Mechanical Systems Developed for Reinforced Baked Clay Structural Panels

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ABSTRACT Through systematic literature review it became apparent that no attempt has ever been made to cast, baked, post-reinforced structural clay panels which could replace reinforced cement concrete. Therefore, to start with beam panels have been molded, dried, baked, post-reinforced through grouting, properly cured and tested to check their suitability as pre-cast structural panels. A large number of pieces of devices, equipments and machinery were required for this particular purpose but majority of items were not available in the market as Standard equipments which could be purchased. Therefore, all such items were conceived, devised, designed and fabricated according to specific needs of various operations. When they were put at use they showed satisfactory performance. The complete details of all such items are presented in this paper.

Key words: Baked Clay, Beam panels, Steel mould, Compaction system, Platform Lift, Grouting system, Mobile Lift.

INTRODUCTION

Reinforced cement concrete found wide acceptability all over the world during past more than hundred years as major material of construction. But due to escalation of cost of steel and cement and particularly the transportation charges for bringing these materials of construction to the sites in the distant areas where the soil is alluvial / clayey / fertile in nature (in the plains), it could be more beneficial and economical to produce baked clay panels of structural members for swift and economical construction without sacrificing the strength and durability of the buildings. With this particular intention in mind, a systematic programme of experimental study visualizing the future construction in the rural areas at relatively cheap and affordable prices for the poor masses, a large number of beam panels were cast, baked, post reinforced, cured and tested [1-8].

One of the major challenges to the socio-economic development of third-world countries resides in the utilization of the local natural resources by using both the empirical data of ancestral practices and the modern exploration technologies for control and scientific elaboration of those materials [9].
Clay is a very common, abundant and inexpensive material. It is easy to extract and does not require significant transformation. Clay is also a capricious material with very variable physical properties. Clay shrinks during drying and firing. This creates many problems. Certain clays shrink more than others. The finished products of clay crack during cooling [10].

Clay is cohesive material and this property improves if clay is micro-fined and properly kneaded after mixing the water. Wet clay having a sufficient quantity of water acts like a lubricant but with only a little quantity of water, it acts like a plastic body. It has no elastic limit and could be worked to any shape with little pressure without rupturing. Clay possesses the property of a binding agent [11].

A systematic review of a large number of journals pertaining to the field of Civil Engineering including those of ACI, ASCE and British Institute of Civil Engineering was carried out but as expected, there is no mention of any research conducted up to this time for studying the behaviour of the pre-fabricated, post-reinforced baked clay structural panels which would be used as replacement for pre-cast concrete panels for erection of buildings at relatively lower cost without sacrificing durability, reliability and elegance [12].

Economy of construction can be achieved.

(i) By using very cheap local materials i.e. clay and pit-sand.
(ii) Mechanized mass scale production of the panels of structural members with relatively lower cost of production under very controlled conditions emulating those of laboratory.
(iii) Saving in terms of cost of transportation of heavy materials over long distances.
(iv) Minimization of expenditure for finishings like plastering and painting.
(v) Quick and speedy erection of building by making use of pre-cast panels.

Since the use of reinforced baked clay panels was a new idea, it was not possible to find standard equipments and machinery in the market. Therefore all such items had to be devised / designed and fabricated according to the specific needs of the project. Complete details are given below.

**EQUIPMENT AND MACHINERY DEVELOPED.**

*Stiff Steel Mould*

For casting the models of beam panels, stiff steel moulds were fabricated. The design of these moulds was accomplished on the basis of elastic analysis performed by using computer based numerical approach of Finite Element. The photograph and dimensioned sketch of the mould is presented in figure 1(a) & 1(b). The major force for which these moulds were to be designed was the lateral outward force induced by vertical compression applied for compaction. The thickness of base and wall plates was 12.7 mm (1/2 inch). The Finite Element analysis predicted bulging of the mould to the extent of about one inch. Therefore stiffners were also welded, so that bulging may not occur. One inch diameter holes were drilled in the end plates, two at top and two at the bottom for placing steel shafts which were removed after casting the beam models so that these
holes could later be used to accommodate longitudinal flexural steel. The mould showed no bulging at design compaction load of 3.5 N/mm² (480 psi).

![Image 1(a): STRENGTHENING OF THE MOULD TO REDUCE THE LATERAL BULGING.](image1a)

![Image 1(b): SKETCH OF THE MOULD.](image1b)

**Restraining System of Mould.**

During the experimental study it was deemed imperative to increase the compacting force to increase the density and the strength of the baked clay panels comparable with that of concrete. Therefore, special restraining system was manufactured as shown in figure 2. This is the best and most efficient system from amongst those tried by the author.

**Compaction system.**

Initially the system of applying compression for compaction consisted of the bolts which were tightened with spanner. However, this proved to be very inefficient and time consuming system. Therefore, the system shown in figure 3 was adopted. This consists of 50 mm (2 inch) diameter bars threaded at top fitted with clamping system both at top and bottom. The compression was applied by tightening the wing nuts and the intensity of the force was measured with the help of load cells together with digital display system. The load was in DVM units which was converted into Newtons through calibration.

**Puller System**

Special puller system was manufactured to pullout the steel shafts from the mould after casting the beams, so that the holes in the beams could be provided. Quite considerable force is required to pullout the shafts. The puller consisted of a tapering skeletal steel frame and a vertical steel channel to accommodate chain cuppie set up of ¼ tons. A 100mm (4 inch) diameter steel pulley is provided at the toe of the channel to facilitate the movement of chain for pulling out the shafts from the mould. The photograph and dimensioned sketch of this system is shown in figure 4 (a) & 4(b).
Beam Drying System

Shrinkage and resulting cracking of beams was one of the biggest problems faced during drying of the beams. Therefore in the first instance a 76 mm (3 inch) thick timber plank was placed in the bottom of the mould, on which stain-less steel sheet was stuck. The steel sheet was very smooth and well oiled. However, drying in the open air still caused hair cracks. Therefore, the models were wrapped with polythene sheets to reduce the rate of evaporation. This helped a lot to overcome the problem of cracking. Later on another system consisting of two springs was designed and tried three days after casting the model. This helped to accelerate the rate of drying by removing the wrapper without any cracking and allowing smooth shrinkage. The photograph and dimensioned sketch of these arrangements are presented in Figures 5 (a) & 5(b).
Trolley

After casting the clay model when it is to be removed from the mould the clay is almost in plastic state. Therefore it is to be handled very carefully. Again after drying in its unbaked form, it is very fragile and must be moved to the kiln very carefully. For all these movements special trolley was designed and manufactured. The photograph and dimensioned sketch of this trolley is shown in Figure 6 (a) & 6(b).

Platform Lift

Where as trolley is used to sh ift the clay beams from place to place horizontally on the ground, they must be raised sufficiently high so that they could be placed in the kiln through a rectangular hole provided for this purpose. Therefore, an assembly/arrangement was required for this vertical movement of clay beams. Therefore, along the side of the kiln at appropriate location platform lift was installed. Complete details in terms of dimensions and other specifications are presented in figure 7 (a) & 7(b). Apart from the steel frame and steel platform, the major components of this lift are as under:

Grouting System

Grouting system was also conceived, designed and manufactured as shown in figure 8. Here one steel stand was fabricated along with a chain cuppie system with an arrangement to raise one end of the beam so that it is in inclined position resting on supporting wooden frame. Separately the grouting system with a long lever arm forced the cement slurry from steel cylinder through a pipe into the holes of the beams where steel bars had already been inserted. Beneath the cylinder an electric motor was fitted for continuous stirring of the slurry so that the cement particles would remain in suspension rather than settling and setting.
Mobile Lift

Based on the requirement of the research project for the movement of heavy baked clay beams which are so fragile and can not be safely shifted from place to place manually even by a large number of workers, mobile lift was manufactured. This proved to be very useful, specially for moving the beam over relatively a long distance from the place where they were made and the testing machine placed in a separate laboratory. The photograph and dimensioned sketch of this lift is presented in figure 9(a) and 9(b). It consist of a frame manufactured from hollow rectangular steel sections welded together. The design of each component of the frame was performed according to the stresses which were likely to be induced in that particular
component. The lifting system consisted of two rectangular steel clamps suspended with steel rope passing over the pulley of the mechanical system that was operated by electric motor.

Fig. 8: THE DETAILS OF MECHANIZED

End Fixity Attachment

The original Torsee’s Testing Machine consists of a very stiff steel platform with roller supports but no arrangement for fixing the ends of the beam emulating those which are built in an structural frame on both the sides. Therefore an attachment was fabricated by using 19 mm (0.75 inch) thick plates, which are tightly bolted in the platform of the machine. The bolts were one inch thick which passed through the existing holes. Photograph and dimensioned sketch, with complete details of all the parts are given in figure 10(a) and 10(b). This consists of side plates 19 mm (¾ inch) of the dimensions 305mm x 457mm (12” x 18”). This plate is firmly bolted with the stiff steel platform of the Torsee Machine where the bolts passed through the existing holes. Inner plates “B” served dual purpose of raising the level of beams and supporting the base plate “C” which is welded with plate “B” and the beam directly rest on plate “C”. Two more vertical plates “D” are resting on the plate “C” and upon them rests plates “E” with four holes through which threaded rods pass and the fixity is created by tightening the nuts in these rods, because the beam end is in between plates “D”.

CONCLUSIONS

1. All the equipment and machinery developed/manufactured for the particular project of “Pre-perforated Post-reinforced baked clay beam panels”, performed their functions quite well and infact beyond the expectation.
2. According to market survey and estimation the cost of fabrication was only about 20% of the cost if they were available in the market and were to be purchased.
3. Fabrication of the mechanical systems developed led to the successful progress of the project of baked clay with encouraging results in terms of structural behaviour of these pre-cast panels comparable with that of concrete.
Fig. 9(a): ATTACHMENTS FOR END FIXITY OF THE BEAMS.

Fig. 9(b): ATTACHMENTS FOR END FIXITY OF THE BEAMS.

Fig. 10(a): VIEWS OF MOBILE LIFT DEVISED, DESIGNED, MANUFACTURED FOR BAKED

Fig. 10(b): THE SKETCH OF MOBILE LIFT MANUFACTURED TO LIFT THE CLAY BEAMS FROM HERE TO THERE.

ACKNOWLEDGEMENT

The research work, details of which are presented in this paper was carried out in the Structures Laboratory of Civil Engineering Department, Quaid-e-Awam University of Engineering Science & technology, [QUEST], Nawabshah, sindh, Pakistan. The authors are thankful to the University authorities for providing facilities and funds to make this undertaking possible.

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