beams with top steel and vertical steel is checked. These beams were cast with holes at appropriate locations for placement of steel both horizontal and vertical. A compressive force of 4.75 N/mm² (690 psi) was applied for compaction. The water content was maintained at 18 to 20 percent. After drying the beams were baked initially for a period of 6 hours at 250 °C and then the temperature was raised to 950 °C for a total period of 22 hours. Two beams were reinforced with horizontal steel only while another two beams were reinforced with horizontal as well as vertical steel. The bond between steel and surrounding baked clay material was created by forced grouting using cement and sand slurry in equal proportions. The beams were roller supported and finally tested by applying Uniformly Distributed Load gradually in small increments. The behaviour of beams was studied in terms of load-displacement history, strain at various stages of loading, crack pattern, ultimate load and mode of failure.

RESULTS AND DISCUSSIONS

The experimental results along with the estimated flexural strength calculated by using the recommendations of CP-8110 & ACI-318 are presented in Table 1. For the sake of comparison the values of one singly reinforced rectangular baked clay beam have also been presented in this table.

Table 1: Estimated flexural strength and shear strength, Displacement and level of Strain measured during experimentation of phase-III

<table>
<thead>
<tr>
<th>Code</th>
<th>S#</th>
<th>Description</th>
<th>British steel</th>
<th>Pak steel</th>
<th>Flexural strength (baked clay)</th>
<th>Shear strength (calculated)</th>
<th>Experimental. Load</th>
<th>Exp. Load</th>
<th>Experimental displacement</th>
<th>Exp. shear strength</th>
<th>Cal. shear strength</th>
<th>Av.</th>
<th>Strain at a level of steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BCRRUDE-1</td>
<td>110573</td>
<td>117929</td>
<td>240916</td>
<td>18966</td>
<td>166995**</td>
<td>83497</td>
<td>12.18</td>
<td>12.24</td>
<td>4.40</td>
<td>4.41</td>
<td>0.0028</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BCRRUDE-2</td>
<td>110842</td>
<td>118357</td>
<td>242931</td>
<td>18966</td>
<td>167455</td>
<td>83727</td>
<td>12.31</td>
<td>4.41</td>
<td>0.0026</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BCRRUDTE-1</td>
<td>109475</td>
<td>118275</td>
<td>242896</td>
<td>18966</td>
<td>158255</td>
<td>79127</td>
<td>11.47</td>
<td>11.49</td>
<td>1.03</td>
<td>1.04</td>
<td>0.0027</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>BCRRUDTE-2</td>
<td>112549</td>
<td>118542</td>
<td>243921</td>
<td>18966</td>
<td>158715</td>
<td>79357</td>
<td>11.52</td>
<td>11.49</td>
<td>1.04</td>
<td>1.04</td>
<td>0.0027</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>ACI</td>
<td>100441</td>
<td>106034</td>
<td>236856</td>
<td>21598</td>
<td>126515**</td>
<td>63257</td>
<td>11.11</td>
<td>11.11</td>
<td>2.92</td>
<td>2.92</td>
<td>0.0025</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BCRRUDE</td>
<td>118960</td>
<td>126316</td>
<td>174843</td>
<td>298333</td>
<td>158255</td>
<td>79127</td>
<td>11.47</td>
<td>11.49</td>
<td>0.90</td>
<td>0.91</td>
<td>0.0027</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>ACI</td>
<td>119351</td>
<td>127213</td>
<td>175972</td>
<td>28895*</td>
<td>158715</td>
<td>79357</td>
<td>11.52</td>
<td>11.49</td>
<td>0.91</td>
<td>0.91</td>
<td>0.0027</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ACI</td>
<td>87808</td>
<td>86870</td>
<td>28895*</td>
<td>158715</td>
<td>79357</td>
<td>11.52</td>
<td>11.49</td>
<td>2.10</td>
<td>2.10</td>
<td>0.0025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BCRRUDE: Doubly Reinforced Rectangular Beam, Roller support, subjected to Uniformly Distributed Load with additional Enhanced Compression Force.

BCRRUDTE: Doubly reinforced roller supported rectangular subjected to Uniformly Distributed Load with additional Enhanced Compressive Force.

BCRRUDTVE: Doubly reinforced with vertical bars, roller supported rectangular subjected to Uniformly Distributed Load with additional enhanced compressive Force.

* Assuming that the contribution of vertical bars is zero.

** For comparison of experimental ultimate load of single and doubly reinforced beams.
It must be mentioned here that the shear strength for the beams containing vertical steel as shear reinforcement was calculated both by including its contribution and by ignoring its presence altogether assuming that the contribution of this steel towards the shear strength of the beams is zero. Comparing the experimental ultimate load of singly reinforced beam at column 8 and serial No. 5 with that of doubly reinforced beam at serial No. 1 in the same column, it can be found that there is an improvement of the strength by 32 percent due to presence of flexural steel in compression zone; although the failure was dominated by shear. Thus it can be concluded that substantial improvement of shear strength can be achieved due to presence of steel in compression zone. However, within the same column when ultimate experimental load of those beams which were not only doubly reinforced but contained vertical steel as well (at serial No. 3) is compared with that of singly reinforced beam (serial No. 5), the improvement is only of the order of 25 %, which is even less than those containing no vertical bars by 7 %. Comparing the experimental ultimate load of doubly reinforced beams without shear reinforcement with those containing shear reinforcement, it can be observed that there is a reduction of the strength by 5 %. From this it can be concluded that the vertical steel the way it has been accommodated does not contribute at all towards the strength, rather its presence causes some what reduction which might be equivalent to the effective area of the baked clay that has been replaced by the steel. Therefore, a certain alternative scheme shall have to be adopted for strengthening the structural components for shear.

From 13th column of table 1, it is apparent that for doubly reinforced beams, the average ratio of experimental shear strength divided by calculated shear strength (CP-8110) is 4.41 as compared with 2.92 for singly reinforced beam at serial No. 5. Similarly this ratio for the values calculated by using the recommendations of ACI-318, is 2.81. From this it can be concluded that there is sufficient margin of safety against shear failure for baked clay even though the strength is estimated by using codal recommendations originally proposed for concrete. However, the situation is altogether different when presence of vertical steel is taken into consideration. Here this ratio is 4.18 and 2.69 respectively (CP-8110 & ACI-318) for the beams containing vertical steel if its contribution is assumed to be zero. However, if its presence is taken into consideration, the ratio is reduced to 1.05 and 0.9 respectively. It can therefore be concluded that presence of vertical steel as shown in figure is fruitless.

From the photographs presented in Figure 1 & 2, it is obvious that flexural cracks occurred at all those points where vertical steel was embedded. However, final failure in both the cases was controlled by diagonal cracks near the supports showing that the failure was governed by shear.

Fig. 1. Photograph showing doubly reinforced baked Clay beam supported on roller after failure.

Fig. 2. Photograph showing doubly reinforced baked clay beam with vertical bars supported on roller after failure.
All the strain is measured in micro-strain. Here it is quite obvious that the strain in concrete in compression zone did not reach its ultimate value. The level of strain as high as 3220 has been reached in tensile zone. As per the recommendations of ACI-318, the yielding is assumed to have occurred if the strain in steel exceeds 0.00207. Assuming that the strain in baked clay at the level of steel reflects the level of tensile strain in flexural steel, it is inferred that yielding might have been initiated.

CONCLUSIONS

01. The mode of failure of all the baked clay beams of phase-III of experimental study was shear.
02. Presence of longitudinal steel in compression zone proved to be beneficial, causing an improvement of 32 % of ultimate strength when compared with that of singly reinforced beams.
03. Vertical steel provided as shear reinforcement proved ineffective.
04. Generally the ultimate strength was up to 4.41 times higher than that estimated by using the recommendation of CP-8110 for doubly reinforced beams containing no vertical steel. However, this is 2.81 times higher if the strength is estimated by following the recommendations of ACI-318.

ACKNOWLEDGMENTS

The research work, the details of which are presented in this paper was carried out in the Structure’s Laboratory of Civil Engineering Department, Quaid-e-Awam University of Engineering, Science & Technology, [QUEST], Nawabshah, Sindh, Pakistan.

REFERENCES