Thermal Behaviour of Unfired and Fired Clay Bricks from Different Environmental Locations of Cauvery Riverbed

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Abstract - The purpose of the research presented in this paper was to determine the thermal properties of unfired and fired clay bricks. In this study, the mineralogical characteristics of raw materials were measured. The strength of clay brick was primarily influenced by a number of factors such as pre/post environmental condition. The x-ray diffraction studies were carried out on seven different samples of clay bricks (unfired and fired) collected from different locations of cauvery riverbed areas of Salem District of Tamilnadu, India. The elemental characterization of the raw materials which were commonly expressed upto ppm level. Using ICP-AES spectrometer. The results obtained in this study demonstrate that clay brick (fired) at TMB is the optimal mixture for both unfired and fired bricks.

Keywords: Clay bricks, Fired bricks, thermal properties, cavery riverbed, ICP-AES

1. Introduction

Bricks are one of the oldest building materials known to man [1]. The use of sub-soil materials in building is a large subject along eras [2]. The brick work has attracted considerable interest over the years: bricks have been divided according to different criteria depending on fabric, dimensions, regularity of shape and appearances [3]. Fired or burned bricks have been used on a large scale in buildings from the very beginning of the third Millennium B.C [4].

Population growth in India leads to uncontrolled urbanization. This has many consequences such as access to decent housing. To address this issue, many governments have opted for the construction of social housing. With regard to clay soil, some authors have investigated on the unfired clay bricks, some reviews were published on unfired clay bricks. About fire bricks, clay soil is generally used as a raw material. Clay is type of earth mostly fine grained and possessing cohesive properties. It become plastic when wet. As enumerated above, a thorough comprehension of the clay incorporated properties in terms of their chemical compositions, molecular structural bonding, mineralogical compositions, Phase transformation and thermodynamic behaviour is paramount in all cases before processing them into desirable tailor-made products.

2. Experimental Program

Locally available reddish-brown clay, (brick making clay) was used for this study; it was sourced from brick machine industry site located cauvery river bank side, from mettur to omallur, Salem District of Tamil nadu, India. The materials properties, sample preparation procedures and standard test procedures are explained in this section.

2.1 Sample Preparation and pre-treatment of raw materials

Industrial pre-treated fine powdered of brick making clay and brick materials of particle size less than or within 200 μm was acquired from individual locations. The brick making clay was constituted by admixing appropriate amount of water, the sampling location and samples are presented in Table 1. Thus the brick making clay materials were used in their as-received state without further preconditioning.

Table 1. Sample Location

S.No.	Brick Making Clay & Brick Samples	Location
1	TMC & TMB	Tharamangalam
2	TPC & TPB	Tharapuram
3	KKC & KKB	Kottakavundampatti
4	PPC & PPB	Puliyampatti
5	MSC & MSB	M.Settipatti
6	KUC & KUB	Kuppur
7	KPC & KPB	Kamalapuram

2.2 Characterization of raw materials

In this study, a total of seven brick making clay and brick (seven) materials were examined (Table 1). The elemental characterization of the raw materials which were commonly expressed upto ppm level using ICP-AES (The ISA JOBIN YVON 24 model ICP-AES) spectrometer.

The mineralogical composition of BMC and Brick samples were assay from their characteristic X-ray diffraction (XRD) patterns using an XPERT-PRO X-ray diffractometer system. The system was equipped with a cu Kα(1.5406A) radiation source and a NaI(Tl) scintillation detector. The radiation source was operated at room temperature with voltage and current settings as 40KV and 30mA, respectively. The XRD peaks were recorded in the range $10^0<2\theta<80^0$ at a scan step time of 10.16(S) and a 2θ step size of 0.05^0. The XRD recorded peaks were then compared with standard peaks database (JCPDS 2000) [5].

With the view of improving the accuracy of the test results obtained and elucidating the phase transformations at various sintering temperature, the test brick sample (S_1) was subjected to sun drying at ambient temperatures for a week. The unique samples of 10 numbers were sintered in an electrical kiln (heating rate 2^0C/min, Maximum temperature: 200^0C, 400^0C, 600^0C, 800^0C and 1000^0C; soaking time of 2h at each reached maximum temperature). The sintered bricks were then cooled to room temperature by natural convention.

3. Results and Discussion

3.1 Chemical compositional analysis

Table 2 presents the Inductively coupled plasma atomic emission spectrometry (ICP-AES) analysis of raw clay materials as shown in Table 2, the concentration of major and trace elements (expressed as ppm) of Al, Mn, Fe, Mg, Zn, Pb, Na, and K present in various samples (7) of brick making clays collected from Cauvery river bed, Salem district, Tamilnadu.

Table 2. ICP-AES analysis of unfired brick making clay samples (ppm)

Samples Name	Na	K	Al	Mn	Fe	Mg	Zn	Pb
TMC	05.52	71.50	100.0	1.40	20.24	1.99	03.10	66.54
TPC	11.97	27.36	47.74	1.62	03.80	1.94	03.17	41.06
KKC	26.48	59.09	100.0	1.23	01.24	6.06	08.08	26.38
PPC	16.37	61.53	100.0	1.51	05.84	3.99	09.84	29.94
MSC	17.63	46.79	91.22	1.73	51.62	3.16	06.94	84.21
KUC	58.55	93.41	19.84	0.51	05.29	1.28	10.26	02.90
KPC	14.46	21.48	09.26	1.35	09.26	0.59	03.06	17.63

In the brick making clay samples from Cauvery riverbed, the concentration of sodium (Na) from TMC to KPC vary from 5.52 to 58.55 ppm (shown in Table 2) with minimum at Tharamangalam (TMC) and maximum at Kuppur (KUC). From the Table 2 the values of Potassium in brick making clay samples from TMC to KPC varies from 21.48 to 93.41 ppm with minimum value at Kamalapuram clay (KPC) and maximum value at Kuppur clay (KUC).

The values of Al in those brick making clay samples varies from 9.26 to 100 ppm with minimum value at Kamalapuram (KPC) and with maximum values at three places viz, Tharamangalam (TMC), Kottakavundampatti (KKC), Puliyampatti (PPC). The low Al content and high Na and K contents indicate very low chemical weathering conditions like those prevailing under relatively cold environments. Strong chemical weathering occurs in hot, rainly tropical conditions, as these environmental conditions have a direct effect on the chemical composition of rocks and clays high weathering rates reaches the K and Na of the clays while Al is enriched in the alteration profile [6] But on the other hand, these samples contain elements like Fe, Al, in a significant quantity that indicates it has potential to be used as building materials [7].

From the table 2, it could be seen that manganese concentration varies from 0.51 to 1.73 ppm. The lowest and highest were recorded at Kuppur (KUC) and M.Settipatti (MSC). In the present study, this element concentration was to be lower than austral abundance as deep-sea sediment. This is may be due to the dissolution of carbonate causes the formation of manganese bicarbonate, which is stable is aerobic environment at low.

From the table 2, the values of Fe in these brick making clay sample vary from 1.24 to 51.62 ppm. With a minimum value at Kottakavundampatti clay (KKC) and with maximum value at M. Settipatti clay (MSC). The elemental analysis shall be used to assess the quantities of Fe and Al accompanies with Si which are the elements that help or affect the manufacture of bricks (plasticity) based on the percentage used [8].

This may be to the insignificant amount of iron might be fixed by clay minerals except kaolinite. During weathering processes iron might also form on ferric oxide coating on clay minerals. Another possible reason is that large flux of metal oxides can be supported by a basin input from nearby revering sources by re-deposition of metal oxide-rich material eroded from coastal areas or by deposition of oxides formed in water column [9-10]. Another possible reason is attributed to the input of trace metal, in the costal sediments comes from rivers and the atmospheric deposition [11].

From the table 2, it has been observed that the concentration of magnesium (Mg) in brick making clay samples show a variation from 0.59 to 6.06 ppm with minimum value at Kamalapuram clay (KPC) and with maximum value at Kottakavundampatti clay (KKC).

From the table 2, it is seen that zinc content ranges from 3.06 to 10.26 ppm with minimum value at Kamalapuram clay (KPC) and with maximum value at Kuppur clay (KUC) The value of zinc concentration in the present study is compared to the coastal abundance, it is found to be lower. This is mainly due to the process of hydrolysis and alteration as the silicified, among others, of the present metal mineralization, which correspond to the surrounding areas of the mining districts of Kanjamalai mount, in which the mineralization is low sulphidation epithermal therefore these associated factors of weathering thus also give the formation of secondary as even tertiary minerals phase.

From the table 2, the values of lead (Pb) in brick making clays vary from 2.90 to 84.21 ppm with minimum value for sample KUC and maximum value for sample MSC.

3.2 XRD analysis

The seven Cauvery riverbed clay samples collected from seven sites named TMC, TPC, KKC, PPC, MSC, KUC and KPC were subjected to the powder X-ray diffraction study. From the diffractogram (Fig.1), sample TMC has kaolinite ($A1_2O_3$ $2SiO_2$, $2H_2O$), montmorillonite (Na, Ca) 3(A1, mg)$_2$ $Si_4O_{10}(OH)_2$ n(H_2O), Dickite ($A1_4Si_4$ O_{11} (OH_8), quartz (SiO_2) and Hematite (Fe_2O_3). As the minerals with d-spacing values, Kaolinite (7.062, 4.218, 4.038, 3.473, 3.118, 2.385, 1.733 and 1.580 Å), montmorillonite (2.949 Å, dictate (3.781) Å , quartz (3.334, 3.365, 2.457, 1.672, 1.541, 1.453, 1.371 and 1.225 Å) Feldspar (3.663, 3.196, and 2.126Å). Hematite (2.518, 2.010, 1.925 and 1.262 Å) These results were obtained from the search matching of the d - spacing value in the JCPDS file [12].

For the common clay (TMC), as shown in Fig. 1. Kaolinite and quartz and the dominant clay and non clay minerals. The minerals like montmorillonite, dickite, Feldspar and hematite are in minor level.

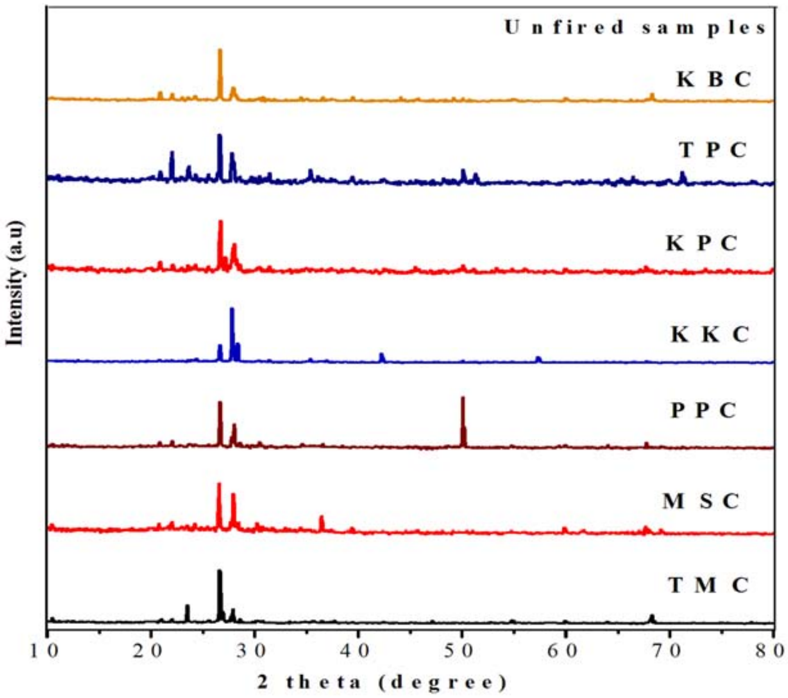

Figure 1 X-ray diffraction pattern of unfired brick making clay samples

The commercial common clay showed an expected typical composition rich in SiO_2, Al_2O_3 as Fe_2O_3, with minor amount of Ca, K, Na and Mg oxides. The content of iron oxides is high and characterizes the common clays as red firing clay.

The XRD patterns, samples TPC,KKC, PPC, MSC, KUC & KPC) (Fig.1) showed that the unfired samples (brick making clay) contained kaolinite, montmonillonite, quartz, feldspar, dickite and hematite.

Quartz facilitated the drying step (diminishing of the drying and of the risk of crack formation) but also contributes to the glassy phase formation during the sintering step the formed glassy phase reduces the porosity of the sintered samples. The consequence of these above phenomena in the improvement of the mechanical strength.

The presence of hydrated Fe-compounds has a less important role in the brick making technology, their amount being usually up to 2 wt%. they don’t produce high H_2O volatilization to initialize and cracking, and neither requires extra heat input during firing to maintain the rising of temperature.

The only difference noted between the clays and non-clay minerals is in the intensities of the diffractograms some of these peaks are poorly resolved, due to the variable compositions and degree of crystallinity these causes mutual interference with the diffraction patterns analyses [13].

In the remaining six samples (TPC, KKC, PPC, MSC, KUC and KPC), the XRD analysis show the presence of kaolinite, quartz, montmonillonite, feldspar, dickite and hematite. From these minerals, quartz and kaolinite have large number of peaks which indicates their abundance .The XRD results on samples (TMC,TPC, KKC,PPC,MSC,KPC) indicate two distinct clay types regarding their composition, with minor difference in their subtypes, regarding their behaviour during brick firing, we may split the minerals from clays in two major groups(a) suffering thermal decomposition and (b) without thermal decomposition,the first group composites all clay minerals (silicates and hydroxides, carbonates ,Fe- sulphide and hydrous minerals (eg. Gypsum and altered muscovite which upon heating will decomposite and recrystallize) .The second group comprises feldspar ,quartz and other SiO_2 varieties and few oxides (magnetite TiO_2 variables etc),mineral second group may have structural transformatics upon heating but they mainly serve as catalyzing agents of the decomposition and recrystallization reactionsThe entire peaks are assigned in accordance with the reported in the literature [14-17].

3.3. Mineralogy of the sample TMB at different temperature (200, 400, 600, 800 and 1000°C)

The X-ray diffraction pattern is modified by changes in the clay structure on heating and the nature of the modification may be used for diagnostic purposes. Each clay mineral undergoes structural changes at different temperatures. The removal of absorbed water in smectites. Vermiculites as hydrated hallosite occurs at temperature below 300°C. All clay minerals exhibit structures changes at higher temperatures (>500°C) when the removal of combined water occurs. The ultimate effect of heat treatment is for the X- ray pattern to be replaced by that of the fixed product which is often amorphous to X–rays (e.g Kaolinite).

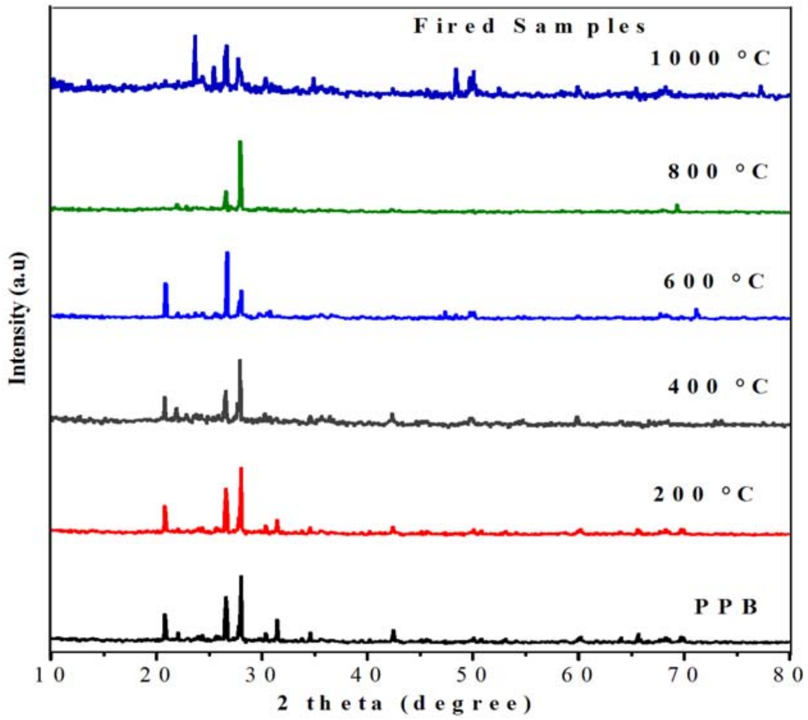

Figure 2 X-ray diffraction pattern of selected sample TMB at different temperature (200, 400, 600, 800 and 1000°C)

The results of XRD analysis of the TMB Brick is illustrated in Fig 2. Here, reflection of the TMB at different temperature are seen Fig. 3 quartz and feldspar do not change their intension at firing temperature lower than 1000°C [18] Calcite is also present in the brick, which shows that the firing conditions were not sufficient for its full decomposition. A remenant of kaolinite was also found. (The clay bricks are usually fired at around 1000°C).

The explanation for this is that transformation of clays from one phase to another or from one type of clay to another type is a function of temperature, pressure, time contact with microbes and chemicals, the type and quantity of impurities and exposure the radiations [19]. Clays may be thermally transformed into other phases when subjected to heating. This process is accompanied by weight loss are sometimes conservation of the residual structurally bound water in to the next phase [20]. The dehydration of Kaolinite (99% pure English china clay) completes by~150°C, followed by dehydroxylation at ~500-600°C and its structural breakdown occurs in the temperature range ~800-900°C, depending upon the particle size and amount and type of the impurities present [21-23].

TMB brick containing kaolinite, quartz, feldspar is major amount, if feldspars were not involved dehydroxylates to metakaolinite at ~400-600°C depending on the type and amount of impurities present [24]

~400-600°C

$$\mathrm{Si_2\,Al_2\,O_5\,(OH)_4 \rightarrow Al_2O_3.2SiO_2 + 2H_2O}$$

which involves the combination of two OH groups to form H_2O and oxygen which remains incorporated in metakaolin. At about 800-1000°C, metakaolinite decomposes to amorphous SiO_2 as $\overset{\rightarrow}{\alpha\text{-}\mathrm{Al_2O_3}}$ - type spinel.

~800-1000°C

$$\mathrm{Al_2\,O_3\,2SiO_2 \rightarrow \gamma\text{-}Al_2O_3 + 2SiO_2}$$

$\overset{\rightarrow}{\alpha\text{-}\mathrm{Al_2O_3}}$ - type spinel as SiO_2 re-crystallize into mullite at temperature above 1100°C

>1100°C

$$\mathrm{3\gamma\text{-}Al_2\,O_3 + 2SiO_2 \rightarrow 3Al_2O_3\,.2SiO_2}$$

Even though if the excess SiO_2 at 900°C, the formation of mullite begins at temperatures > 900°C as the process continues till 1000°C. The case of the TMB sample concerned of more than binary phase, the presence of feldspar, kaolinite together with the quartz make phase changes involved to be more complex [25]. This may account for the initial increase in density of the samples as they were fixed from 800°C to 1000°C. An overall examination of the typical XRD spectra in the sample TMB at different temperature showed the quartz and feldspar is again one of the main mineral species and the unreached residue of excess quartz present is the brick body Fig. 3.

The reaction between silica and alumina, and calcium compounds to give anorthtite occurance at lower temperature with respect to the characteristic temperature of mullite formation.

X-ray diffraction study shows the presence of quartz, kaolinite, hematite, calcite, feldspar, mullite and gibbsite. The obtained results are identical with the results obtained by other authors, who worked in the production of building bricks.

This improvement should facilitate the more wide spread use of these handmade bricks in the local construction industry in Tamilnadu, India. Clay minerals tend to form solid solution during backing. This work had demonstrated the suitable condition required to procedure an engineering quality brick. The advantage of less porosity, high density is to gain more compressive strength in making building bricks.

4. Conclusion

The analytical results indicate that a selection of raw material was used (Brick making clay) for each production variant. Significant differences in the technology have been detected for each sample. From the different site samples of Cauvery riverbed brick making workshop different fabrics have been used for producing difference types of bricks.

In the above all brick making clay samples (TMC-KPC), the XRD analysis show the presence of kaolinite, montmonillonite, quartz, feldsbar, dickite and hematite. From these minerals, quartz and clay mineral (Kaolinite) have a large number of peaks, which indicate their abundance and feldspar and hematite as minor components, with occasional dickite in trace amounts on average the access any minerals as in very small percentages to show on diffractograms. The Cauvery riverbed clay mineralogy results as similar those of their deposits like research an mineralogy of redclay in vellaru riverbed Cuddalore district, Tamilnadu [26].

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