Utilization of Waste Materials In Brick Construction: A Review Paper

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Abstract- *Reuse of waste generated from industrial and agricultural activities as building materials appears to be viable solution to problem of pollution and waste disposal. In India it has been estimated that nearly 30% of the daily production turns on waste during the manufacturing, transportation and usage. From decades burnt clay bricks have been used in the building construction and it helps to reduce the energy consumption of buildings due to its excellent thermal insulation property. As a result of this, there is still an existing demand for clay bricks and huge quantity of soil is being exploited for its production. This paper presents a review of research on utilization of waste materials to produce bricks. A wide range of successfully recycled materials and their effects on the physical and mechanical properties of bricks have been discussed. This reviewed approach on bricks manufactured from waste is useful to provide potential and sustainable solution.*

Keywords- Reuse, waste materials, Properties

I. INTRODUCTION

Housing is one of the basic requirements for human survival. Masonry is an inevitable component of housing. Among different types of masonries, brick masonry is one of the most widely used in our country, because of low cost, easy availability of raw materials, good strength, easy construction with less supervision, good sound and heat insulation properties, and availability of manpower. Brick masonry is a composite material of systematic arrangement of brick units and mortar joints. The behaviour of masonry is dependent on the properties of its constituents such as brick units and mortar separately and together as a unified mass. Burnt clay bricks are widely used around the globe but in recent years many other varieties of bricks have been developed.

Brick is one of the oldest manufactured building materials in the world. The fired bricks were further developed as archaeological traces discovered in early civilizations, such as the Euphrates, the Tigris and the Indus that used both fired and unfired bricks. The development of different types of bricks continued in most countries in the world and bricks were part of the cargo of the First Fleet to Australia, along with brick molds and a skilled brick maker. Bricks have continuously been used by most cultures throughout the ages for buildings due to their outstanding physical and engineering properties. Brick is one of the most demanding masonry units. It has the widest range of products, with its unlimited assortment of patterns, textures and coolers. In 1996, the industry produced 300 million bricks in Victoria, which were about 55% of the potential production of the facilities available. The export markets included Japan, New Zealand, the Middle East and other Asian countries. Brick is durable and has developed with time. With the advancements in technology, it led to the development of concrete, mortar, cellular and hollow blocks. The main advantage of using clay bricks is its thermal insulation property. It helps the building to remain cool during summers. As a result of this, there is still a rising demand for clay brick. The main raw material for bricks is clay besides clayey soils, soft slate and shale, which are usually obtained from open pits which may include disruption of drainage, vegetation and wildlife habitat. Soil used for brick making vary broadly in their composition and are dependent on the locality from which the soil originates. Different proportions of clays are composed mainly of silica, alumina, lime, iron, manganese, Sulphur and phosphates.

II. LITERATURE REVIEW

Muhammad A. Saleem et. al. (1) studiedrice husk ash (RHA) and sugarcane baggase (SBA) incorporated in the replacement of clay in fired clay bricks and the effect of finding difficulty in disposal. Utilization of RHA and SBA has resulted in production of lighter clay bricks. Based on the results it was found that incorporation of 5% RHA and SBA can be used for brick production with economy and sustainability. The porous nature of the brick incorporating increased dosage of SBA and RHA may be due to the organic matter decomposition during firing. Due to the porous nature of the bricks there may be an increase in water absorption of the bricks. By using fluxing agents,it may help in reducing porosity by compressing the interspaces during the process of firing. This can also help in reducing water absorption. So, when the organic matter content is more there is a need for adding fluxing agent or reduce the amount of the organic matter to reduce porosity and to improve the compressive strength of the clay brick.

Nonthaphong Phonphuak et. al. (2)studied thewaste glass utilization, to enhance physical-mechanical properties of fired clay brick. The physical and mechanical properties of fired clay bricks incorporating 0, 5, 10% waste glass and fired at 900- 1000^{o}C were investigated. It was observed that the properties were improved with increase in waste glass content as well as firing temperature. The optimum waste glass content was found to be 10% at firing temperature 900^{o}C as it had compressive strength like the brick without incorporating waste glass and fired at 1000^{o}C. Increasing the firing temperature can increase the density and lower water absorption of clay bricks. The increase in compressive strength and decrease in the porosity may be caused due to the closing of the pores by the glassy phase at higher firing temperature. The waste glass particles on fusing with the clay particles may contribute to the densification of the clay brick. The densification of the intermolecular particles might have decreased the porosity and hence the water absorption. So, the addition of more percentage of waste glass may increase compressive strength and reduce porosity, water absorption and firing temperature.

Osman Gencel et. al. (3) investigated the utilization of waste marble powder in fired clay brick production. It was found that the bulk density of bricks decreased with the increase in marble waste. The compressive strength up to 30% replacement was found to be above the maximum standard required. Weight loss was found for the brick incorporating marble powder. The weight loss may be due to the burning of organic matter or the removal of chemical water in brick clay material. The bulk density tends to increase with increase in temperature due to consolidation of particles. But, the bulk density was found to be decreasing with increase in marble powder content, which may be due to the increase in decomposition of carbonates in the brick mixture. The porosity of the bricks incorporating marble powder was increased which may be due to the decomposition of $CaCO_3$ in marble powder. Due to the increase in porosity the water absorption also increased. The compressive strength of the bricks incorporating marble powder was found to be decreasing, which may be due to the increase in porosity of the bricks. Thus, the bricks cannot be incorporated with more percentage of waste marble powder (>30%) since the porosity and compressive strength was decreasing.

S.M. Moniruzzaman et. al. (4)studied the feasibility of arsenic iron sludge in clay brick production. The strength of the brick depends upon the temperature and the sludge content. Compressive strength of prepared bricks initially increased and then decreased with the increase of sludge proportion. Clay particles consist of negatively charged colloids and this forms bond with the positively charged iron hydroxides. With the further increase in iron sludge content the iron content might not find charge particles to bond with which may be the reason for the decrease in the compressive strength. Thus, only optimum percentage of sludge (6%) should be incorporated in the preparation of burnt clay bricks. Tests on leaching characteristic shows that the amount of arsenic and iron leaching from the sludge-bricks were higher for both acidic and alkaline mediums. Thus, the prepared bricks should not be exposed to those mediums.

Ahmed Mohammed Hassanain et. al. (5) studied incorporation of water sludge, silica fume (SF), and rice husk ash (RHA) in brick making. The waste treatment plant sludge (WTP) sludge can be successfully used in brick manufacture incorporated with agricultural and industrial waste materials, which contain high silica content, such as RHA and SF. The chemical composition of water treatment plant sludge was extremely close to brick clay but higher sintering temperatures are required for sludge due to its lower silica and higher alumina contents. The maximum percentage of WTP sludge, which can be used in the mixture, should be determined by the practiced firing temperatures. A mixture consists of 50% of WTP sludge, 25% of SF, and 25% of RHA was the optimum materials proportions to produce brick from water treatment plant sludge incorporated with SF and RHA; by operating at the temperatures commonly practiced in the brick factories and based on the experimental scheme such as tested materials and testing procedures employed in the research.

Joo-Hwa Tay (6) studied the utilization of dried sludge and sludge ash as brick making materials. Sludge from wastewater treatment plants creates problems of disposal. The maximum percentages of dried sludge and sludge ash that could be mixed with clay for brick making are 40% and 50% by weight, respectively. The large amount of organic matter present in the sludge resulted in high shrinkage of the bricks during firing. The texture and finish on the surface of the bricks made from the mixtures of clay and sludge are rather poor, and they may not be acceptable for use as facing brick. For the sludge ash bricks, the specific gravity of the bricks increases slightly as the percentage of sludge ash increases. Water absorption of the bricks increases as the percentage of dried sludge increases. This indicates that durability of the bricks would be lower at higher percentages of sludge. Bricks made with sludge ash have lower water absorption values than those with dried sludge. This indicates that bricks made with sludge ash would probably have a better durability than those made with dried sludge.

Shrikant S Jahagirdar et. al. (7) had investigated the utilization of textile mill sludge in clay bricks. The study demonstrates that textile mill sludge can be used as partial replacement for clays in burnt clay bricks. Textile mill sludge can be used up to 15% without compromising on the compressive strength of 3.5 N/mm^2 and water absorption of 20% as per the IS code requirements.Organic matter present in the sludge gets burnt at temperature more than 550^0C, because of which large number of voids are created in the body of the bricks. This makes bricks porous resulting in lesser compressive strength and greater water absorption capacity. TGDTA analysis shows there is decrease in weight of sludge with increase in temperature because of burning of organic matter present in the sludge. Due to which large number of voids are created in the body of the bricks. This results in porous brick structure and lesser compressive strength and increased water absorption.

Ibrahim et.al.(8)studied acid resistant sewage bricks wherein local Egyptian siliceous plastic clay along with granite processing waste(dust) were used as the starting raw materials. Study was done for bricks with and without feldspar along with granite dust.According to the Egyptian standard the acid resistance bricks should have a crushing strength greater than 30MPa and weight loss less than 3.5% in an acid solution. 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. Microstructural study and the analysis of the sintered brick suggested formation of Neogenic feldspar minerals in the structure. The Neogenic feldspar formation has been correlated with the fine granite waste present in the body, which lowered the temperature of formation of liquid phase and the viscosity. It has been reported that the bodies 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(5to10%) showed increased values of strength and acid resistance, which were correlated with the increase in Na+ ions in the structure.

Menezeset.al. (9) studied the characterization of ceramic bricks and tiles, wherein granite sawing wastes from the process industries in Paraiba State, Brazil had been used as an alternative to the ceramic raw materials. The waste materials, in the form of granite sawing wastes, lead to pollution and damaging of the environment. Studies has been conducted to determine its suitability of use. It has been reported that the physical and mineralogical characteristics of granite wastes were similar to the conventional ceramic raw materials. The addition of wastes in ceramic compositions for production of bricks, up to 35% in weight, caused a slight increase in the water absorption.

Medhat S. et. al.(10) studied bricks resistible to the action of chemicals, wherein kaolin fine quarry residue (KFQR), the granulated blast furnace slag (GBFS) and granite basalt fine quarry residue (GBFQR) were used as raw materials. The study mainly concentrated on making bricks resistible to sewage waters, and possessing better properties than the conventional brick. Attempt has been made to study the properties of the bricks with composition KFQR (constant at 50%), GBFQR (increasing from 10 to 40%) with decreasing values for GBFS (decreasing from 40 to 10%). The different batches were studied and it was observed that ceramic properties were significantly harmed if the percentage of GBFQR is increased above 25%. This can be correlated to the presence of excess feldspar from the granite which forms large amounts of low melting phases. It was concluded that the batch containing 50% KFQR, 20% GBFQR and 30% GBFSfired at 1125°C exhibited the requisite ceramic properties and was in conformity to the Egyptian standards for Acid Resistant Bricks.

Aeslina Abdul Kadir. et. al. (11) studied possibile utilization of cigarette butts in lightweight fired clay bricks. Over a million tons of cigarette butts (CBs) are produced worldwide annually. The bricks became more porous as cigarette butts content increased. Low-densityor lightweight bricks had great advantages in construction, lower structural dead load, easier handling, lower transport costs, lower thermal conductivity, and a higher number of bricks produced per ton of raw materials. Light bricks can be substituted for standard bricks in most applications except when bricks of higher strength are needed or when a look or finish was desirable for architectural reasons

Miqueleiz L. et al.(12) studied the application of alumina filler wastes and coal ash waste for unfired brick production. There is a potential in using alumina filler(AF) waste as a target clay replacement material for unfired brick production. Although when AF waste was introduced the performance of the unfired test brick specimens was lower relative to the conventional unfired bricks. However, the strength resistance and water absorption values were within the acceptable limits for masonry unit. On the other hand, when coal ash (CA) waste is combined with cement or lime, it has a potential for various binding applications. The strength characteristics of the test specimens are improved by the presence of CA. This, may be due to the action of strong bounding of the soil particles. The use of bioenergy waste materials such as AF waste is recommended, especially when the materials add advantages of environmental benefits.

Saeed Ahmari et al. (13) studied the feasibility of utilizing copper mine tailings for production of eco-friendly bricks based on the geopolymerization technology. In this study, the effects of four major factors, sodium hydroxide (NaOH) solution concentration, water content, forming pressure, and curing temperature on the physical and mechanical properties of copper mine tailings based geopolymer bricks are investigated using water absorption and unconfined compression tests. Higher initial water content means larger amount of NaOH at a constant NaOH concentration and thus increases the strength of the geopolymer brick specimens. Higher forming pressure leads to larger degree of compaction and thus higher unconfined compressive strength, if no water is squeezed out during the molding process. When the forming pressure is too high, some water and thus NaOH will be lost and the UCS will decrease. By selecting appropriate preparation conditions (NaOH concentration, initial water content, forming pressure, and curing temperature), ecofriendly geopolymer bricks can be produced from the copper mine tailings to meet the ASTM requirements.

C.A. Garcia Ubaque et al. (14) studied the quality study of ceramic bricks manufacture with clay and ashes from the incineration of municipal solid wastes. The quality verification tests show that the bricks with low ashes content support higher loads and have higher resistance than those bricks made of pure clay. When the ashes content is increased to 20 or 40% the properties decreased with respect to the ones without ashes or with lower ash content. In the 90:10 proportion the quantity of pores reduces but their size lightly increases, whereas in the other proportions the number of pores increases as well as their size. This is due to the decomposition of the organic matter. Based on the stability and the quality tests and comparing the results with the current local regulation, is possible to have clay and ashes calcined units, the optimum proportion is 90% of clay with 10% of ashes.

Ismail Demir et al.(15) studied the utilization potential of Kraft pulp production residues in clay brick. One way of the increasing the insulation capacity of the brick is generating porosity in clay body. Combustible organic types of pore forming additives are most frequently used for this purpose. Due to the organic nature of pulp residue, pore forming ability in clay body was investigated. According to drying shrinkage and dry bending strength values, pulp residues can be used to stabilize the drying period of the clay brick. Pulp residue is easily burnt out from the clay body during firing. Organic nature of pulp residue makes a positive contribution to the heat input of the kiln. Pulp residue can be effectively used for the pore forming up to 5% addition level, further addition is not so effective for the decreasing of the bulk density of the clay body. Kraft pulp production residues can be used as an organic type pore-forming additive in clay body without any detrimental effect on the other brick manufacturing parameters.

Giuseppe Cultrone et al. (16) examined the changes in brick porosity upon firing (700 up to 1100^0C) and its relation to the mineralogical composition are examined by. Two types of raw clay with a composition representative of that used in brick-making industry were selected to manufacture the bricks, one contains notable amounts of carbonates, with a grain size of under 1 mm, and the other is predominantly quartzitic and lacking in carbonates. the presence or absence of carbonates strongly influences the porosity development and, therefore, the brick texture and physical mechanical properties. The carbonates in the raw clay promote the formation of fissures and of pores under 1 mm in size when the bricks are fired between 800 and 1000°C. The absence of carbonates results in a continuous reduction in porosity and a significant increase in the pore fraction with a radius >1 mm as the firing temperature rises and smaller pores. the main problem with calcareous bricks, therefore, is the presence of large amounts of small pores (<1 mm) and the formation of fissures which progresses quickly over time. The fissures, which radiate out from the grains, and the <1 mm pores, is formed by the decomposition of $CaCO_3$ and its transformation into CaO. This result in a notable increase of the water absorption values whereas the drying is slower. When there are high proportions of carbonates, higher temperature must be reached to obtain a good quality bricks.

Houda Mekki et al. (17) studied the introduction of olive mill wastewater (OMW) to replace fresh water normally used in clay brick manufacture. If introduced at the factory scale, this innovation would allow a substantial volume of OMW to be recycled, saving on the fresh water currently used in the brick-forming process. It was found to have no detrimental effect on extrusion performance when compared with the standard (control) product. During the subsequent brick drying operation, most of the OMW ie 98% water would be released as vapor. When it is inkiln, the remaining solids in the bricks would liberate additional heat, reducing the gross energy from fossil fuel currently required during firing. This resulted in the formation of open pores and produces slightly lighter bricks, with modestly improved thermal insulation properties.

Burak Is Ikdag et al. (18) studied the manufacture of high heat conductivity resistant clay bricks by incorporation of perlite. Perlite is an extremely useful material for heat insulation. Compressive strength decreases withincrease in replacement ratio of perlite.Heat conductivity resistance and shrinkage of perlite bricks increase as the replacement ratio of perlite increases. Maximum 30% and minimum 24% perlite were used to ensure expected heat conductivity resistance for perlite bricks. The most convenient series was determined as 30% replacement because the compressive strength obtained was at upper limit. It was proved that perlite brick is a good insulator.

L. Pitak et al. (19) studied the effect between rice husk and rice husk ash to properties of bricks. The results showed that increase in adding rice husk decreased compressive strength and density of specimens. This is because the combusted rice husk replaces with the space in the product which effect the density and compressive strength. The 2% of rice husk ash by weight increase the compressive strength and density. The main component of rice husk ash is Silicon Dioxide which effect of increasing interaction. The interaction is that heated ash in quartz form rises due to solid state sintering, effects strength of brick.

Ping Huai Chou et al. (20) studied Lightweight bricks manufactured from water treatment sludge and rice husks. Rice husk addition increased the porosity of sintered samples and higher sintering temperatures increased the compressive strengths. In the case of 1000^0C, the compressive strength of the sintered products gradually decreased with increasing rice husk addition. Theamount of open pores in the sintered products manufactured from WTP sludge and rice husk addition increased gradually compared to bricks made from WTP sludge alone. Due to the large amounts of open pores, sintered products have good thermal insulation properties for future green building applications.

III. DISCUSSION

It is evident that researchers have used various types of waste materials in different proportions and adopted different methods to produce bricks. Different tests were conducted on the bricks manufactured from waste. Physical and mechanical property of bricks 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. Regarding the bricks kiln firing, alternative fuel should be experienced as gas methane or petroleum in which environmental protection will be assessed. The increase in organic matter may lead to decrease in compressive strength. Similarly, decomposition of organic matter during firing may lead to increase in porosity. Clay particles consist of negatively charged colloids and this forms bond with the positively charged iron hydroxides, with the further increase in the waste content, it might not find charge particles to bond with which may be the reason for the decrease in the compressive strength. Addition of fluxing agent or reducing organic matter may help to improve the compressive strength of the bricks. Addition of powder in clay bricksmay help in reducing the shrinkage.

IV. CONCLUSION

By incorporating various waste materials, a more environment friendly and economical bricks can be produced. Such a brick neither consumes much of the energy resources nor emits pollutant gases and provides an economical option to green building design. 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.

REFERENCES

[1] Syed M. S. Kazmi, Safeer Abbas, Muhammad A. Saleem, Muhammad J. Munir and Anwar Khitab, “Manufacturing of Sustainable Clay Bricks: Utilization of Waste Sugarcane Bagasse and Rice Husk Ashes,” Journal of Construction and Building Materials, vol. 120, no. 1, pp. 29-41, September 2016

[2] Nonthaphong Phonphuak, Siwadol Kanyakam and Prinya Chindaprasirt,“Utilization of Waste Glass to Enhance Physical-Mechanical Properties of Fired Clay Brick,” Journal of Cleaner Production, vol. 112, no. 4, pp. 43057-3062, January 2016.

[3] Mucahit Sutcu, Hande Alptekin, Ertugrul Erdogmus, Yusuf Er and Osman Gencel,“Characteristics of fired clay bricks with waste marble powder addition as building materials,” Construction and Building Materials, vol 82, no. 1, pp 1–8, May 2015.

[4] Khondoker Mahbub Hassan, Kensuke Fukushi, Kazi Turikuzzaman, S.M. Moniruzzaman,“Effects of Using Arsenic-Iron Sludge Wastes in Brick Making,” Journal of Waste Mangement, vol 34, no. 6, pp 1072-1078, June 2014.

[5] Badr El-Din Ezzat Hegazy, Hanan Ahmed Fouad and Ahmed Mohammed Hassanain,“Incorporation of water sludge, silica fume, and rice husk ash in brick making,” Construction and Building Materials, vol 1, no. 1, pp 1568-1593, April 2012.

[6] Joo-Hwa Tay,“Bricks manufactured from sludge,” International Journal of Civil and Environmental Engineering, vol 113, no. 2, pp 153-167, April 1987.

[7] Shrikant S Jahagirdar, S. Shrihari and B. Manu,“Reuse of textile mill sludge in burnt clay bricks,” International Journal of Advanced Technology in Civil Engineering, vol 2, no. 1, pp 2231 –5721, June 2015.

[8] Ibrahim, D.M., Mostafa, A.A., Nour and W.M.N, "Granite processing waste as a source of flux for the production of acid resistant sewage brick," Journal of the European Ceramic Society, vol 55, pp 186-190, 2006.

[9] Romualdo R. Menezesa, Heber S. Ferreirab, Gelmires A. Nevesb, Helio de L. Lirab and Heber C. Ferreirab,"Use of granite sawing wastes in the production of ceramic bricks and tiles," Journal of the European Ceramic Society, vol 25, no. 7, pp 1149–1158, May 2005.

[10] Medhat S. El-Mahllawy,"Characteristics of acid resisting bricks made from quarry residues and waste steel slag," Construction and Building Materials, vol 22, no. 8 1887–1896, August2008.

[11] Aeslina Abdul Kadir and Abbas Mohajerani,"Possible Utilization of Cigarette Butts in Light-Weight Fired Clay Bricks," International Journal of Civil and Environmental Engineering, vol 2, no. 9, 118-122, 2008

[12] L. Miqueleiz, F. Ramirez , J.E. Oti , A. Seco , J.M. Kinuthia , I. Oreja and P. Urmeneta,"Alumina filler waste as clay replacement material for unfired brick production," Journal of engineering geology, vol 163, no. 19, pp 68–74, August 2013.

[13] Saeed Ahmari and Lianyang Zhang,"Production of eco-friendly bricks from copper mine tailings through geopolymerization," Construction and Building Materials, vol 29, pp 323–331, April 2012.

[14] C.A. García-Ubaque, Liliana Giraldo and Juan Carlos Moreno-Pirajan, "Quality study of ceramic bricks manufacture with clay and ashes from the incineration of municipal solid wastes," Sustainability, vol 70, no. 561, pp 736-749, January 2012

[15] Ismail Demira, M. Serhat Baspınara and Mehmet Orhanb Utilization of kraft pulp production residues in clay brick production, Building and Environment, 40, 1533–1537. (2005)

[16] Giuseppe Cultronea, Eduardo Sebastian, Kerstin Elert, Maria Jose ́ de la Torre, Olga Cazallaa and Carlos Rodriguez–Navarroa,"Influence of mineralogy and firing temperature on the porosity of bricks," Journal of the European Ceramic Society, vol 24, no. 3, pp 547–564, March2004.

[17] Houda Mekki, Michael Anderson, Emna Amar, Glynn R Skerratt and Mourad BenZina,"Olive oil mill waste water as a replacement for fresh water in the manufacture of fired clay bricks," Journal of Chemical Technology and Biotechnology, vol 81, no. 8, 1419–1425, August 2006.

[18] Iker Bekir Topcu and Burak Iskdag,"Manufacture of high heat conductivity resistant clay bricks containing perlite," Building and Environment, vol 42, no. 10, pp 3540–3546, October 2007.

[19] J. Sutas, A. Mana and L. Pitak,"Effect of Rice Husk and Rice Husk Ash to Properties of Bricks, Procedia Engineering, vol 32, pp 1061 – 1067, 2012.

[20] Kung-Yuh Chiang, Ping-Huai Chou, Ching-Rou Hua, Kuang-Li Chien and Chris Cheeseman,"Lightweight bricks manufactured from water treatment sludge and rice husks," Journal of Hazardous Materials, vol 171, no. 1-3, pp 76–82, November2009