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ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

Potential of Industrial Waste to Manufacture Brick and Ceramic Products- A Review

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***Abstract:*— This paper analyses the significant scientific publications worldwide concerning ceramic products and brick manufactured with various industrial wastes added to the ceramic raw material for the improvement of properties and for eco-friendly disposal. Utilization of industrial waste in production of bricks can be divided into three methods: firing, cementing and geo polymerization. The authors have reviewed works with a focus on the firing method in which industrial solid waste have been added with basic raw materials for the purpose of manufacturing clay ceramics. The publications reviewed in this paper are grouped into two categories, the first category contains the publications in which work has been done to manufacture acid resistant bricks using industrial wastes and the second category contains the publications working with industrial waste to manufacture fired bricks and other ceramic products. The ceramic mixture compositions, molding and firing conditions, final strength, water absorption and other parameters of the final ceramic samples are described and highlighted here. The study reveals that there is good scope of utilizing industrial waste for the sake of manufacturing clay ceramic products and bricks for the next few decades.**

***Index Terms*— Acid resistant brick, fired bricks, industrial waste, sintering.**

I. INTRODUCTION

The disposal of industrial wastes comprises one of the major worldwide environmental problems as these wastes render the environment unfriendly. The prime focus on waste material utilization is due to the exhaustion of the natural resources and conservation of not renewable resources. The utilization of various industrial wastes in the industry of construction ceramics is a hot topic. It is interesting to both the enterprises producing waste and the producers of ceramic brick, stone, tile, and so on. On the one hand, the high temperature 900–1200 0C firing of ceramics makes it possible to neutralize and reliably store in a body of ceramics many types of waste, and on the other hand, such additives to clay raw materials make it possible to increase the product quality. For example granite dust waste has the potential to be used to form acid resistant bricks and improving the properties like compressive strength, water absorption and acid weight loss. Industrial wastes may contain mineral substances that increase the strength of ceramics with low water absorption percentage and better thermal insulating properties. Proper management in this field can solve the important problems like (a) utilization of industrial waste to save the environment, (b) conservation of non-renewable resources, (c) improving the quality of ceramic products through use of local wastes.

II. REVIEW ON USE OF WASTE MATERIALS TO MANUFACTURE ACID RESISTANT BRICKS

Medhat S. El-Mahllawy [1] uses kaolin fine quarry residue (KFQR) combined with granulated blast-furnace slag (GBFS) and granite basalt fine quarry residue (GBFQR) to make a brick resistible to chemical actions. Five batches of bricks are prepared containing 50% KFQR and as a constant percentage, while the percentage of GBFS was increased from 10 to 40% on the expense of GBFQR percentage which was decreased from 40 to 10% (by weight). Bricks of 5 cm side length cube were prepared by pressing under 225 kg/cm2. These bricks were then fired at different firing temperatures of 1100 0C, 1125 0C, 1150 0C and 1175 0C at 5 0C/m firing rate and 4 h soaking time. The fired specimens are examined for water absorption, acid weight loss, compressive strength, firing volume change, bulk density and firing weight loss. The study shows that the batch containing 50% KFQR, 20% GBFQR and 30% GBFS fired at 1125 0C exhibits the most satisfying ceramic properties having water absorption 0.02%, acid weight loss 0.06% and compressive strength of 710 kg/cm2. The study also indicates that the addition of more than 25% of GBFQR is not recommended, as it is significantly deleterious to the ceramic properties.

Saker et al. [2] studied the possibility of making acid resistant brick using bashteel clay (BC), wastes of fine kaolin quarry (FKQW) and waste water glass sludge (WGS). These materials are added in four different compositions keeping FKQR at fixed weight% of 25% and BC from 25% to 40% at the expense of WGS from 50% to 35%. These starting materials were crushed then separately ground in a laboratory ball mill and screened to pass 90 µm sieve. Then these mixtures were molded in articles of 5cm-side length cube by pressing under 225 kg/cm2. Mixing the composition of the mixtures was performed on dry basis with spraying 5% water by weight before molding. The prepared articles were fired at different firing temperatures ranging from 1050 0C to 1150 0C at 5 0C /m firing rate and 4 hours soaking time. The fired specimens are examined for water absorption, acid weight loss, compressive strength, firing weight loss and volumetric shrinkage. The result shows that firing temperature leads a very important role in the final properties of the bricks as at lower temperature the brick may not sintered having low compressive strength and at higher temperatures the brick may get partially melted. The batch containing 25% FKQW, 30% BC and 45% WGS gives best result at 1075 0C having water absorption 0.09%, acid weight loss 0.49%, and compressive strength of 902 kg/cm2. The study also shows that increase of water glass sludge plays an important role in the enhancement of the fired article properties at relatively low firing temperatures.

Medhat S. El-Mahllawy [3] studied the possibility of making acid resistant bricks using plastic clay, kaolin, glauconite, cement kiln dust and soda ash. Three different compositions were prepared using these materials keeping 30% clay, 30% kaolin and 10% soda ash at fixed weight% and percentage of glauconite decreased from 25% to 15% on the expense of cement kiln dust percentage which increased from 5% to 15%. Every mixture was first homogenized in a laboratory blender for 3min.The moisture content (moisture mass / dry mass) was adjusted to 10% before molding. The prepared mixtures were pressed in 5cm-side length cube under a load of 225 kg/ cm2. After forming, the resulting briquettes were dried out in an electrical dryer at 80 0C for 24h, and then fired at different firing temperatures of 1100 0C 1125 0C and 1150 0C at 5 0C /min firing rate for 2h as a holding time in a controlled laboratory muffle furnace. The fired specimens were then examined for water absorption, acid weight loss and compressive strength. The result shows that the final product strongly dependent on percentage of cement kiln dust and glauconite and also on the firing temperature. With increase in percentage of cement kiln dust the technical properties of the bricks decreases. Only the bricks with 5% cement kiln dust and 25% glauconite fired at 1150 0C can be used as acid resistant bricks as per Egyptian standard specification (ESS 41-1986).

Owoeye et al. [4] in their work attempted to develop acid resistant brick using quarry fine waste residues (stone dust, kaolin and silica sand). In order to investigate the possibility of producing acid resistant bricks, nine suggested batches were prepared. Five batch contains 40% kaolin by weight and 10% to 50% stone dust and silica sand. Other four batch contains 50% kaolin by weight and 10% to 40% stone dust and silica sand. The collected quarry residue and silica sand both were fined in ball mill and then sieved through a 75µm mesh. The batches were dry mixed in a mortar pestle to ensure homogenization. The Samples of each batch were prepared by uniaxial pressing machine with little amount water of (<5%). Samples were dried at a room temperature and were later sintered in a furnace at 970°C. The fired specimens were then examined for apparent porosity, bulk density, water absorption, volume shrinkage, compressive strength and acid weight loss. The test result shows maximum water absorption achieved is around 4%, maximum compressive strength achieved is around 16 MPa, and maximum acid weight loss achieved is <4%. From the above results it can be said that the bricks did not achieved promising properties to be used as acid resistant brick. The bricks did not achieved the standard properties may be because of they did not sintered at 970°C.

Ibrahim et al. [5] uses local Egyptian siliceous plastic clay along with granite processing waste (dust) as the starting raw materials to construct acid resistant ricks. Attempt has been made to study the properties of acid resistant bricks with and without addition of potash feldspar along with the above mentioned raw materials. It has been reported that the sintering of the brick occurs in the temperature range 1100- 1175 0C due to the formation of low melting phases in the above temperature. It has been reported that cold crushing strength of the bodies were relatively high in the range 74 - 124 MPa and the bodies also exhibited high resistance to the attack by acids (weight loss in the range between 0.22 and 0.64%). The values obtained were in conformity to the Egyptian standards. Bricks prepared along with potash feldspar (5 to 10%) showed increased values of strength and acid resistance.

III. REVIEW ON USE OF WASTE MATERIALS IN FIRED BRICK AND OTHER CERAMIC PRODUCTS

Leiva et al. [6] studies the feasibility of utilizing co-combustion fly ashes for the production of eco-friendly fired bricks. Six different composition of clay and fly ash mix were prepared with composition of clay (decreasing from 100% to 0%) and fly ash (increasing from 0% to 100%). Cylinders of

32.5 mm diameter and 50 mm length, were manufactured by compressing at 10 MPa. The cylinders were dried at 60 0C until constant weight is achieved. Then they were burnt at different temperatures of 800, 900 and 1000 0C. Then the fired specimens were tested for shrinkage, density, water absorption, efflorescence, and compressive strength. No one of the sample have shown much shrinkage. It is observed that at 800 and 900 0C the density is reduced with increase in fly ash content but at 1000 0C density is increased with increase in fly ash content. At 800 and 900 0C water absorption is increased with increase in fly ash content but at 1000 0C it decreased with increase in fly ash content. The compressive strength also decreased with increase in fly ash content for the samples treated at 800 and 900 0C where at 1000 0C compressive strength increased rapidly with increase in fly ash content and achieved maximum of around 47 MPa. It can be said that the properties of the bricks improved with the firing temperature. The compressive strength decreased with the ash content, except at 1000 °C, this may be because of at this temperature sintering of the bricks were achieved.

Quesada et al. [7] uses olive pomace bottom ash (OPBA) to replace different amounts (10–50 wt %) of clay in brick manufacturing. To obtain a uniform particle size, clay was crushed and ground to yield a powder with a particle size suitable to pass through a 150 µm sieve. The waste, olive pomace bottom ash, was dried in an oven at 105 0C and milled in a ball mill until homogeneous particle size was obtained. Particles were sieved through 150 µm mesh prior to their incorporation into clay. Six different batches were prepared using 0% to 50% OPBA with a gap of 10% in each batch. Bricks of size 60mm X 30mm X 10mm were molded under pressure of 54.5 MPa. Then the samples were fired in a laboratory furnace at a rate of 3 0C/min up to 950 0C for 4 h. Then the samples were tested for water absorption, compressive strength and thermal conductivity. From the test results it can be said that the bricks obtains superior engineering properties when 10 wt% of waste is added. Adding higher amount of waste (30–50 wt %) resulted in bricks with higher water absorption and low compressive strength. The addition of 10 and 20 wt % of OPBA produced bricks with a bulk density of 1635 and 1527 kg/m3 and a compressive strength of 33.9 MPa and 14.2 MPa, respectively. Fired bricks fulfil standards requirements for clay masonry units, offering, at the same time, better thermal insulation of buildings due to a reduction in thermal conductivity of 14.4% and 16.8% respectively, compared to control bricks (only clay).

Lingling et al. [8] uses fly ash in wet state with low quality as raw material to replace clay to make fired bricks. Pulverized fly ash also used along with clay to make bricks. Fly ash was mixed with clay in different compositions from 50% to 80% by volume%. The mixed were then caste to brick in 60mm X 60mm X 25mm and dried at ambient condition for 2 days, followed at 60 0C for 4 h and at 100 0C for 6 h. The unfired bricks were burnt in electric furnace. Heating rate was 100 0C /h below 500 0C, then 50 0C /h from 500 0C to the highest temperature, and keeping 8 h at sintering temperature. The bricks were tested for apparent porosity, water absorption, bulk density and compressive strength. The results indicate that the plasticity index of mixture of fly ash and clay decrease dramatically with increasing of replacing ratio of fly ash. The sintering temperature of bricks with high replacing ratio of fly ash was about 1050 0C, which is 50–100 0C higher than that of clay bricks. Maximum compressive strength achieved was 98.5 MPa with water absorption 17.62% which is mixture of 50% fly ash and 50% clay by volume and sintered at temperature of 1050 0C. The properties of fired bricks were improved by using pulverized fly ash. The fired bricks with high volume ratio of fly ash gives high compressive strength, low water absorption and did not cracking due to lime.

Namkane et al. [9] studied possibility of using coal bottom ash (CBA) as the raw material to produce ceramic floor tiles. The major properties of the production were investigated, including chemical, physical, mechanical, and thermal properties. The formulations of the batch samples prepared by mixing the CBA with clay from 20 to 80 % and later improvement in properties also checked due to addition of sand. A quantity of 20 g of each batch sample was mixed with water (5 %). Samples of cylindrical shape to be fixed in a basic cylindrical device used for water absorption with a diameter of 4.60 cm and thickness in the region of 0.65 cm were molded in a dry press and dried for 24 h at 110 0C. After that, the test samples were fired at temperatures of 1100, 1150, 1175, or 1200 0C. The body of ceramic properties was investigated. For large scale study the test specimens were produced in the form of a square ceramic floor tile with the size of 10 cm X 10 cm X 0.8 cm. Each group of the test specimens was fired at 1100, 1150, 1175, or 1200 0C at a heating rate of 5 0C /min and a soaking time of about 30 min at the appropriate temperature. The results indicated that the optimal firing temperature was approximately 1175 0C, yielding low water absorption. Results showed that CBA content combined with clay in the batch samples should not be more than 40 wt%. The addition of sand could reduce linear shrinkage and increase the whiteness of the fired body. Water absorption <3% and flexural strength in the range of 22–30 MPa can be achieved using these materials.

Kae Long Lin [10] studied the effect of municipal solid waste inclinator (MSWI) fly ash slag on fired clay bricks. The MSWI fly ash slag was prepared by first melting it at 1400 0C for 30 min. The molten slag was then water quenched to produce a fine slag. The water quenched slag was then further pulverized in a ball mill. The MSWI slag content in the clay MSWI slag mixture was varied from 0 to 40% (by weight). The mixtures were then homogenized in a blender and molded under 60 kg/cm2 of pressure to form 50mm (L) X 25mm (W) X 50mm (H) bars. The results obtained from the laboratory tests can be applied to the commercial size brick since it was constructed by the same component and process. Therefore, the scale up of the brick sample should be acceptable in this study. The molded specimens were air dried at room temperature for 24 h, and then oven dried at 80 0C for another 24 h to remove the water content. The dried specimens were then heated to a designated temperature (800, 900 and 1000 0C). The results indicated that the bulk density of the bricks increased when the MSWI slag content increased. Compressive strength above 600 kg/cm2 was achieved when 40% MSWI slag were added to the brick and heated to 1000 0C. The heating temperature of 1000 0C, produced a significant densification, resulting in a total shrinkage in volume, a decrease in the water absorption rate and an increase in the density and compressive strength.

Loryuenyong et al. [11] uses wasted glasses from structural glass walls up to 45 wt.% added into clay mixtures in brick manufacturing process. The wasted glasses were first ball milled and screened to1 mm opening size. The mixtures with various proportions of glass powders (0, 15, 30 and 45 wt.%) were added with clay. Then brick of size (6.5 X 14.0 X 4.0 cm3) were molded and fired at 1000 0C to 1200 0C. The results indicated that with proper amount of wasted glasses and firing temperature, clay bricks with suitable physical and mechanical properties could be obtained. The compressive strength as high as 26–41 MPa and water absorption as low as 2–3% were achieved for bricks containing 15–30 wt.% of glass content and fired at 1100 0C. When the glass waste content was 45 wt.%, apparent porosity and water absorption was rapidly increased and compressive strength decreased.

IV. DISCUSSION

From the reviewed works it can be said that temperature leads a very important role for the manufacturing of ceramic products. The products will not develop strength or other physical properties if they are fired at temperature below the sintering temperature and if they were fired at more temperature than sintering temperature then they will melt. Not much work has been done to produce acid resistant bricks using waste materials but the works which are reviewed have shown a promising results. Very good physical properties are achieved in the works [1, 5] in which granite waste is used to manufacture acid resistant brick. Granite waste which contains high amount of SiO2 and potassium feldspar can be a suitable material to be used to manufacture acid resistant bricks. Granite also has high density and its compressive strength generally lies above 200 MPa. Lot of work has been done to manufacture fired bricks using fly ash. In work [6, 8, 10] bricks made with fly ash achieves high amount of compressive strength. The bricks produced using fly ash [6, 10] as waste shows improvement in its properties with increase in fly ash content whereas the bricks produced using olive pomace bottom ash [7] and fly ash [8] as waste shows decrease in its properties with higher content of ashes. The results came opposite may be because they are batched with different ashes and different clay. Fly ash also has low thermal conductivity so bricks made by fly has low thermal conductivity than the bricks made with clay only. Though fired bricks made with fly ash shows good physical properties but their uses in fired brick is very limited.

CONCLUSION

Based on the review of the various studies on production of bricks from waste materials, the following conclusions can be drawn:

- Much work is not done to produce acid resistant brick using industrial waste and more works needs to be done to understand the potentiality of the various waste for better utilization.
- Though fly ash is been used to manufacture fired bricks and promising results came but no work is been done to check possibility of using fly ash to manufacture refractory bricks.
- Uses of industrial waste will reduce the consumption of non-renewable resources and natural resources such as clay.
- The addition of wastes to the ceramic mixture can improve the quality of brick and reduce its manufacturing cost.
- More works need to be done to properly understand the potentiality of these industrial waste for the production of various ceramic products.

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