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Development Of Bricks From Waste Material: A Review Paper

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Abstract: Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population which causes a chronic shortage of building materials, the civil engineers have been challenged to convert waste to useful building and construction material. Recycling of such waste as raw material alternatives may contribute in the exhaustion of the natural resources; the conservation of not renewable resources; improvement of the population health and security preoccupation with environmental matters and reduction in waste disposal costs. In the review of utilization of those waste, this paper reviewed recycling various waste material in bricks production. The effects of those wastes on the bricks properties as physical, mechanical properties will be reviewed and recommendations for future research as out comings of this review will be given. This reviewed approach on bricks making from waste is useful to provide potential and sustainable solution.

Key words: bricks, waste material, bricks properties

INTRODUCTION

The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting the environment as well as maintaining the material requirements affirmed in the standard. Recycling of waste generated from industrial and agricultural activities as building materials appears to be viable solution not only to such pollution problem but also to the problem of economic design of buildings (Perez JA *et al*, 1996). Brick belongs to the wide family of construction materials since it is mainly used for the construction of outer and inner walls in buildings. The brick industry is the most indicated technological activity sector to absorb solid waste due to the large quantity of raw material used by the sector as well as by the large volume of final products in construction (Andreola et. al, 2005)

Various attempts were made to incorporate various waste material in bricks production such as natural fibers, textile laundry wastewater sludge, foundry sand, granite sawing waste, perlite, processed waste tea, sewage sludge, structural glass waste, PC and TV waste, fly ash, sugar cane baggase ash, organic residue, steel dust, bottom ash, rice husk ash, silica fume, marble and granite waste, municipal solid incineration fly ash slag (Chee-Ming, 2011- Raut *et al*, 2011). This review highlights the effects of various waste material on the bricks property like physical and mechanical properties as well as thermal insulation.

Development Of Bricks From Industrial Waste:

(Chee Ming, 2011) examined the mechanical properties of clay brick made by adding two natural fibers like oil palm fruit (OF), and pineapple eaves (PF) to clay-water mixture with baked and non baked conditions. Compressive strength, water absorption and efflorescence were performed according to British standard BS3921:1985, and Malaysian Standards MS 76:1972. Results indicated that the compressive strength of the bricks were fulfilled the minimum requirement of BS3921:1985 for compressive strength which is 5.2 MPa for conventional bricks. Efflorescence was only feasible for baked samples as the non baked ones formed severe deterioration while testing. The prevailing benefit of the fiber inclusion was more benefit for baked specimen where the strength get surpassed that of non baked added only specimen.

(Paki *et al*. 2012) investigated the potential use of crumb rubber–concrete combination for producing a low cost and lightweight composite brick with improved thermal resistance. The obtained compressive strength, flexural strength, splitting strength, freezing–thawing resistance, unit weight and water absorption values satisfy with the relevant international standards. The experimental observations reveal that high level replacement of crumb rubber with conventional sand aggregate does not exhibit a sudden brittle fracture even beyond the failure loads, indicates high energy absorption capacity, reduces the unit weight dramatically and introduces smoother surface compared to the current concrete bricks in the market. Thermal insulation performance is improved by introducing various amount of crumb rubber into the ordinary cementitious mixes.

(Luciana C.S *et al*., 2012), proposed mixing of textile laundry wastewater sludge with clay to produce bricks for civil construction. All bricks were fabricated by extrusion method, dried at 100°C and then fired at 900°C. Mechanical properties of ceramics as flexural strength and water absorption were satisfactory within the Brazilian legislation. The obtained results showed that sludge can be incorporate bricks until a concentration of

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20% (mass basis) producing suitable bricks in terms of its mechanical properties. Besides, the produced brick are safe and inert according to the applied leaching a solubilization tests.

(Hanifi *et al*., 2005) presented an earthquake-resistant material with high compressive strength. He elaborated the compressive strength of fiber reinforced mud bricks made out of clay, cement, basaltic pumice, lime and gypsum using plastic fiber, straw, polystyrene fabric as fibrous ingredients, each at a time. It was demonstrated that the fiber reinforced mud brick fulfill the compressive strength requirement of Turkish codes, whereby reducing the weight and material handling cost for housing. Furthermore, it can store more elastic energy compare to the other type of mud brick which renders it more resistance to earthquake.

(Alonso *et al*., 2012) developed a comparative study to produce ceramic bricks from clay with two types of foundry sand (green and core sand). Clay/green sand bricks with 35 % green core and 25 % green sand fired at 1050°C have the better physical properties values, while the mineralogy is not significantly affected. It was shown that foundry sand is recommended as raw material in the manufacture of ceramic product, whereby saving in costs of brick production. (Romualdo *et al*., 2005) investigated the possibilities of using the granite sawing waste as alternative ceramic raw materials in the production of ceramic bricks and tile. Samples were uni axially pressed and then fired at 850 °C. Results for tests on ceramic compositions showed that samples with (10-30) % granite waste have physical and mineralogical characteristics similar to those of conventional ceramic raw materials. Ceramic compositions with the addition of those waste produced water absorption lower than 3%, it was proved that recycling sludge in the production of ceramic bricks and tiles was feasible.

(Kay and Volker, 2002) conducted a pilot experiment at a full-scale in recycling the harbour sediments mixed with waste brick and clay. Bricks were produced according to German industrial standards. The leaching of the bricks was not hazardous to soil or groundwater neither by their use, for example, in masonry, nor afterwards, when they will be deposited as mineral demolition mass. (lker *et al*., 2007) had investigated the production of high heat conductivity resistance bricks from perlite and clay with some binding materials such as cement, gypsum, lime, bitumen and clay were used for manufacturing perlite brick. Samples were dried in 200°C and then fired at 950°C. It was demonstrated that the compressive strength of bricks was decrease, shrinkage and heat conductivity resistance were increased with the increase of perlite dose. It was proved that perlite brick is good insulator according to bricks standards and the best mixture content was determined as containing 30% of perlite.

Faria *et al*. (14) recycled the sugarcane bagasse ash waste through replacement of natural clay, samples were prepared by uni axial pressing at 21 MPa, dried at 110°C and then fired at 1000°C. Results for scanning electro microscope (SEM) showed that the sugarcane bagasse ash waste is mainly composed by crystalline silica particles and it could be used as a filler in clay bricks, thus enhancing the possibility of recycling it in a safe and sustainable way. Recycling of sugarcane baggase ash in clay brick showed highly positive results in terms of environmental protection, waste management and saving of raw material. (Taner, 2006) studied the feasibility of utilizing the clay waste (CW) and fine waste of boron (FW) as a fluxing agent in production of red mud (RM) brick. Bricks were dried in a room temperature and then fired at 1000°C. The mineralogical and mechanical tests confirmed the possibility of recycling the boron waste as a fluxing agent in the production of RM bricks .

(J.A. Cusido´*et al*. 2003) developed lighter, more thermal and acoustic insulating clay brick, compared with conventional clay-bricks by mixing clay with sewage sludge, and forest debris. Bricks were dried at 100°C and then fired at 1000°C. It was shown that level of emissions of green house gas was 20 times higher than the conventional ceramic firing even though they are still legally allowed within the limitation of Environmental Protection Agency recommendations. (Carretero, 2003) produced clay brick from very different clay, calcareous and non-calcareous. Samples were obtained by three processes pressing, extrusion and firing at 110°C. The mechanical resistance, pore size distribution and critical pore diameter did not clearly reflect the influence of shaping techniques.

(Vorrada *et al*., 2009) recycled wasted glasses from structural glass walls into clay mixtures. The compressive of bricks was as high as (26–41) MPa and water absorption as low as (2–3) % were achieved for bricks containing (15–30) % by weight of glass content and fired at 1100°C. When the glass waste content was 45 % by weight, apparent porosity and water absorption was rapidly increased. (Martínez *et al*., 2012) replaced clay in a ceramic body with different proportions of sludge. Results for mechanical properties as water absorption, compressive strength and water suction showed that the bricks incorporated 5% of sludge showed good mechanical properties.

(Michele et. al., 2010) studied the potential utilization of tionite as coloring agent in clay bricks. Samples were dried at 100°C and then fired at 1000°C. Additions over of 5% of tionite induced significant variations, such as increase of working moisture and water absorption, decrease of bulk density and bending strength. Therefore, the optimum proportion of tionite was found to be 3 %. (Dondi *et al*., 2009) investigated the utilization of funnel and panel glass of TV and PC glass waste mixed with clay, sample was dried at 100°C and then fired at 900°C. It was demonstrated that adding of 2% of glass waste to clay body doesn't bring about significant changes in the technological performance of fired bricks. However, adding more than 5% of the waste may have deleterious on mechanical properties and efflorescence. Results for leaching test demonstrated

no significant environmental pollutant emission. (Kae Long, 2006) investigated the addition of municipal solid waste incineration fly ash slag (MSWI) on fired clay bricks, bricks were fired at 1000°C. Results for leachates test met the current thresholds. Results for the mechanical properties met the Chinese National Standard (CNS) for building requirements for second-class brick. It was shown that the increasing of MSWI decreased the water absorption and increased the compressive strength of the sintered bricks.

(Eliche *et al*., 2006) recycled various industrial wastes such as urban sewage sludge, bagasse, and sludge from the brewing industry, olive mil wastewater, and coffee ground residue were blended with clay to produce bricks. It was shown that the compressive strength increased with the increase of sintering temperature. The incorporation of coffee grounds and olive mill wastewater of clay was more beneficial, compressive strength values were similar to bricks without waste and with a 19% improvement in thermal conductivity; the bricks met the required specifications for the water absorption and compressive strength. (Ismail *et al*., 2003) studied the addition of waste-brick material to clay bricks. The results showed that the reuse of this material in bricks industry would contribute to the protection of farmland and the environment. (Pai-Haung *et al*., 2004) manufactured bricks from clay and steel slag. Results showed that when the firing temperature was greater than 1050°C and the slag addition less than 10 %, the bricks met the Chinese National Standards for third-class brick for builders.

(Eduardo *et al*., 1996) tested the use of clay in the formulation of ceramic body incorporated steel dust. The bricks met the standard commercial regulations being inert to leaching tests and ceramic process had law emission of dangerous gases. The addition of steel dust reduced the firing temperature of the ceramic process in which meeting the recycling Environmental Protection Agency requirement for the disposal of hazardous waste.

(Abdul *et al*. 2004) recycled the sewage sludge as a raw material in clay brick making. Results for the physical and mechanical properties of bricks were capable of meeting the relevant technical standards. However, bricks with more than 30% sludge addition were not recommended for use since they were brittle and easily broken even when handled gently. Therefore, sludge bricks of this nature were only suitable for use as ceramic bricks which are normally not exposed to view because of poor surface finishing. (Acosta *et al*., 2002) developed red mud brick by mixing sterile clay deposit with IGCC slag. Results for this experimentation suggested that the IGCC can be applied to the ceramic process. Moreover, it had exhibited other advantages as water savings and improvements on the properties of the final products. In the finished product, IGCC slag increases the water absorption as well as frost resistance and vitreous sound. The bricks manufactured from IGCC slag can be classified as rugged and face view.

(Geiza *et al*., 2004) recycled the solid waste generated by the steel work in Brazil for manufacturing clay-based structural products. Tests results for mechanical properties and leaching indicated that the solid generated by steel works can be used in construction materials, thereby reusing those waste in environmentally safe manner. (Chihpin *et al*., 2005) did a study on recycling the water treatment residual (WTR) and the excavated soil, the ceramic bodies were prepared and sintered to formulate into building bricks and artificial aggregates. The sintering temperature requirement by WTR was higher than normally practiced in brick works due to the higher Al_2O_3 and lower SiO_2 content. Test results of specific gravity, water absorption, and compressive strength of the ceramic bodies confirmed its applicability in construction.

(Rania *et al*., 2011) recycled marble and granite waste of different sizes in the manufacturing of concrete bricks, with full replacement of conventional coarse and fine aggregates with marble waste scrapes and slurry powder. Results on the physical and mechanical properties of bricks qualified them to be used in the building sector as non load bearing spacing construction materials, where all cement brick samples tested in this study complied with the Egyptian code requirement for structural bricks. (Chin *et al*., 1998) developed a technology for reusing the paper sludge and co-generation ashes generated by the paper industry in producing bricks, bricks were fired at 1000°C. The constructional bricks made from co-generation ashes and other raw material had a water absorption rate lower than 15 %, and compressive strength greater than 150 kg/cm^2, conformed to the relevant specifications and the bricks can be used as non load bearing spacing construction material. (Quintilio *et al*., 2011) produced an earthen brick from straw fibers and coarse sand by manual compaction. Mechanical properties had been investigated by a combined experimental and theoretical approach. Results were discordant because of the lack of more statistically relevant data.

(Cheng *et al*., 2006) investigated the properties of water permeable bricks made of water treatment sludge and bottom ash (BA) without involving an artificial aggregate step. The mechanical properties of the sintered bricks were examined with respect to relevant standards. It was found that 20 % by weight content of bottom ash under a sintering condition of 1150°C could generate a brick with a compressive strength of 256 kg/cm^2, a water absorption ratio of 2.78 % and a permeability of 0.016 cm/s. Bricks developed in this study could be used as water permeable, environmentally friend product as pavement brick in an urban area. (Chiang *et al*., 2000) produced novel light weight bricks by sintering mixes of dried water treatment plant sludge and agricultural waste with rice husk ash. Bricks containing 40 % by weight rice husk sintered at 1100ºC produced low bulk density and relatively high strength that were compliant with relevant Taiwan standards for use as lightweight bricks in future green building. Results for toxic characteristic leaching procedure (TCLP) concentration

indicated that TCLP concentrations of Cu, Zn, Cr, Cd, and Pb in the sintered products were lower than regulation thresholds.

(Kidsarin *et al*., 2001) developed a new approach in making bricks from 100 % lingnite fly ash. The fly ash bricks developed in this study showed superior mechanical strength especially compressive strength compared with red-fired clay brick, facing bricks and other types of fly ash bricks. (Badr *et al*., 2012) investigated the complete substitution of clay brick by sludge mixed with rice husk ash (RHA) and silica fume (SF). Bricks were fired at 1000°C. Bricks contained 25% SF and 50% sludge showed superior mechanical properties as compared with conventional bricks and with those available in the Egyptian code. (Weng *et al*., 2003) developed bricks from dried sludge collected from an industrial wastewater treatment plant. The bricks incorporated sludge conformed to the Chinese National Standards for building bricks.

(Malhotra and Tehri,1996) developed bricks from granulated blast furnace slag. The study revealed good quality bricks can be produced from a slag-lime mixture and sand by pressing the mix at 50 kg/cm^2 pressure. Compressive strength of final products ranged in (80-150) kg/cm^2, it was evidenced that the slag consumes less energy as compared with conventional burnt clay or calcium silicate brick.

(Oti *et al*., 2009) produced unfired clay brick by recycling a ground granulated blast furnace Slag (GGBS) activated with an alkaline lime and Portland cement combined with clay soil. The mixed materials were manually pressed with 140 bar. Mechanical properties and durability assessment were all within the acceptable engineering standards for clay masonry units. (Yin sung, 2003) produced bricks from reservoir harbor sediment mixed with fly ash. The mixed materials were pressed by 15000psi. (Sivakumar *et al*., 2012) manufactured bricks from thermal power plant bottom ash, fly ash mixed along with water and cement. The bricks were produced by making flow-able mix with high w/c ranged in (1.5-5.5). Results for compressive strength ranged in (5-10) MPa, water absorption varied from 7 to14 %, ultra sonic pulse velocity fell in range between (2.556-2.819) km/s. Unlike the conventional method for producing bricks, the new procedure neither used clay and shale nor required high temperature kiln firing, having significant environmental and ecological benefits

(Saeed and Lianyang, 2012) investigated the feasibility of utilizing copper mine tailings for producing eco-friendly bricks based on the geo-polymerization technology. The mixed material was placed in a miniature compaction cylindrical mould with minor compaction. The compacted specimens were then compressed with a Geo-test compression machine at different loading rates ranged from (0.5-30) MPa. Physical and mechanical properties of copper mine tailings-based geo-polymer bricks were investigated using water absorption and unconfined compression tests. Results showed that copper mine tailings can be used to produce eco-friendly bricks based on the geo-polymerization technology to meet the American Society Testing Material (ASTM) requirements.

(Raut *et al*., 2011) did a review study in developing bricks from various industrial and agricultural waste material like paper processed residues, cigarettes buts, fly ash- lime gypsum, cotton waste, limestone powder waste, textile effluent treatment plant, Organic residue, kraft pulp residue, petroleum effluent treatment plant sludge and recycled sludge welding flux. Water absorption and compressive strength of bricks developed from those waste were reviewed. It was concluded that the bricks developed from paper processing residues and waste paper pulp showed the highest compressive strength greater than 12 times from the minimum recommended by Indian Standard IS1007:1992.

Discussion:

It was shown that the past studies recycled various sorts of waste in bricks making. Different tests were conducted on the bricks manufactured from waste. Bricks property like physical, mechanicals has been positively influenced by the additional of waste material. Moreover, utilization of waste in bricks manufacturing may contribute to the conservation of natural resources, environmental protection and saving in land for construction. Furthermore, there will be energy conservation which is in otherwise, will be spent in extracting, handling and reclaiming the virgin resources as clay or shale in bricks production. It was evidenced that researches like Oti *et al*., 2009), (Yin sung, 2003), (Sivakumar *et al*., 2012) and (Saeed and Lianyang, 2012) were successfully produced non fired bricks from waste material. This option would be more economical when accounting the extensive consumption of energy resources as electricity or fossil fuel in kiln brick firing (Syed and Mike Starr, 2009), (Michael Chusid *et al*, 2009). Besides, the pollutant gasses as carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3) and in some cases chlorine and fluorine which are unsafe gases which are usually emitted through bricks firing (Toledo *et al*, 2004), (Gonzalez *et al*, 2011) and (Christopher *et al*, 2007) will be considerably reduced in non fired bricks, hence sustainability will be achieved. Future works should hold more studies in producing the bricks by an economical and environmental approach neither consume energy nor emit pollutant gases. Regarding the bricks kiln firing, alternative fuel should be experienced as gas methane or petroleum cock in which environmental protection will be assessed.

Conclusion:

The various wastes that are currently recycled in bricks manufacturing have been reviewed. The effects of those wastes on the bricks properties are reviewed .Enhance performance in terms of making more environmental and an economical brick neither consumes energy resources nor emits pollutant gases gives an economical option to design the green building. Certain bricks are produced without firing which is an advantage over other manufacturing of bricks in term of low embodied energy material. The study in turn is useful for various resource persons involved in using industrial or agricultural waste material to develop sustainable construction material.

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