HOUSING FOR POVERTY STRICKEN MASSES

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ABSTRACT

Systematic research has been carried out over past several years to check the suitability of baked clay as chief material of construction as replacement of Reinforced concrete, for low-cost housing without sacrificing elegance, strength and durability of multistory buildings. Initially soil was dug from 25 sites at a depth of 4 ft. and its physical properties were determined. The presence of various salts and their proportion were also found. From test results it was observed that the salts did not affect the structural properties of baked clay specimens. A very large number of cubes were cast with clay as major material and percentage of pit-sand (silica) as major parameter. The results of preliminary study in terms of shrinkage, specific gravity, crushing strength, tensile strength, poison's ratio, and modulus of elasticity of baked clay specimen and the best possible combination of clay and pit-sand were obtained. The material was then compacted by applying compression and cube crushing strength as high as 27.61 N/mm^2 (3950 psi) was achieved. Fifty two beams with 70% clay and 30% pit-sand, 20 percent water and 4.5 N/mm^2 compacting force were cast, dried, baked, post-reinforced, grouted with cement and hill-sand slurry with the ratio of 1:1 for proper bond between steel bars and surrounding baked clay were tested with point load, UDL and various boundary conditions including roller support, plate support and complete end-fixity. 35 beams were singly reinforced and 8 contained compression steel as well, while 8 contained special types of vertical reinforcement to resist shear. All the beams failed in shear. Cubes were cut from the body of the beams after testing and structural properties were determined. The crushing strength as high as 42 N/mm^2 (6100 psi) has been achieved. The results are encouraging and further research is being carried out.

Keywords: Low-cast housing, Preliminary study, Specific gravity, Shrinkage, Modulus of Elasticity

1. INTRODUCTION

The modern tendency is towards the use f reinforced cement concrete for the construction of

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multistory buildings consisting of structural frames and slabs. The cost of construction and the time of completion are drastically reduced, if instead of casting the structural members' insitu, factory made pre-cast panels are transported and used for the erection of buildings. It is more beneficial if the buildings are to be constructed on mass scale and the variation of sizes is kept to a minimum.

The plains of our country where the soil is alluvial and there is dearth of fine as well as coarse aggregate, almost every single item i.e. cement, steel bars, fine & coarse aggregate are to be transported from very long distances. Being very heavy materials substantial amounts are to be paid as their cost of transportation

Thus it is beyond the reach of a common man to opt for RCC construction. The universally available materials of construction in the plain areas are clay and pit sand. At present burnt clay bricks are being used for masonry construction and for lintels to span over small openings like those of doors and windows.

If instead of bricks we can produce baked clay panels of beams, columns, slabs and footing etc. which are preperforated so that the reinforcement bars could later be placed and grouted with proper bond and if we can attain the strength properties resembling to those of cement concrete and if a reasonably good margin of reduction of prices could be achieved, then the dream of low-cost housing in its real sense could come true.

Before I start, let me clarify that I have remained engaged in research since last more than twenty years. One of the aspects that are presenting here is a new technology which pertains about bringing the well-known material i.e. clay for construction of houses resembling to those as RCC. Several options are available but the modern tendency is towards the construction of the houses which are sufficiently strong, durable and elegance. I have been working (Ansari & Memon 1999; Ansari 2006; Ansari 2007; Ansari 2008; Ansari 2009; Ansari et-al 2011; Ansari 2011; Ansari & Lakho 2013;) and I am very much satisfied that clay is not inferior material but only because it did not receive proper attention that is why we are still back-a-head.

Clay is a fine-grained, natural firm earthy material that is plastic when wet at appropriate water content, hardens when dry and gains strength like a permanent solid when heated intensively, consisting of hydrated silicates of aluminum (Hendrik N, 1997).

Natural, non-toxic, healing, easily available, recyclable, low embodied energy, a pleasure to work with, soft & soothing, limitless creative possibilities are some of the properties of clay. Some people may describe it primitive, inferior and dirty. But it is author's candid opinion that with the information provided here in this paper the above mentioned views will change. Depending on the contents of the soil, clay can appear in various colours, from a dull gray to a deep orange-red. The formation of clay from rock is a most common event, taking place daily everywhere in the world. Clay consists of soil particles, the diameters of which are less than 0.005 mm (Greyt. G. 1968).

2. METHODOLOGY

Initially pH value, Electric Conductivity, Exchangeable Sodium and Gypsm, Total salts content in solution (PPM), Moisture Contents, Specific Gravity, Liquid Limit, Plastic Limit, Flow Index, Liquidity Index, Plasticity Index, Consistency Index, Toughness Index, Density of wet and dry soil are to obtain from twenty five different sites is determined. Preliminary studies are performed in terms of shrinkage, specific gravity, compressive strength, tensile strength, Poisson's ratio and modulus of elasticity of baked clay specimens consisting of hundreds of specimens including cubes, cylinders and briquettes. The major parameter is clay and pit-sand ratio.

A large number of baked clay specimens are compacted by applying compacting force of 6 N/mm^2 to improve the structural properties. Substantial equipment and testing arrangements required are also fabricated to like; Stiff steel mould are fabricated for casting the models of beam panels. The design of these moulds is accomplished on the basis of stress analysis performed by using computer software using Finite Element Analysis. The analysis is particularly aimed at finding the lateral deformation of the mould due to applied compression for compaction. Elastic out-ward displacement is determined in order to ensure that bulging of the beam resulting in the expansion of the sections should not occur. Special arrangement for applying the pre-compression manually (so that density could be improved and compaction to the desired degree could be achieved), is designed.

3. PRESENT STUDY

It may be re-iterated here that the total research work has been divided into two series i.e. Preliminary Test Series and Main Test Series. The latter is further sub-divided into five phases. The effective span of all the beams was 1670 mm (65.75 inch). Apart from baked clay beams four concrete beams were also cast, cured and tested for the sake of comparison.

Altogether Fifty two beams were tested out of which fourteen were rectangular and nine were I-shaped. Six beams were cast baked with an increased compaction force to the level of 4.7 N/mm^2 from 3.5 N/mm^2. Two beams were reinforced with horizontal steel only while another two contained vertical steel as well. A number of beams were tested with various boundary condition i.e. roller support, plate support and fixed ends.

Mixing of materials depended upon best proportions of clay and pit-sand. Total water content as percentage in terms of dry material was maintained at about 18 to 20 percent on the basis of the results pertaining to workability and strength to be achieved.

The clay was obtained from various sources at a depth of 1220 mm (4 ft) from the ground level. It was dried at a temperature of 105 ^{O}C for 24 hours. The clay was then pulverized for micro-fining it. Then as per previous research conducted by the author (Memon & Ansari 2003) 30% of pit-sand, was mixed. Mixing of the materials and the water was done with the electrically operated Pan mixer. Mixing was done for approximately 10 minutes for each batch. After delivery of the material in the mould, compressive force was applied and measured with the help of electric load cells and digital display amplifier system. Compression was applied by tightening the wing nuts as shown in Fig 1. Whereas the strength of concrete depends upon the proper mix design for a certain required characteristic strength, the compression force for compaction is the major factor to achieve required strength of baked clay. For concrete water: cement ratio, compaction and curing are the major factors. However, for baked clay water content is the most important factor which should be maintained at the minimum possible level (optimum moisture content) to reduce the void ratio and increase the density with enormous compaction force. Several impediments and hurdles were experienced. For example enormous shrinkage occurred during drying which caused cracking of the beams rendering them useless. The drying under the shade without exposure to sunshine with a thin plastic wrapper solved the problem. Special scheme was resorted by providing a heavy wooden plank fitted with a very smooth surfaced metallic sheet properly oiled to support the beam specimen at the bottom during its drying period; so that shrinkage and consequent deformation (i.e. shortening of the beams) did not cause any cracking. However, a system of slight compression with the help of springs was also devised and used.

It must be mentioned here that the beams cast, dried, baked and tested during this experimental investigation were 150 mm (6 inches) wide 300 mm (12 inches) deep and 1950 mm (6.5 ft.) long initially but were reduced in length by 100 mm (4 inches), breadth decreased by 7.2 mm (0.3 inches) while the depth showed a shrinkage of 14.3 mm (0.6 inches). The thickness of flange of I-section was 50mm and that of web 100mm. The load was applied gradually in small increments of 4.6 kN each. After drying for sufficient time under the shade the beams were exposed to sunshine to exclude as

Fig 1: Compacting system

Fig 2: Beam before baking.

Fig 3: Beam after baking

much moisture as possible which was trapped deep inside them. A few rectangular and I-section beams before baking are shown in Fig. 2. The beams were then placed in the Kiln where the temperature was measured with the help of Thermo-Couples. The temperature and time periods were selected after trying a large number of temperature and duration combinations to achieve the best possible results because the thickness of beams is obviously much more than bricks and therefore the complete baking of the beams could be possible only on the basis of experimental investigation. A few beams after baking but before testing exhibited in Fig. 3.

The beams were pre-perforated near the bottom with two holes of one inch diameter for placement of tensile reinforcement. However, a few beams were reinforced both at top and bottom hence there were two holes near top and two near the bottom in these beams. A few beams contained vertical holes at 6 inch center to center for shear reinforcement. The steel bars of 3/8”, ½” and 5/8 inch diameter were used as longitudinal reinforcement. A puller as shown in Fig. 4 was manufactured to pull out the steel shafts from the beams after their casting. The bond between steel bars and the surrounding baked clay was achieved through forced grouting of cement slurry with fine aggregate in the ratio 1:1 as shown in Fig 5.

After grouting curing was done for 14 days as shown in Fig 6. This created sufficient bond to avoid the problem of slipping of bars up to the ultimate load. The study was carried out in terms of modulus of rupture, shear/flexural behaviour, mode of failure, crack pattern and ultimate load.

Figure 4: Puller system

Fig 5: Grouting system

Figure 6: Curing Tub

Figure 7: Trolley

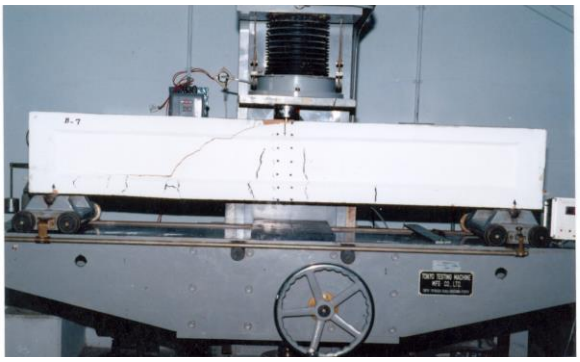
Figure 8: Platform Lift

Figure 9: Mobile Lift

Trolley (Fig 7) was used for shifting the beams from place to place and platform lift used for lifting up of clay beams for placement in the kiln as shown in Fig 8. Mobile Lift was used for carrying the beams to the testing laboratory as shown in Fig 9, for placement of these models on the Machine for testing. Torsee Testing Machine was used to test the beams. Load cells were used together with digital display system to measure intensity of the load independently.

Demec Gauge was used to measure the strain at various locations with reference to the neutral axis. Thirteen pairs of demec pads were stuck on the beam to measure the strain with the help of demec gauge. To test the fundamental structural properties of the beam material itself specimens were cut from the intact portions of beams after testing. The flexural strength of all the beams in terms of steel and baked clay was estimated by using the recommendations of BS CP-8110 (BS-1972) and ACI-318 after removal of partial safety factors. The shear strength was also estimated.

After curing for 14 days the beam was allowed to dry completely for another 14 days. The beams were finally tested by applying Uniformly Distributed Load, gradually in small increments. The strain was measured at the center throughout the depth at thirteen points. After every load increment each beam was checked carefully to detect cracks, if any. The beams were tested by applying load with the help of Torsee Testing Machine as shown in Fig 10 & 11. The displacement at the center of the beam was also noted.



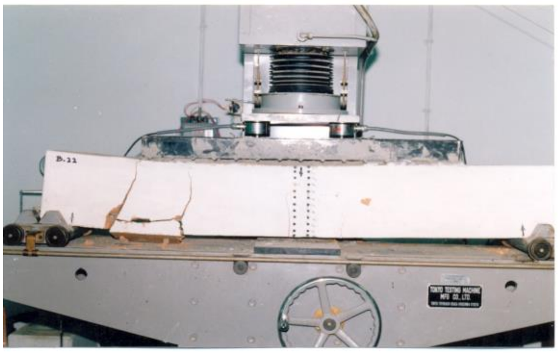


Figure 10 & 11: I-section & Rectangular beam are tested on Torsee Testing Machine

4. PRESENT INVESTIGATIONS

First phase consisted of twenty three beams, out of which fourteen were rectangular and nine were I-shaped. All were reinforced with two bars. The beams were compacted by applying a compression of 3.5 N/mm^2. During first phase the beam panels were fired for a total period of 19 hours. In few cases after testing the beams, it was observed that the inner core of about one inch thickness was not properly baked.

2nd phase consists 6 beams which were cast, baked, post-reinforced, grouted and tested. The major parameter was to increase compressive force i.e. 4.73 N/mm^2 instead 3.5 N/mm^2 and also increase the firing period.

Phase 3rd of Main Test Series was to check the behaviour of baked clay beams with top steel and vertical steel.

Phase 4th is the continuation with the work that has been done regarding suitability of replacement of concrete; more beams have been tested containing double longitudinal reinforcement as well as vertical reinforcement to emulate the real structural actions which occur in the buildings.

Phase 5th is the advanced idea emanated to apply a certain intensity of compression on beam panels so that their shear strength could be improved without inserting the shear reinforcement. Altogether eight beams were tested for this purpose and the results have been compared with previous research results to determine the viability of this particular idea. Although the actual ultimate conditions could not be reached due to immature failure of the end connections anchorage system consisting of nuts and welding on threaded steel bars which were used to reinforce and apply pre-compression to the baked clay. However, from the results it appears that if the anchorage is to be properly designed and strengthened the system would definitely work and positive results could be achieved.

A mix design of concrete grade-20 was prepared and beams were cast. This scheme of testing was particularly aimed at finding the difference between the structural behaviour of concrete and the baked clay. It was particularly a system where we could know whether the baked clay could be used as structural material like concrete and from the results as will be shown, It could be deduced that baked clay if not superior, could match RCC.

5. CONCLUSION

Based on test results the following conclusions have been arrived at:

1. An idea of using the most natural material i.e. clay requires no industrial processing except baking which is an established form of processing clay.
2. Buildings must be erected cheaply but for a sufficiently long life and for generations to use them and the cost must be within the reach of common man.
3. The future of the Off-spring must not be mortgaged for a roof over their heads.
4. The major aim of this research is to make it possible in the plane of Pakistan for every rich and poor to afford a home of his own, which may resist the rigors of climate, environment and catasphrophies and must not cause a hazard to at least the occupants.
5. The human generation shall be best served if clay is used for roof over their heads.
6. It was observed that best results could be achieved when the clay is 70% and Pit sand 30%.
7. Compactive force seems to have drastic effect on the properties like specific gravity and shrinkage of baked clay specimens. Specific gravity as high as 2.35 has been achieved when compacting force (compression) was 6 N/mm^2 for a 70% clay + 30% pit-sand.
8. When cubes and cylinders were cut from the body of the beams themselves after testing the Poisson's ratio was found to be 0.173 as compared with that of concrete which ranges between 0.15 to 0.21.
9. The average value of modulus of elasticity for all tested beams was found to be 33.7 KN/mm^2 as compared with 25 KN/mm^2 for concrete of grade-20.
10. Predominantly all the beams failed in shear and full flexure strength was not achieved.

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