Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 122 (2017) 104–108

Energy Procedia

www.elsevier.com/locate/procedia

CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale, CISBAT 2017 6-8 September 2017, Lausanne, Switzerland

Studies into structural and thermal properties of building envelope materials

K. Gourav[a]*, N. C. Balaji[b], B. V. Venkatarama Reddy[c], Monto Mani[d]

[a,b]*Department of Civil Engineering, The National Institute of Engineering, Mysore - 570008, India*
[c] *Department of Civil Engineering, Indian Institute of Science, Bangalore - 560012, India*
[d] *Centre for Sustainable Technologies, Indian Institute of Science, Bangalore - 560012, India*

Abstract

The structural and thermal properties of masonry units influence the behaviour of masonry. In load bearing masonry, wall elements play a major role in supporting the structure through load transfer mechanism from roof to foundation. Also, wall elements regulate the thermal interaction between the indoor and outdoor environment. A variety of masonry units are available as an alternative to burnt clay brick masonry. Fly ash-Lime-Gypsum (FaL-G) brick is one such alternative, which is a low carbon and energy efficient brick made of industrial waste fly-ash. The current paper investigates the characteristic properties of FaL-G bricks and compares them with the locally available conventional table moulded brick (TMB). The characteristic results reveal that the FaL-G brick performs better as a masonry unit and also for building envelopes in tropical conditions. Based on investigations regarding structural and thermal performance, suitable guidelines can be issued to integrate this material in the building envelope.

Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale

Keywords: Burnt clay brick; FaL-G brick; Masonry unit; Low carbon material; Building envelope.

1. Introduction and scope of the investigation

Studies into the structural and thermal properties of masonry units are fundamental in understanding building envelope performance in buildings. Several separate studies have been carried out with respect to structural and thermal characteristic properties of masonry materials. An attempt has been made in the current study towards understanding both properties together.

*Corresponding author. *Email address:* gouravmys@gmail.com

1876-6102
Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale
10.1016/j.egypro.2017.08.037

The objective of the current project is to study the structural and thermal properties of two masonry units, viz. table moulded bricks and Flyash blocks, and to compare their performance.

Nomenclature

γ	Density
Cp	Specific heat capacity
C	Thermal Mass
k	Thermal conductivity in W/(m K)
FaL-G	Fly ash-Lime-Gypsum brick
TMB	Table moulded brick

2. Methodology

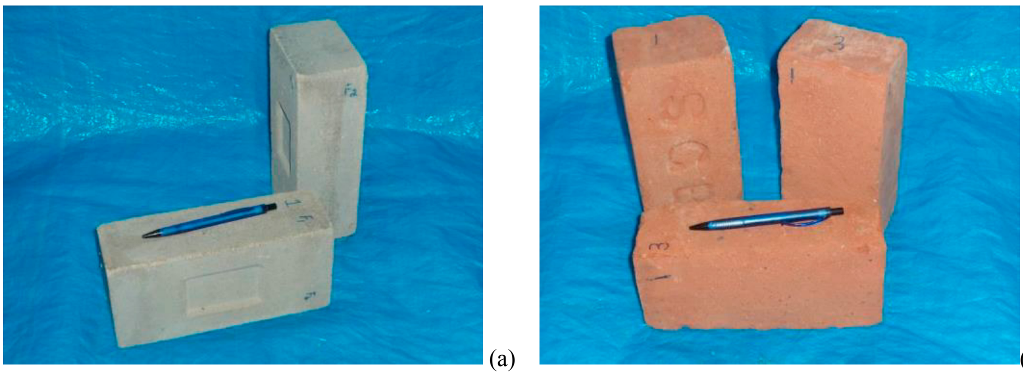
2.1. Selection of materials

The main objective is to study the structural and thermal properties of the masonry units (building envelope materials). This was necessitated by choosing a low and high embodied energy masonry material. Table 1 shows the material selected for the study, as shown in the studies of Balaji et.al. [1].

Table 1. Selection of building envelope materials

Particulars	Designation	Material selection criteria
Table Moulded Brick	TMB	High embodied energy material
Fly ash-Lime-Gypsum Brick	FaL-G	Low embodied energy material

Fly ash bricks are made from a combination of fly ash, sand, lime, and gypsum in proportions and compacted design for the requisite structural performance. Fly ash is a waste product from coal based thermal power plants. India produces about 170 million tons of fly ash with only 67.63 percent of fly ash being utilized [2]. Fly ash is being used in the construction industry for making bricks and other applications. Venkatarama Reddy & Gourav [3] extensively studied the structural and durability characteristics of fly ash bricks.



(a) (b)

Fig. 1. (a) Fly ash bricks (FaL-G) and (b) Table moulded bricks (TMB)

In the current study, compressed stabilized fly ash bricks of size 230 x 100 x 75 mm, with a proportion of fly ash and sand (0.35 fly ash : 0.65 sand, by weight) + 10.5% lime + 2% gypsum (mineral), and with a dry density of 1.65

g/cc were used; Locally available Table moulded burnt clay bricks were used. Fig. 1 (a) and (b) show the Fly-ash (FaL-G) and Table moulded bricks used in the study.

2.2. Testing methods

Masonry units were tested for structural and thermal performance. Structural performance such as compressive strength, water absorption and initial rate of absorption were performed following the procedure outlined in IS 3495 - Part I (1992), IS 3495 - Part II (1992) and ASTM C67 (1994) code respectively [4, 5].

Thermal performance parameters such as specific heat capacity defined as ― "quantity of heat required to provide a unit temperature change to a unit mass of material" [6], were obtained using Differential Scanning Calorimetry (DSC) thermal analysis. A thermal conductivity test was performed using a quick thermal conductivity meter QTM-500 instrument (Fig. 2) from Kyoto Electronics Manufacturing Company Ltd, used for measuring thermal conductivity values of building materials. The QTM-500 Instrument used for measuring the thermal conductivity has a limiting measuring range of 0.023 W/ (m K) to 12 W/ (m K) with a precision and reproducibility of ± 5% and ± 3% on reading values respectively. The minimum sample size required for testing is 100 x 50 x 20 mm thickness [7]. Thermal conductivity of materials was tested at room temperature and at completely saturated conditions using QTM-500. Thermal mass can be defined as the ― "product of the specific heat capacity and density of material"; its SI unit is kJ/K m^2. In actual conditions, the hygroscopic property of a building masonry element also influences its thermal performance [1]. This is however not within the scope of the current study. The interaction between the microstructure and its hygroscopic propagation and storage is complex and difficult to regulate. Further, given the fact that the microstructure of building materials is difficult to replicate, such studies are difficult to be made repeatable with consistency for scientific study and investigation.

The surface porosity was determined using the image analysis software (ImageJ) from the SEM images. The FEI Environmental Scanning Electron Microscope (ESEM) Quanta 200 was used to capture the SEM images. ESEM Quanta has the capacity for operation at high vacuum as well as under environmental conditions (with water vapour); in addition it is equipped with a standard secondary (Everhart - Thorley) and solid state backscatter detector. Imaging samples were placed on the aluminium holder using double sided conductive carbon tape. To prevent charging, the sample was coated with a 10 nm thin layer of gold using a gold sputter.

Fig. 2. Quick Thermal Conductivity Meter (QTM-500) for measuring thermal conductivity.

3. Results

3.1. Structural performance

Strength and absorption values of TMB and FaL-G bricks are given in Table 2. The initial rate of absorption value represents the average of ten results, IRA of TMB and FaL-G bricks is 1.32 and 0.83 kg/m²/min respectively having a standard deviation of 0.15 and 0.17 respectively. The water absorption values represent the average of ten results, water absorption of TMB and FaL-G bricks is 14.82 and 14.53 % respectively. The compressive strength value representing the strength characteristic is the average of 6 bricks, the compressive strength of TMB and FaL-G brick is 10.66 and 9.81 MPa respectively.

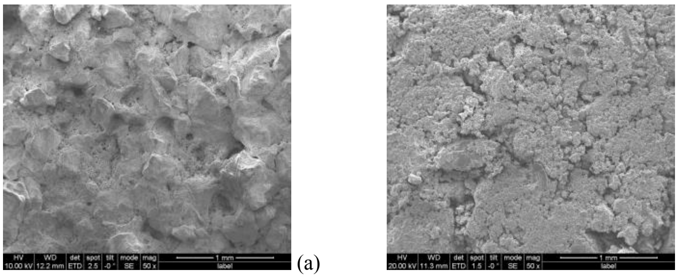
Table 2. Structural Properties: Absorption and strength characteristics values

Characteristics	TMB	FaL-G
Initial rate of absorption, IRA (kg/m²/min)	0.83 (0.17)	1.32 (0.15)
Water absorption (%)	14.53 (1.29)	14.82 (0.45)
Compressive strength (MPa)	9.81 (0.96)	10.66 (1.58)

(*Standard deviation values in parenthesis)

3.2. Thermal performance

Thermal properties of masonry units measured for TMB and FaL-G bricks are given in Table 3. The value of density of TMB is high compared to FaL-G bricks. As such the surface porosity value of the FaL-G is 20.46% and has a standard deviation value of 3.31; similarly, TMB has a range of 20% – 32.17%; this variation is due to the quality maintained during manufacturing of bricks. The specific heat capacity of the FaL-G is lower than that of TMB bricks, which regulate heat storage and flow through masonry units. The TMB has a higher thermal mass compared to a FaL-G brick. The thermal mass depends on the density and specific heat capacity of the masonry units, where property can be controlled and designed by varying the density of the materials. The thermal conductivity of the materials plays a major role in regulating the heat transfer through the masonry units. It can be measured at two extreme conditions, viz. for completely dry and completely saturated materials. It is well known that thermal conductivity at saturated conditions will be greater than at dry conditions. Similar results were obtained for the TMB and FaL-G brick in the current study as shown in Table 3.



(a) (b)

Fig. 3. Scanning Electron Microscope image of (a) TMB and (b) FaL-G

Table 3. Thermal Properties: Density, specific heat capacity, thermal mass and thermal conductivity values

Characteristics	TMB	FaL-G
Average Density (g/cc)	1.775	1.650
Specific heat capacity (J/kg K)	1020.5 (20.83)	930.9 (6.16)
Surface porosity (%)	20 – 32.17	20.46 (3.31)
Thermal mass (kJ/K m^2)	1.81 x 10^6	1.54 x 10^6
Thermal conductivity (W/m K)		
Dry condition	0.564 (0.031)	0.856 (0.038)
Saturated condition	1.668 (0.154)	2.144 (0.054)

(*Standard deviation values in parenthesis)

3.3. Comparative study

Figure 4 shows the comparison of structural (compressive strength) and thermal properties (thermal mass) of two masonry units TMB and FaL-G brick. It can be seen that the materials have lower compressive strength than FaL-G bricks, which has better thermal mass, which regulates heat storage and transfer through masonry unit. By contrast, FaL-G bricks have higher compressive strength than TMB and lower thermal mass than TMB bricks.

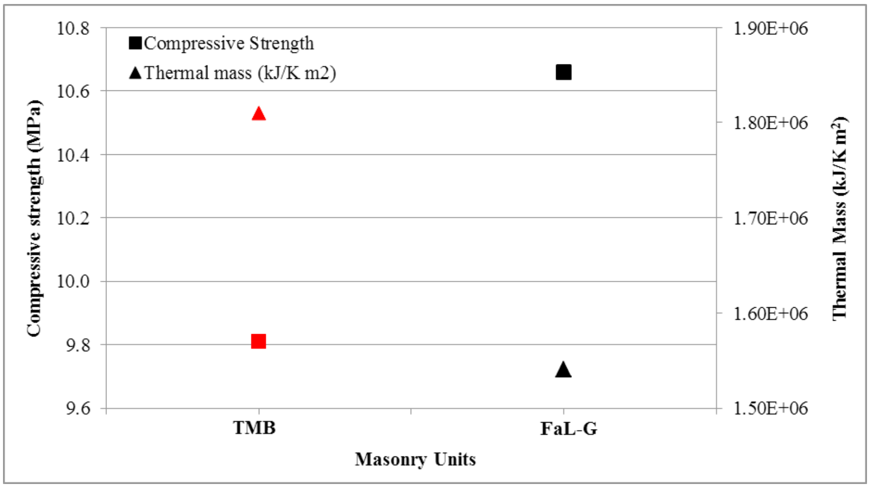


Fig. 4. Comparison of compressive strength and thermal mass of TMB and FaL-G bricks

4. Conclusions

Details of different types of building materials/masonry units used in the study were discussed. Two types of masonry units (TMB and FAL-G) were selected for evaluating the thermo-physical and structural properties. An overview of testing methods and procedures adopted in testing thermal properties of building materials was presented. From this study it can be concluded that structural performance of masonry units, for both TMB and FaL-G brick are inversely proportional to the thermal performance.

References

[1] Balaji N. C., Monto Mani and Venkatarama Reddy B. V., “Dynamic thermal performance of the conventional and alterative building envelope materials”, 4th International conference on Central Europe towards Sustainable Building 2016 (CESB 2016), Innovations for Sustainable Future, 22th – 24th June 2016, Prague, Czech Republic., 2016: pp.982-989.
[2] CEA, “Fly ash generation and its utilization in the country for the year 2013-14”, 2014, India
[3] Venkatarama Reddy, B. V & Gourav, K., 2011. Strength of lime-fly ash compacts using different curing techniques and gypsum additive. Materials and Structures, 2011, 44(10), pp.1793–1808
[4] I S: 3495 (1992) Methods of tests for burnt building bricks—part 1 determination of compressive strength. Bureau of Indian Standards, New Delhi, India
[5] ASTM C67-08, “Standard test methods of sampling and testing brick and structural clay tile”, American Society for Testing and Materials, 2008.
[6] ASTM E1142-14, “Standard Terminology Relating to Thermophysical Properties”, American Society for Testing and Materials, 2014
[7] Kyoto Electronics, 2009. “Quick Thermal Conductivity Meter”, QTM-500, Operation Manual. , p.70