Effect of Firing on Cracking and Warping of Clay Beams

NAWAB ALI LAKHO*, MUHAMMAD AUCHAR ZARDARI*, AND NAEEM AZIZ MEMON*

RECEIVED ON 28.05.2015 ACCEPTED ON 16.09.2015

ABSTRACT

Reinforced baked clay beams may be considered to be a substitute of reinforced cement concrete beams in order to build low cost houses. The baking of these clay beams can pose problems such as cracking and warping. This paper presents the effect of different treatments applied to clay beams during baking to reduce cracking and warping. These clay beams were baked in pottery kiln in which the temperature could not be raised to the extent of fusing of clay beams placed at bottom of firing chamber. As expected, the beams were not baked properly and a number of them got cracked. Then these beams were baked in a commercial Hoffman's kiln. The beams, in preheating stage, were moistened to full depth due to humidity and moisture of flue gases. As a result, the beams cracked and warped at the time of firing. In order to avoid the beams from being moistened by the moisture of the flue gases, different treatments were opted. Firstly, these beams were covered with plastic sheet, the cracks were reduced to some extent. Secondly, double layer of mud, with a layer of gunny bags between them, was applied. Consequently, a few cracks occurred in the beams. The treatments suggested in this paper can be used for baking of clay beams in Hoffman's kiln at commercial level.

Key Words: Baked Clay, Firing Temperature, Cracking, Warping, Flue Gases.

1. INTRODUCTION

Clay is basic constituent of low cost materials of building construction [1-8]. Sun-dried clay bricks have been used as walling material for centuries in Mesopotamia, Indus valley and in other parts of the world [9-12]. Clay, when stabilized and properly compacted in small units called Stabilized CEB (Compressed Earth Blocks), is successfully used as low cost and environment friendly material of construction [13-18]. When clay bricks and these compressed earth blocks are baked, their cube crushing strength is directly related to the degree of compaction and firing temperature [19-20]. In order to use baked clay as replacement of concrete in flexural members, clay beams were cast, compacted and baked in a kiln. This type of kiln is generally used for baking of pottery. In case of the pottery, the whole firing chamber of the kiln is filled with the unbaked clay vessels before firing. During baking, the temperature is higher in the upper portion of the chamber, this temperature can bake the vessels properly. The clay beams were baked in a batch of four beams and

* Assistant Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah.
** Associate Professor, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro.

were placed at the bottom of firing chamber of this kiln during baking. Since the temperature at the bottom of the kiln is comparatively low and could not bake the beams properly. Thus to bake these beams properly, another type of kiln was needed. A commercial Hoffman's kiln [21] was selected for this purpose. In Hoffman's kiln, flue gasses which include much moisture and humidity are used for pre-heating of the bricks before actual stage of firing. These flue gases and hot moisture can moist these clay beams before actual firing and can cause the beams to crack and break into pieces during firing [21]. Hence, proper treatments were to be deciphered practically to save these sun-dried clay beams from being highly moistened and make it possible to bake them without cracking, braking or warping.

2. MATERIALS AND METHOD

2.1 Beam Specimen

Indigenous clay, in the vicinity of Nawabshah (Pakistan), after being excavated at a depth of more than 1200 mm, was properly dried and pulverized. Pit-sand in a ratio of 30% was added in pulverized clay. This mixture, in addition of 20% of water, was mixed in a pan mixer for more than 15 minutes. Beams having size of 150x300x2000 mm were cast in a mechanized casting and compacting system. These beams were compacted at the intensity of 6 MPa during casting. These beams were then dried in a shade, being covered in a plastic sheet, in order to decrease the possibility of cracking due to unequal rate of evaporation. Then these clay beams were baked in a kiln constructed in the laboratory. The beams were also baked in a local Hoffman's kiln in order to see the possibility of proper baking of such size of clay beams commercially.

3. RESULTS AND DISCUSSION

3.1 Cracking and Warping of Clay Beams when Baked at Two Different Types of Kilns

When clay- pit sand beams were baked in the kiln present in the laboratory, about 25% of the beams got cracked as shown in Fig. 1. And a large quantity of wood was needed to bake these beams in the kiln. It was possible to bake only four beams at a time, and therefore, this process of baking of clay beams was time consuming. This type of kiln is used to fire pottery traditionally and a very intensive care is needed to control the interior temperature of the kiln. In this condition, if the pre-heating of the beam is not properly completed and due to small interior size of the kiln, it is difficult to control the temperature and with the shoot up of temperature in its initial stage of baking, the moisture present in the beam can be converted abruptly into the steam and can explode and crack the beam as shown in Fig 1.In order to decrease the possibility of cracking of clay beams during process of baking and to bake these beams economically it was thought to bake these beams in commercial Hoffman's Kiln called Batha. A batch of twenty, properly sun-dried, clay beams were baked in a nearby Batha. When these beams were baked, all the beams warped and cracked with de-shaped surface and broken into a number of parts as shown in Fig. 2.

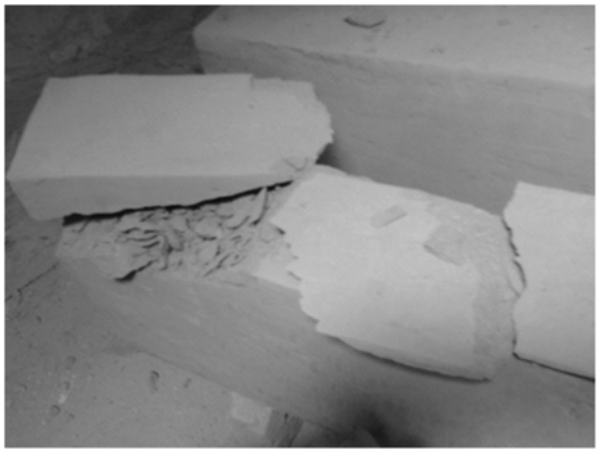

FIG. 1. CRACKING OF CLAY BEAMS DURING FIRING IN THE LABORATORY KILN

This cracking of these beams was supposed to be due to the hot moisture evaporated from the body of semi-dried clay bricks during pre-heating. The hot and very humid flue gases are locally called 'draf', which moistened the clay beams and bricks to their full depth.

The fact that the bricks do not crack or break into pieces when they are baked in this kiln, because the size and mass of bricks is very small as compared to the beams. The draf must have moistened the bricks and the beams to their full depth measured from their surface during the process of pre-heating of two days. The minimum thickness of the commercial brick is three inches (76mm), whereas the minimum thickness of clay beam is six inches (152mm).

The zone of pre-heating varies from 45-60 min length. There is high temperature and low humidity in the first 15m, measured from firing zone, as compared to remaining 30-45m of pre-heating zone. Firing zone is of 0.6 m length where fuel is being added and combustion is continued for three hours. At this speed of fire the bricks get dry, but the beams do not get dry to their full depth. The moisture, which still remains in the depth of beam, causes cracking and breaking of beams on further heating. An idea was conceived to save these sun-dried clay beams from the moistening effect of the so called draf. Another batch of twenty beams was covered with plastic sheet (Fig. 3) and baked in the same kiln. These beams showed encouraging results. The beams did not break into parts and only small number of cracks occurred after baking as shown in Fig. 4.

FIG. 2. THE BEAMS BAKED IN THE COMMERCIAL KILN WITHOUT APPLYING ANY TREATMENT

The beams which were covered with plastic sheet were safe from the effect of being moistened by the draf until and unless the plastic sheet on the beams was intact. With the abrupt increase in firing temperature, the plastic sheet completely burnt and allowed the draf to moisten the clay beam to a small extent. As the temperature increased and caused these plastic sheets to burn, these beams were moistened to small depth by the low moisture of draf. A second solution was conceived to apply a double layer of mud with a fabric sheet of gunny bags between them. For this purpose, first of all, the dried clay beams were properly covered with plastic sheet and then jute rope was wounded around the beams covered with plastic sheets as shown in Fig. 5. Then a uniform layer of mixture of mud and chaff was applied to the beams and jute rope was wound again on the singly mud plastered clay beams (Fig. 6). After drying of this layer of mud, these beams were wrapped properly with gunny bags as shown in Fig.

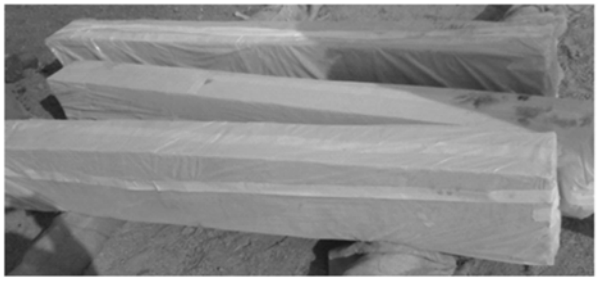

FIG. 3. BEAMS COVERED WITH PLASTIC SHEET BEFORE BAKING

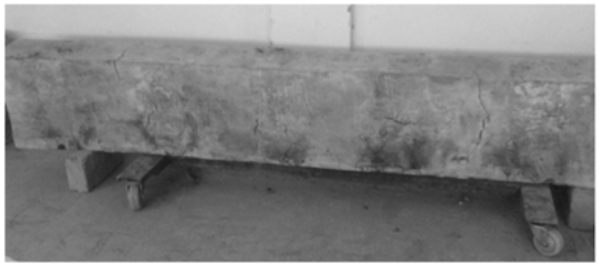

FIG. 4. CLAY BEAMS BAKED WITH THE TREATMENT OF PLASTIC SHEET COVER BEFORE BAKING

7. Jute rope was again wound on these beams and the second layer of mixture of mud and chaff was applied to these beams (Fig. 8). The beams were allowed to dry in shade. Then a batch of 22 beams was baked with these treatments in same Batha. All the beams were baked satisfactorily (Fig. 9) with a few cracks of small size in some of the beams (Fig. 10). And about 5% of the beams got slightly warped as shown in Fig. 11.

3.2 Reduction of Fragility of Baked Clay Beams

Baked clay beams are generally very fragile during handling and testing. In order to decrease fragility and brittleness of baked clay beams, a preliminary study was conducted in which the beams were partially pre-stressed and very encouraging results were obtained. In this regard, further detailed investigation is required to determine optimum percentage of pre-stressing in order to reduce fragility of the baked clay beams.

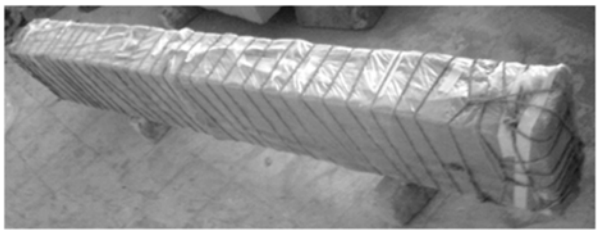

FIG. 5 THE CLAY BEAM BEING WOUND BY JUTE ROPE AFTER COVERING WITH PLASTIC SHEET

FIG. 6. A LAYER OF MUD AND CHAFF APPLIED TO CLAY BEAM

FIG. 7. BEAMS COVERED WITH GUNNY BAGS

FIG. 8. BEAMS COVERED WITH SECOND LAYER OF MUD AND CHAFF

FIG. 9. BEAMS WARPED DURING THE PROCESS OF COMMERCIAL BAKING

FIG. 10. CLAY BEAM WITH A FEW CRACKS AFTER BAKING IN COMMERCIAL BATHA

FIG. 11. CLAY BEAMS WARPED DURING BAKING IN COMMERCIAL BATHA

4. CONCLUSIONS

The conclusions obtained from the experimental study of the clay beams baked with different treatments in two types of kilns are:

(i) Clay beams could not be baked to the point of fusing in pottery kiln, when placed at the bottom of firing chamber.

(ii) These beams could be baked in Hoffman's kiln up to the stage of fusing.

(iii) These beams when baked in Hoffman's kiln got cracked, warped and split into parts.

(iv) When these beams were covered with a plastic sheet during baking in Hoffman's kiln, the problem of cracking and warping was reduced.

(v) The cracking and warping was curtailed to higher degree when these beams were covered with double layer of mud with a layer of gunny bag between them.

ACKNOWLEDGEMENTS

The authors would like to thank Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah, and Mehran University of Engineering & Technology, Jamshoro, Pakistan, for their support to conduct this research study.

REFERENCES

[1] Staubach, S., "Clay: The History and Evolution of Humankind's Relationship with Earth's Most Primal Element", University Press, New England, 2013.

[2] Keefe, L., "Earth Building: Methods and Materials, Repair and Conservation", Routledge, 2012.

[3] Pacheco-Torgal, F., and Jalali, S., "Earth Construction: Lessons from the Past for Future Eco-Efficient Construction", Construction and Building Materials, Volume 29, pp. 512-519, 2012.

[4] Oti, J.E., and Kinuthia, J.M., "Stabilized Unfired Clay Bricks for Environmental and Sustainable Use", Applied Clay Science, Volume 58, pp. 52-59, 2012.

[5] Zhang, L., "Production of Bricks from Waste Materials: A Review", Construction and Building Materials, Volume 47, pp. 643-655, 2013.

[6] Miqueleiz, L., Ramírez, F., Seco, A., Nidzam, R.M., Kinuthia, J.M., Tair, A.A., and Garcia, R., "The Use of Stabilised Spanish Clay Soil for Sustainable Construction Materials", Engineering Geology, Volume 133, pp. 9-15, 2012.

[7] Velasco, P.M., Ortíz, M.M., Giró, M.M., and Velasco, L.M., "Fired Clay Bricks Manufactured by Adding Wastes as Sustainable Construction Material: A Review", Construction and Building Materials, Volume 63, pp. 97-107, 2014.

[8] Parashar, A.K., and Parashar, R., "Comparative Study of Compressive Strength of Bricks Made with Various Materials to Clay Bricks", International Journal of Scientific and Research publications, Volume 2, No. 7, pp. 1-4, 2012.

[9] Woods, M., and Woods, M.B., "Ancient Construction Technology: From Pyramids to Fortresses", Twenty-First Century Books, 2011.

[10] Shaikh, J.M., "The Evidence Based Design of Sun Dried Adobe Brick", Civil Engineering and Architecture, Volume 2, No. 6, pp. 245-250, 2014.

[11] Ahmed, M., "Ancient Pakistan- An Archaeological History: Volume III, Harappan Civilization-the Material Culture", Create Space Independent Publishing Platform, 2014.

[12] Bhattacharya, B., "Urban Development in India: Since Pre-Historic Time", Concept Publishing Company, 2006.

[13] Yu, H., Zheng, L., Yang, J., and Yang, L., "Stabilized Compressed Earth Bricks Made with Coastal Solonchak", Construction and Building Materials, Volume 77, pp. 409-418, 2015.

[14] Deboucha, S., and Hashim, R., "A Review on Bricks and Stabilized Compressed Earth Blocks", Scientific Research and Essays, Volume 6, No. 3, pp. 499-506, 2011.

[15] Kabiraj, K., and Mandal, U.K., "Experimental Investigation and Feasibility Study on Stabilized Compacted Earth Block Using Local Resources", International Journal of Civil and Structural Engineering, Volume 2, No. 3, pp. 829, 2012.

[16] Danso, H., Martinson, B., Ali, M., and Mant, C., "Performance Characteristics of Enhanced Soil Blocks: A Quantitative Review", Building Research and Information, Volume 43, No. 2, pp. 253-262, 2015.

[17] Danso, H., "Building Houses with Locally Available Materials in Ghana: Benefits and Problems", International Journal of Science and Technology, Volume 2, No. 2, pp. 225-231, 2013.

[18] Nasly, M.A., Azam, A., Yassin, M., Zahrizan, Z., and Khairunisa, M., "Compressed Stabilized Earth as Load Bearing Interlocking Block", International Journal of Civil Engineering and Geo-Environmental, Volume 1, No. 1, pp. 1-9, 2010.

[19] Salleh, I., "Study on Properties of Clay Brick and CB Brick Under Different Heating Rates", Bachelor of Civil Engineering Thesis, Universiti Tun Hussein Onn Malaysia, 2012.

[20] Maskell, D., Heath, A., and Walker, P., "Geopolymer Stabilization of Unfired Earth Masonry Units", Key Engineering Materials, Volume 600, pp.175-185, 2014.

[21] Lyons, A., "Materials for Architects and Builders", Routledge Publishers, 2014.