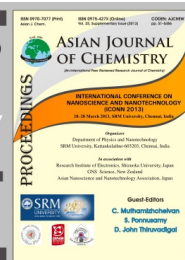




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Articulated Ceramic Bricks with Wastes from Ceramic Industries†

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Production of ceramic bricks from mixtures of ceramic industry wastes and kaolinitic clay were investigated. Different formulations were prepared to evaluate the effects of each component on drying and firing processes and on the final properties of the ceramic bricks. The samples were investigated mineralogically using FTIR spectra recorded in the region 4000-400 cm^{-1} and powder X-ray diffraction. The indication of well ordered kaolinite is by the band at 1115 cm^{-1} in the raw samples which tends to shift towards 1095 cm^{-1} in all the fired samples. The presence of quartz and anorthite is confirmed both by XRD and FTIR. The samples were analyzed for their mechanical strength up to 50 wt % of the rejects addition before and after sintering (900-1200 °C). Additions above 40 % decreased the mechanical strength of both the dry body and the fired ceramic pieces.

Key Words: Kaolinite, Ceramic rejects, Mechanical strength, FTIR, XRD, Recycling.

INTRODUCTION

Alternative methods for the final disposal of wastes from various industries are the need of the hour. For instance, discharge in regular sewage pipelines, accumulation in mud containing reservoirs, direct application in the soil and ocean coast, as landfill, are becoming common practice. However, the waste and associated chemical products remain unaltered in all these cases. At present, the business conscience of recycling stimulates both small and big enterprises to look for alternative solutions aiming at recycling and adding commercial value to the final products taking into consideration the environmental legislation.

An environmentally correct solution, which is nowadays being investigated, is the incorporation of these wastes in cement and clayey bodies^{1,2}. In particular, the recycling of different solid wastes, both from the city and industrial origins, through its addition into red ceramic products like conventional bricks, is worldwide being studied²⁻⁴. The high temperature firing stage typical of the brick manufacturing is fundamental to the sludge/clay particles consolidation. The firing stages also make it possible to immobilize the contaminants within the silicate phases.

The prospective benefits of using fired ceramic wastes as the brick or tile additive in the fired matrix have been studied^{5,6} in which the wastes from bricks was added up in quantities to 20 wt % that were fired at 970 °C. In the present paper, the

effect of the fired ceramic wastes added into a clayey body (up to 50 wt %) was studied with the sintering temperatures of 900-1200 °C in order to evaluate their mechanical strength and their mineralogical compositions for the purpose of their recycling into the own ceramic industries.

EXPERIMENTAL

The ceramic wastes obtained from the Government Ceramic Industry of Vriddhachalam (Tamilnadu state, India) and the raw material kaolinite were mixed with water and the slurry was dried at 100 °C in a rotating drier until 8-10 % humidity. The dried material was then crushed and sieved to pass through a 150 mesh (100 μm) to obtain suitable powders for pressing. Unfired rectangular specimens in lots of 10 for each mixture were moulded using an extrusion apparatus. The compositions of the samples made with different percentage of the ceramic rejects are as in Table-1. Firing was carried out in a laboratory electric furnace reaching different maximum temperatures in the range of 900-1200 °C at regular temperature intervals of 100 °C with a soaking time of 1 h at the maximum temperature needed. Cooling occurred by natural convection after it was turned off.

The FTIR spectra of all the samples were recorded in the region 4000-400 cm^{-1} using the Nicolat-Avatar 330 series. The phase analysis of the samples were performed using X-ray diffractometry with $\text{CuK}\alpha$ radiation and NaI(Tl) scintillation counter detector with a scanning speed of 100/min. Water

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absorption was measured according to the ISO standard 10545-3. The compressive strength of the samples was determined in three point bending tests with a universal testing machine.

TABLE-1
COMPOSITIONS (%) OF THE TEST SAMPLES

Sample	S1	S2	S3	S4	S5	S6
Kaolinite	100	90	80	70	60	50
Ceramic rejects	0	10	20	30	40	50

RESULTS AND DISCUSSION

The FTIR spectra of the ceramic test bodies (S1-S6) in the received state without firing are presented in Fig. 1(a) which corresponds to well order kaolinite structures⁷. Kaolinite with almost Al in the octahedral positions has four absorption bands in the O-H stretching region (Fig. 1a). The O-H stretching of inner hydroxyl group lying between the tetrahedral and octahedral sheets give the absorption band at 3620 cm^{-1} . The characteristic band appearing at 3694 cm^{-1} corresponds to in-phase symmetric stretching vibration whereas two weak absorptions at 3669 and 3652 cm^{-1} are assigned to out of phase stretching vibration⁸. A peak in the fired sample spectra at 1093 cm^{-1} arises from asymmetric Si-O-Si stretching vibration⁹. The strong distinct absorption bands present at 1115 cm^{-1} and 913 cm^{-1} in all the spectra of the studied S5 samples at 1100 °C indicate the well ordered kaolinite structure (Fig. 1b). Well ordered clays are characterized by the presence of bands at 910, 1030 and 1120 cm^{-1} in which 910 and 1120 cm^{-1} are due to Al-(OH) vibrations¹⁰. They are replaced by a single band at 1030 cm^{-1} as the disorder increases¹¹.

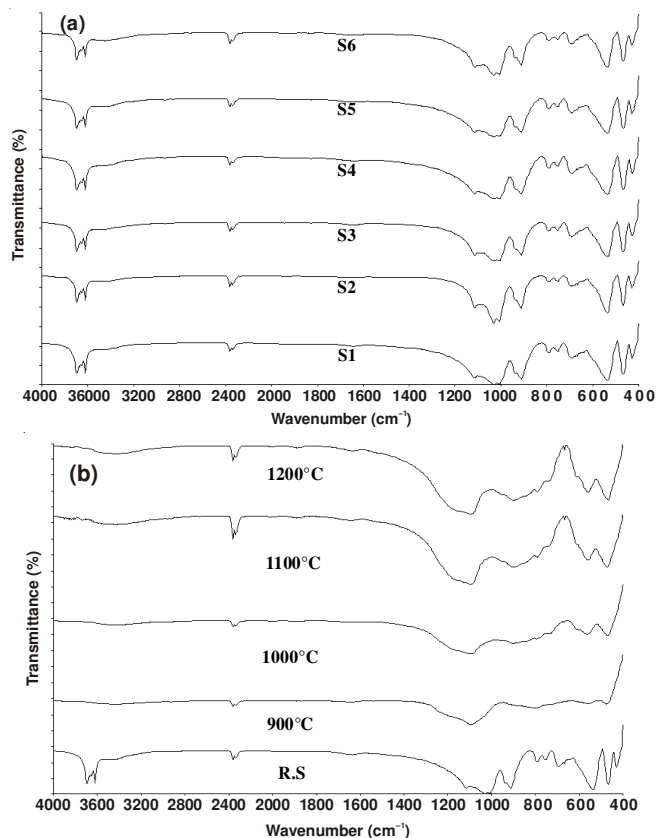


Fig. 1. (a) FT-IR Spectra of CF additive ceramic bricks (received state); (b) FT-IR spectra of S5 samples

The presence of quartz can be explained by Si-O asymmetric bending vibrations at 468 cm^{-1} and Si-O symmetric vibrations at 695 cm^{-1} . These assignments are in good agreement with that reported for quartz¹². The peak at 795 cm^{-1} in the fired samples provides the evidence for the presence of dickite¹³. The major change in the spectra in all the thermally treated samples corresponds to the disappearance of the band at 538 cm^{-1} absorption and the evolution of a band at 567-563 cm^{-1} for the different compositions in all the studied temperatures. These could be confidently assigned to anorthite¹⁴ as a result of solid state reaction between CaO and clay. The rest of the spectrum is similar in its general features because the same phases are maintained.

The X-ray diffractogram results showed kaolinite, quartz and anorthite as main crystalline phases (Table-2). The evolution of different phases with temperatures in the range 900-1200 °C is studied. The kaolinite becomes progressively less crystalline by dehydroxylation to form metakaolinite (amorphous) at a low temperature around 500 °C. It was not possible to accurately establish the complete dehydroxylation by this technique because XRD can reveal little about the occurrence of the poorly ordered material.

TABLE-2
MINERAL PHASES IDENTIFIED IN THE STUDIED SAMPLES

Identified phases	Green samples	Fired samples
Kaolinite	Yes	Yes
Quartz	Yes	Yes
Mullite	-	Yes
Anorthite	-	Yes
Dickite	-	Yes
Tridymite	-	Yes
Eskolaite	-	Yes
Greenalite	-	Yes

The XRD patterns of the fired samples indicated the presence of tridymite, dickite, eskolaite and greenalite along with quartz, kaolinite and anorthite. The minerals like tridymite, eskolaite and greenalite are identified only in XRD analysis which indicates their crystalline order in spite of their meager presence. However, quartz and anorthite are present invariably in all the test samples¹⁵.

According to Fig. 2(a) and (b), it was verified that all the samples with wastes up to 40 wt % have better values for water absorption lower than the maximum values of 25 % for bricks and higher compressive strength values¹⁶. It can also be observed that the ceramic test samples sintered at 1100 °C with the rejects up to 40 wt % have the lowest water absorption with maximum compressive strength.

Conclusion

Based on the mineralogical characteristics and the mechanical properties observed, the test samples have characteristics similar to the conventional ceramic raw material. In this way, the use of ceramic wastes instead of conventional non-plastic raw materials yields a reduction in energetic costs of the ceramic process. The test sample which has up to 40 wt % of the ceramic wastes can be used to produce recycled ceramic bricks with sintering temperature of 1100 °C as it has the maximum compressive strength with low water absorption.

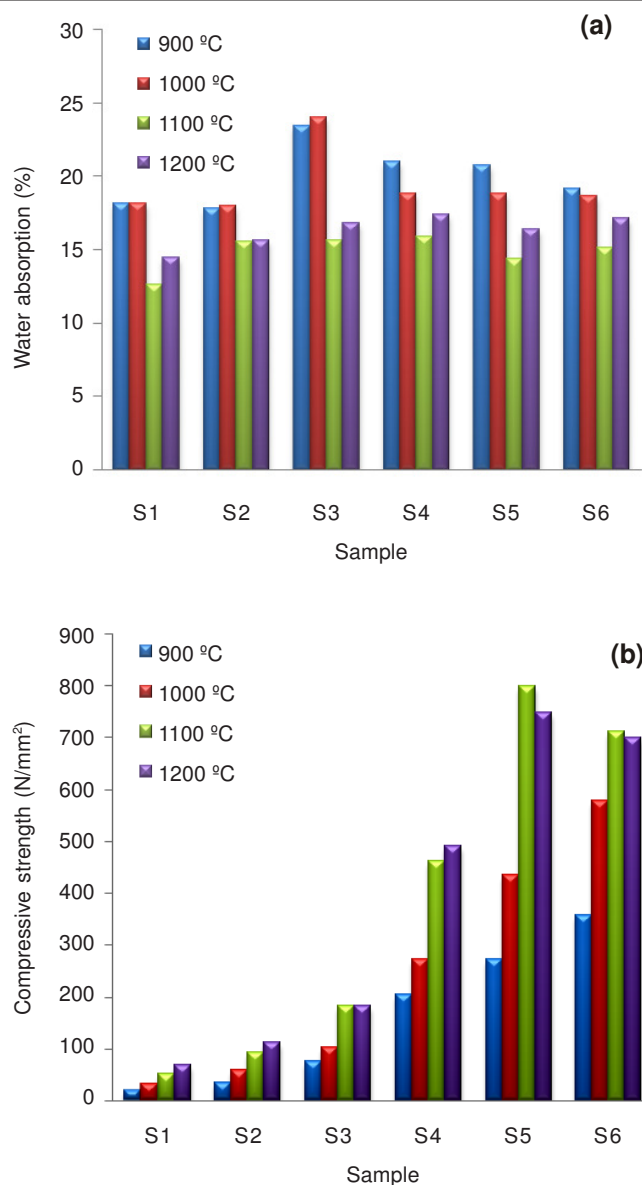


Fig. 2. (a) Water absorption for the test samples; (b) Compressive strength for the test samples

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