Jr. of Industrial Pollution Control 25 (2) (2009) pp 145-150

UTILIZATION OF MARBLE AND GRANITE WASTES IN BRICK PRODUCTS

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Key words : Clay, Marble wastes, Mechanical properties, Bricks

ABSTRACT

Marble and granite sawing powder wastes is one of the major worldwide environmental problems. As a consequence of environmental and financial considerations, there is a growing demand for wastes to be re-used or recycled. Therefore, this work intends to discuss the possibilities of using marble and granite sawing wastes as alternative raw materials in the production of bricks. Samples of marble and granite wastes were collected from companies located in Madurai District. Clay mixture and fired industrial bricks were collected from a brick chamber located in Ramanathapuram District, Tamilnadu, India. Results obtained through chemical and mineralogical analysis (XRF and XRD), Liquid and plasticity limit and plasticity index, particle size analysis compressive strength, flexural rupture strength, water absorption, apparent porosity, apparent density and Bulk density, show that marble and granite sawing wastes can be added to the Ramanathapuram clay mixture upto 50 wt.% with no detrimental effect on the properties of the sintered brick products.

INTRODUCTION

There is a great impetus worldwide towards recycling industrial waste by-products and their utilization as renewable construction materials. The recycling of by-products and wastes represents an increasingly urgent problem for the immediate future of human kind. Leaving the waste material to the environment directly can cause environmental problems. Therefore, many countries have still been working on how to reuse the waste material so that they give fewer hazards to the environment. Developed countries have strict rules to protect the environment whereas many developing countries have almost no rules to protect the environment against wastes. Wastes can be used to produce new products or can be used as admixtures so that natural sources are used more efficiently and the environment is protected from waste deposits (Karasahin and Terzi, 2007). Two major by-products are coal fly ash and marble and granite sawing waste, which are produced in significant amounts in India. Marble and granite blocks are cut into smaller blocks in order to give the required smooth shape. During the cutting and polishing processes about 25% marble and granite is resulted in dust, mainly composed of SiO_2, $Al2O_3$, Fe_2O_3 and CaO, with some minor constituents such as Mg, Ti, Mn and K oxides. Which can cause serious damages in the environment, such as soil and underground water contamination, if not efficiently treated before disposal (Segadaes *et al*. 2005; Dhanapandian and Gnanavel, 2009; Dhanapandian

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et al. 2008; Menezes *et al*. 2005). Therefore, these oxides have been mainly considered as a low cost material resource for the brick industry. But, there has not been done much research on the use of marble and granite waste for brick production. According to Acchar *et al*. (2006), marble and granite waste can be used to obtain durable clay products. In their study, an attempt was made to test the possibility of recycling marble and granite waste in clay-based materials production. Several brick compositions have been formulated using varying proportions of the marble and granite waste. The tailings have been characterized with respect to their chemical composition, X-ray diffraction and mechanical properties. Therefore, the main objective of this work is to study the possibility to incorporate marble and granite wastes in brick products, without to degrade their properties.

MATERIALS AND METHODS

A typical clay mixture used in the brick industry located in Ramanathapuram District and a marble and granite wastes, collected from companies located in Madurai District, Tamilnadu, India, were selected and characterized. The characterization included chemical composition X-ray fluorescence (XRF), particle size analysis (HORIBA LA-910) and mineral composition (XRD-Rikaku) using CuKα radiation at a wavelength of 1.5405Å and 2θ range from 20 to 70°. To study the mechanical properties of waste mixed bricks, the wastes were mixed with raw clay at 0, 10, 20, 30, 40 and 50 wt.% and briquettes specimens of size (5.0 x 2.5 x 2.5 cm) were prepared. Mixing was made in a planetary mill and minimum of 100 briquettes were manually shaped at workable consistency and the specimens were dried in an oven to 110°C for 24h. Briquette specimens were sintered at temperatures between 600 and 900°C for two hour in an oxidizing atmospheric condition with a heating rate of 10°C/minute. After sintering at selected temperatures, the specimens were subjected to several tests in order to verify their technological properties i.e., compressive strength, flexural rupture strength, water absorption, porosity, and bulk density. The compressive strength was determined by dividing the maximum load with the applied load area of the brick samples. The flexural strength was measured with a universal testing machine in a three-point bending test of a constant cross-head speed of 0.5 mm/min. Water absorption, porosity and bulk density of the respective specimens were determined by using the Archimedes water displacement method.

RESULTS AND DISCUSSION

Chemical composition and X-ray diffraction analysis

Table 1 gives the chemical composition of the clay mixture and the marble and granite sawing powder wastes. The clay mixture presents a typical composition and are rich in silica and alumina and minor contents of Mg, Ti, Ca, Na and K oxides. The significant amount of iron oxide (2.82%) is responsible for a reddish colour of the industrial brick after firing (Monteiro *et al*. 2008). The loss on ignition (6.80%) is within the usual range for red-clay mixture and is most likely associated with volatile components and organic matter. From the results of chemical composition, it can be observed that the marble and granite reject is basically formed by SiO_2, Al_2O_3 and CaO, with small amounts of MgO, Fe_2O_3, K_2O and Na_2O. The loss on ignition (LOI) results from the decomposition of carbonates (calcite and dolomite). The alkaline earth oxide content particularly CaO and K_2O, present in the waste material will act as a fluxing agent during the sintering process (Seboya *et al*. 2007).

Fig.1 shows the X-ray diffraction patterns of the clay mixture and the marble and granite waste. It can be observed that the Ramanathapuram clay mixture contains quartz, albite and anorthite. The sample of waste contains quartz, together with albite, dolomite and calcite. The crystalline phases identified by XRD are in agreement with the results obtained by chemical composition analysis (XRF). However, the presence of iron oxide phases on both materials (clay mixture and waste) could not be detected, might have been due to its low concentration and poor crystallinity (Wagner *et al*. 2000; Wagner *et al*. 1998; Wagner *et al*. 1992).

Particle size analysis

The particle size distributions of the marble and granite reject and clay mixture are depicted in Fig. 2 where it can be seen that, for the marble and granite reject, 84% are of silt size and 16% are of fine sand size, indicating, thus, that this material can be classified as a silt-clay like material and suitable for the use in raw material of clay brick (Saboya *et al*. 2007).

For the clay mixture, it can be observed that 46% of the particle size distribution are of clay fraction, whereas 39% are of silt size. The fine and coarse sand proportions are 10 and 5%. This is a typical particle size distribution of Ramanathapuram local alluvial-sedimentary clay deposit.

Atterberg Limits

Atterberg limits express the interaction among adjacent particles of the soil mass in presence of water. Due to its own nature, the marble and granite reject in the form of powder is a no plastic material. However, providing that it is mixed to the clay mixture for molding the brick, it is important to verify the influence of addition of powder in the clay mixture plasticity. Because, Atterberg limits are closely related to the optimum extrusion moisture content of the soil mass. This is also of crusial importance on the quality of the final product because the air-drying shrinkage can disort the body manufactured with high water content.

Table 2 gives the Atterberg Limits of the raw clay mixture as a function of marble and granite powder content. As expected, there is a noticeable decrease in the plasticity index parameter as the reject content increases. The same behaviour is observed for liquid limit (%) as well as for plasticity limit. According to the range of values defined in literature (Menezes, *et al*. 2005) and the values given in Table 2 are in agreement, indicates that appropriate to the production of bricks by extrusion.

Mechanical behaviour

For the evaluation of the mechanical characteristics of the bricks, the specimens were prepared by mixing clay mixture with different reject contents of marble and granite powder of 0%, 10%, 20%, 30%, 40% and 50% in weight. After firing at selected temperatures, the specimens were submitted to several tests in order to verify their technological properties, i.e., compressive strength, flexural rupture strength, water absorption, porosity and bulk density.

The compression and flexural rupture strength tests are the most important tests for assuring the engineering quality of a building material (Lin, 2006). As shown is Fig. 3 and 4, the results indicate that the strength is greater depend on the amount of waste in the brick and the firing temperature. Initially, compressive and flexural rupture strengths of Ramanathapuram industrial brick was measured. As shown, with up to 10 wt.% waste added to the bricks, the strengths achieved at 600°C is almost equal to the strengths measured for Ramanathapuram industrial brick in the as received state. With upto 20 wt.% waste added to the clay mixture, the strengths measured at 900°C, exhibiting higher than that of 10 wt.%. When a 30, 40 and 50 wt.% waste is added in the clay mixture, the achieved brick strengths at 900°C exhibited better values than that of the strengths obtained at lower wt.%. At higher temperatures (900°C), the increase of the reject content has caused an improvement of the compressive and flexural strengths, that can be attributed to an improvement of the densification process. The strengths, water absorption, porosity and bulk density values obtained in this work for clay mixture with marble and granite reject are much better, for all sintering temperatures investigated in this work that the bricks produced in the industry at the same conditions. Thus, the results described above shows that marble and granite sawing powder wastes is a potential raw material to be used in the Ramanathapuram traditional brick industry.

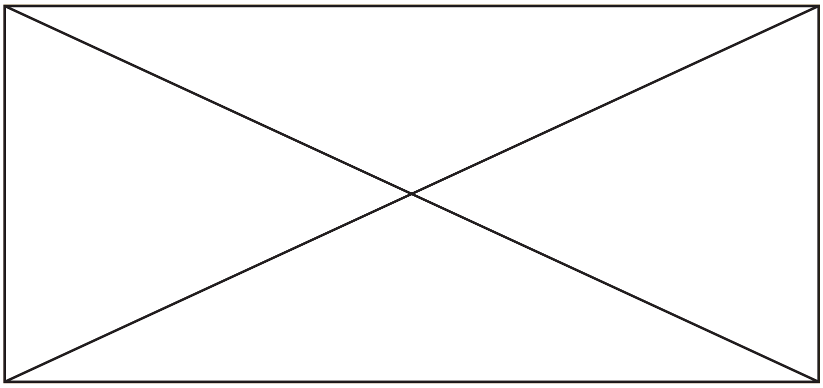
Water absorption and porosity are the key factors affecting the durability of brick. The less water infiltrates into brick, the more durability of the brick and

Table 1. Chemical compositions of the raw materials (%)

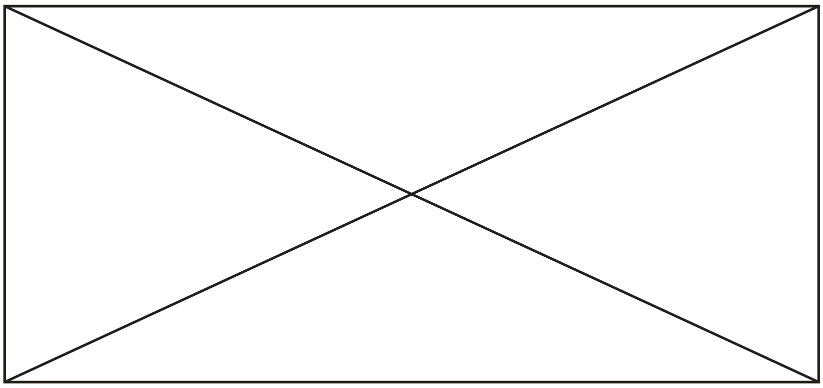
	H_2O-	SiO_2	$Al2O_3$	TiO_2	Fe_2O_3	CaO	MgO	MnO	P_2O_5	Na_2O	K_2O	LOI	Total
Ramanathapuram clay	1.68	70.98	11.58	0.02	2.82	2.24	1.60	0.03	0.01	0.52	1.89	6.80	100.17
Marble and Granite wastes	2.13	62.84	16.15	0.02	2.93	4.50	2.47	0.02	0.01	1.05	1.62	6.21	99.95

Table 2. Liquid and plasticity limit and plasticity index

	Wastes weight percent					
Ramanathapuram Clay	0	10	20	30	40	50
Liquid limit (%)	42.2	39.6	37.5	35.4	32.8	30.7
Plasticity limit (%)	24.3	22.6	20.9	19.2	17.0	15.2
Plasticity index (%)	17.9	17.0	16.6	16.2	15.8	15.5



(a)



(b)

Fig. 1 X-ray diffraction pattern (a) Raw clay material; (b) Marble and granite wastes

resistance to the natural environment are expected. Thus the internal structure of the brick must be intensive enough to avoid the intrusion of water. From Fig. 5 and 6, one should notice that the water absorption and porosity values for the bricks decreases with increased waste addition and sintering temperatures, thereby increasing its weathering resistance. This result indicate that marble and granite wastes are sufficiently fused in the pores of bricks at higher temperatures and acted as flux agent.

The bricks made with clay normally have a bulk density of 1.8-2.0g/cm3 (Lin, 2006). The measurement of bulk density of wastes incorporated briquette specimens at different weight percent and fired at four different temperatures are demonstrated in Figs. 7. As shown, the bulk density of the bricks are directly proportional to the quantity of waste added in the mixture and sintering temperatures. When the mixture absorbs more water, the brick exhibits a larger pore size, resulting in a light density. The firing temperature can also affect the density of the bricks. The results show that increasing the temperature results in an increase in bulk density. The bulk density obtained for waste mixed briquette specimens sintered inbetween 600 and 900°C satisfies the requirements reported in literature and shows its suitability for the use as raw material in brick production.

CONCLUSIONS

Based on the results of the present studies, following conclusions can be drawn:

- Marble and granite waste content up to 50 wt.% can be incorporated into Ramanathapuram clay mixture, without degrading their mechanical properties.
- The presence of marble and granite wastes allow one to obtain a clay brick with better properties as the conventional clay brick at low temperatures as the normally used for brick products in the brick industry, resulting in energy saving and waste reduction.
- The incorporation of marble and granite wastes in brick production anticipates safe for the health an environmentally friendly recycling products.

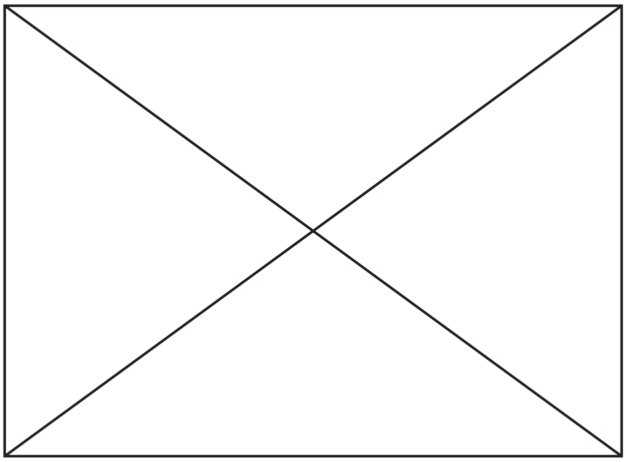


Fig. 2 Particle size distribution of raw materials

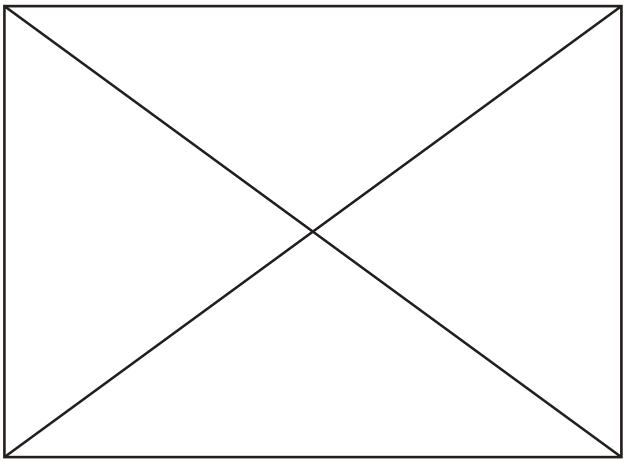


Fig. 3 Variation of compressive strength as a function of waste weight percentage and sintering temperatures

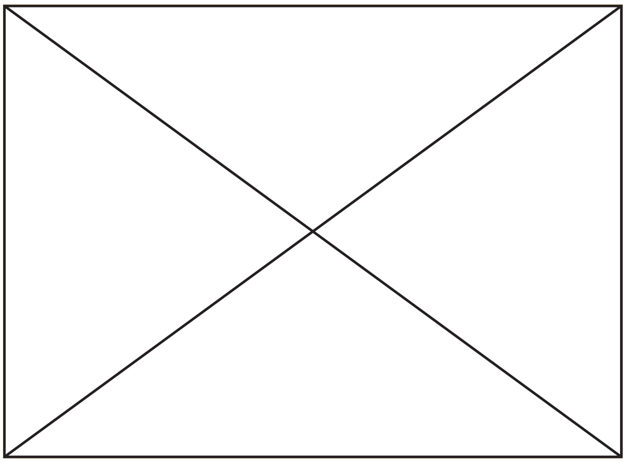


Fig. 4 Variation of Flexural rupture strength as a function of waste weight percentage and sintering temperatures

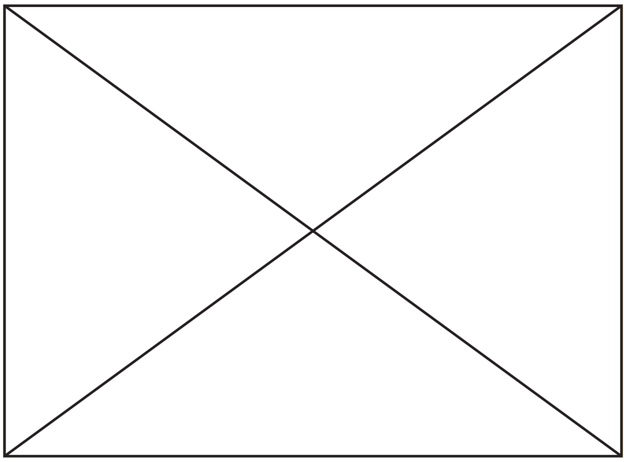


Fig. 5 Variation of Water absorption as a function of waste weight percentage and sintering temperatures

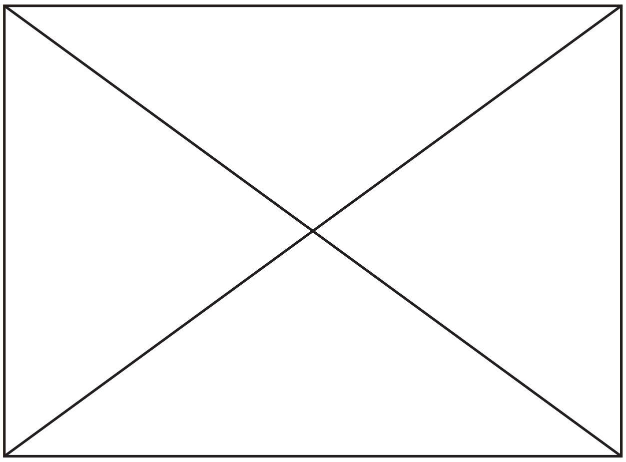


Fig. 6 Variation of Porosity as a function of waste weight percentage and sintering temperatures

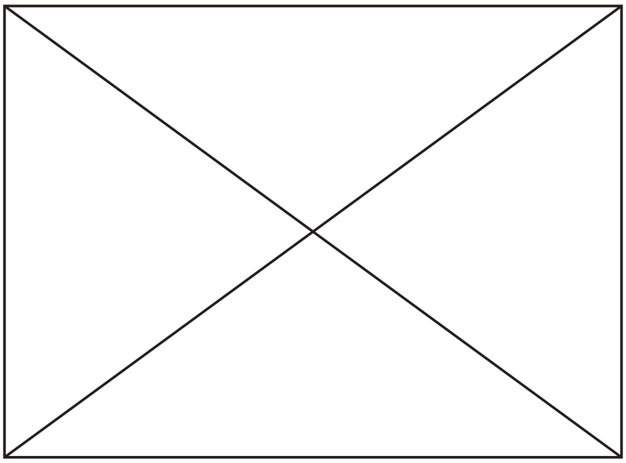


Fig. 7 Variation of bulk density as a function of waste weight percentage and sintering temperatures

ACKNOWLEDGEMENT

The authors are especially indebted to Prof. Ajay Gupta, The Centre Director and Dr. R.J. Choudhary, Scientist, IUC-DAE Consortium for Scientific Research, Indore, Madya Pradesh, India for their help in recording XRD spectra.We are also grateful to Mr.K.SARAVANAN, M.E. Department of Structural Engineering, Faculty of Engineering and Technology (FEAT), Annamalai University, for his help in carrying out Mechanical measurements.

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