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# Manufacturing of Eco-Friendly Brick: A Critical Review

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**ABSTRACT**
The oldest building material in the construction industry is the clay brick and in fact, it is the first manufactured one by man. Now-a-days, brick is one of the most common masonry units used as building material in the construction industry. Hence, the huge demand occurred in building material industry especially in the last decade owing to the increasing population. India is the second largest brick manufacturer in the world. India produces bricks using the traditional methods that are more than 125,000 registered / unregistered clay brick kilns, which meet the annual demand of more than 250 billion bricks. The traditional methods consume 350 million tons of fertile soil and 25 million tons of coal annually (KEN RESEARCH Pvt. Ltd). Consequently, it becomes a big issue of environmental concern.
Recycling of waste materials such as fly ash, marble sludge, granite sludge, stone sludge, ceramic sludge, Plastic, coal and wheat husk, sawdust, Sugarcane Bagasse Ash (SBA), Rice Husk Ash (RHA), residual coal etc., are alternatives for the raw material instead of fertile clay that may contribute to the exhaustion of the natural resources. Hence, an eco-friendly brick manufacturing is utterly needed to overcome the conservation of non-renewable resources, improvement of the biotic health and security preoccupation with environmental matters and reduction in waste disposal costs. Previous researchers have demonstrated positive effects of using various waste materials in the manufacturing of bricks like physical and mechanical properties as well as its impact on the environment. This paper presents a review on the utilization of waste materials for manufacturing of bricks to provide a potential and sustainable solution for the eco-friendly environment.
**Key words**: Bricks, Fly ash, Marble sludge, granite sludge, stone sludge, Ceramic sludge, Rice Husk ash

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## I. INTRODUCTION

In both developed and developing countries, the problem of waste management has already become an issue to be addressed immediately. This problem is compounded by the rapidly increasing amounts of industrial wastes of a complex nature and composition.
Environmental energy also plays a crucial role in the growth of developing countries like India. An increasing interest in environmental issues has pressured industries to develop products and materials that are more environmental friendly. This interest drives in material production and process development for more sustainable practices. This review focuses more on bricks, which are one of the most important materials in construction industry. They are mainly used for constructing partitions and pillars inside the building of any residential apartment, bungalow or in public places like shopping complexes, malls, airport etc. For making a green building, it is important that the material using in such construction process should be environmental friendly.
Various attempts were made to incorporate different waste materials in brick production such as natural fibres, cotton waste, sewage sludge, Plastic waste, fly ash, sugarcane bagasse ash, bottom ash, rice and wheat husk ash, silica fume, marble and granite waste, ceramic waste, saw dust, wood waste, brick debris, crumble rubber, etc.,. This review highlights the effects of these materials on the brick properties like physical, mechanical properties and thermal insulation as well.

For large production of bricks from waste materials, a further research and development is to be required not only on the technical, economic and environmental aspects but also on standardization, government policy and public education related to waste recycling and sustainable development. Due to the demand of bricks as a building material, many researchers have investigated the potential wastes that can be recycled or incorporated as an additive in the manufacturing process of bricks.

## II. A LITERATURE SURVEY

### 2.1 Development of eco-friendly Bricks from Fly Ash

Venkatesh et al. (2017) discussed on the implementation of Fly ash and quarry dust as an effective replacement for cement in the manufacturing of bricks. The author examined three trial mix proportions such as Cement (50%, 60%, 70%), Fly Ash (40%, 30%, 20%) and 10% of Quarry dust. Based on the test results, the author concluded that the percentage of cement content can be replaced with quarry dust up to 25% without much loss in compressive strength and other properties.

Arati Shetkar et al. (2016) researched on fly ash bricks, which are a better alternative to conventional burnt clay bricks in structural, functional and economic aspects as these bricks are manufactured without the use of cement. The raw materials for these bricks are Fly ash (60% to 80%), lime (10% to 20%) and gypsum (10%), which are manually fed into a pan mixer and add sufficient water for intimate mixing. Based on the test results the FaL-G bricks are more safe, economical and having higher strength compare to conventional bricks. The author concludes that the FaL-G bricks are suitable for the construction of masonry structures.

Rinku Kumar and Naveen Hooda, (2016) researched on the effect of fly ash bricks on the performance and the properties with the comparison between clay brick and fly ash brick. The different tests are conducted like crushing strength, water absorption, shape and size, soundness, hardness and efflorescence. Based on the test results, fly ash bricks are stronger, more durable and economical when compared to conventional clay bricks.

Sivakumar Naganathan et al. (2015) an investigation carried out on manufacturing of bricks using fly ash and bottom ash through a non-conventional method. Bricks were cast using self-compacting mixtures of bottom ash, fly ash and cement eliminating both pressing and firing. Bricks are then tested for compressive strength, modulus of rupture, ultrasonic pulse velocity (UPV), and water absorption, initial rate of suction, fire resistance, and durability. The author concludes that the results showed better performance when compared to conventional clay bricks and these bricks can be used as an alternative to conventional bricks and hence it contributes to sustainable development.

Shweta et al. (2015) discussed on replacement of red bricks with eco – friendly AAC (Autoclaved Aerated Concrete) blocks. The usage of AAC block reduces the cost of construction up to 20% as reduction of a dead load of wall on beam makes it a comparatively lighter member. The use of AAC block also reduces the requirement of materials such as cement and sand up to 50%. As per the test results, the compressive strength of AAC blocks is comparatively more than traditional clay brick. Utilization of fly ash leads to the reduction in the cement consumption in production which results in reduction of greenhouse gases.

Watile et al.(2015) conducted an experimental study by utilization of rice husk in brick manufacturing. The materials used in manufacturing of bricks are clay, fly ash and rice husk. Coarse Rice husk (RH) was utilized by weight (0 to 5 %) as a brick material. The prepared mixture was compacted, sintering at brick kiln, and tested in the laboratory. The compressive strength obtained maximum at 2% use of RH in brick proportion and improve their workability properties.

Mayank Varshney et al. (2014) researched on making bricks with fly ash, Stone dust, and cement, which are better alternative to conventional burnt clay bricks in structural, functional and economical aspects and can fulfill the objectives of affordable housing. The proportion of the raw materials is taken in the ratio at 64% of stone dust, 30% of fly ash, 6% of cement and water. The results show that the Stone dust fly ash cement bricks have more compressive strength & less water absorption in comparison to conventional clay bricks. Hence, it concludes that the use of stone dust and fly ash in the brick manufacturing industry is techno-economically viable.

Ravi Kumar et al. (2014) discussed on the behaviour of fly ash bricks by taking different proportions of fly ash, cement, lime, gypsum and sand. Fly ash bricks are prepared with different percentage of cement such as 0%, 3%, 5%. Tests are conducted on these bricks such as compressive strength test, water absorption test, efflorescence, weight test, structural test, in order to have comparison with conventional bricks. Based on the experimental work, the author concludes that it is three times stronger than the conventional burnt clay bricks. Being lighter in weight as compared to conventional bricks, dead load on the structure is reduced and hence saving the overall cost of construction.

Rajendra Prasad et al. (2014) investigated for an alternative material in the manufacturing of brick is accomplished by using industrial byproducts like fly ash, granite dust and sludge lime as key ingredients. Ordinary Portland cement is utilized as a binder material in the proposed brick, i.e. 20%, 25%, 30%, 35%, 40%, 45% of the fly ash is replaced with the granite dust. Six proportions are considered and the materials are weighed according to the proportion and then cast. The casted bricks after drying for 24 hours are cured by two methods – Partial curing, Immersed curing. The chemical and physical properties are studied and then these bricks tested for Compression, Water absorption and Durability. The author concludes that the completely immersed brick samples project a higher Compressive Strength when compared to partially cured brick samples when the percentage of flyash and Granite dust are 55% and 25% respectively.

Apurva Kulkarni et al.(2013) researched on Bagasse ash can be utilized by replacing fly ash and lime in fly ash bricks. Bricks are tested with different proportions of0%, 10%, 20%, 30%, 40%, 50% and 60% with replacement of fly ash and 0%, 5%, 10%, 15% and 20% in replacement of lime. Compressive strength decreases on increase in percentage of bagasse ash as compared to fly ash. In this study, maximum compressive strength obtained at 10% replacement of fly ash.

Tahmina Banu et al. (2013) studied the production of lightweight structural bricks using fly ash as the major ingredient. Based on the test results, the optimum composition of fly ash-sand-lime-gypsum unfired bricks is fly ash 55%, sand 30%, lime 15% and gypsum 14% and optimum brick forming pressure is 3000psi. For optimum composition and pressure, bricks cured under spray water, twice a day exhibited maximum compressive strength of 442.96 gm/cm$^2$. The fly ash–sand–lime-gypsum bricks produced in this study seemed to be suitable for use as construction material.

Mamta Rajgor et al. (2013) discussed on the utilization of stone sludge waste in manufacturing fly ash bricks and its properties. The brick contains fly ash, Lime, Gypsum, sand, water, and stone waste. With the proportions of brick, i.e., 10%, 20%, 30%, 40%, 50% and 60% of the fly ash is replaced by stone waste, the data from the stone waste fly ash brick is compared with that of data from a standard fly ash brick without stone waste. Based on the experimental results, the percentage of stone waste increases, compressive strength increases up to a certain point and then after it decreases. The optimum point at which it gets maximum strength is replaced at 30% of stone waste by class F fly ash. Use of Stone waste in brick can solve the disposal problem; reduce cost and produce a greener Eco-friendly bricks for construction.

Krishna Bhavani Siram (2012) discussed on usage of Cellular Lightweight Concrete (CLC) block is a replacement of red brick in construction industry along with environmental preservation. The author made comparisons of properties like Compressive strength, Water absorption, density, shrinkage and thermal conductivity between CLC Blocks and Clay Bricks. Based on test results, it has shown that the use of fly ash in foamed concrete can greatly improve its properties and CLC blocks may be used as a replacement of burnt clay bricks, for construction purpose, which is advantageous in terms of general construction properties as well as eco-friendliness.

Alaa et al.(2012) investigated on bricks which are made by using fly ash (FA), quarry dust (QD), and billet scale (BS) by a nonconventional method. The procedure for producing the bricks includes mixing the constituents along with cement and water and then forming the bricks within moulds without applying pressure over them. As per the test results, the optimum ratio of fly ash and billet scale, quarry dust and billet scale is found 1:1 and it showed the best performance in compressive strength and modulus of rupture.

Mohammad Nidzam et al. (2016) studied on Lower Oxford Clay (LOC), Pulverized Fly Ash (PFA) materials are stabilized with Lime, Portland cement (PC) and blended binders comprising of Lime, and PC blended with Ground Granulated Blast-furnace Slag (GGBS). There are technological, economic as well as environmental advantages and potential of utilizing PFA, an industrial by-product from the coal industry, and GGBS a by-product from the steel industry, in the development of eco-friendly Clay-PFA building bricks. The recycling of GGBS or PFA as admixtures now-a-days is much more than an alternative for reducing costs. Based on the results the author concludes that all the key parameters of compressive strength and environmental properties were within the acceptable engineering standards for masonry units. The author stated that with new technologies, invention and enhanced waste management, the use of eco-friendly building materials will be a great contribution to the concept of green building.

Aakash Suresh Pawar et al. (2014) studied on the results of testing and the advantages gained on Fly Ash bricks over conventional clay bricks. Fly ash bricks are prepared from various proportions of fly ash in clay material (5-50% by weight, in ratio of dry fly ash to wet clay, at a step of 5% each). The manufacturing process uses techniques and equipment similar to those used in clay brick factories. Based on the results, the author concluded that the 15% of fly ash and 85% of clay is more beneficial than conventional clay bricks.

### 2.2 Development of eco-friendly Bricks from the material wastes in construction

Ramkumarand Rubini (2017) studied on the manufacture of bricks from the construction wastes of brick debris, quarry dust and cement. The quarry dust is used to optimize the common mix to attain the target strength by replacing the debris with 5%, 10%, 15% and 20 % of quarry dust. These bricks satisfy the norms and requirements of a normal brick as per IS code provisions. Their project work merely attempted to reuse the construction wastes in the construction industry.

Nithiya et al. (2016) investigated on manufacturing of brick made with different recyclable materials like coconut fibre, granite waste and egg shell powder. The percentage of waste added is 0%, 3%, 6%, 9%, 12%, and 15% (for all 3 types of wastes). These bricks are sufficiently hard at 4%, 8% and 12% proportions. The percentage of granite waste increases with increase in the hardness of the brick. The author opined that the compression strength is increased up to 6% of granite waste beyond that it gradually decreases.

Chiara Coletti et al. (2016) experimented on the brick made by using ceramic sludge from the industry and aiming to find an alternative eco-friendly additive to produce “eco-bricks” characterized by suitable mechanical and aesthetic properties and durability. For these bricks, two types of bricks are produced by a newly designed brick obtained from the natural clay, with the addition of ceramic sludge in place of the traditionally used siliceous sand. Based on the results, the author concluded that bricks produced with added ceramic sludge can substitute well to the traditional bricks, fulfilling aesthetic requirements and maintaining sufficient mechanical properties. The main drawback is that a new material used in this research has not been responded to freeze-thaw cycles, highlighting their potential vulnerability in cold climates.

Murugesan et al. (2016) this research reveals that marble sludge powder, a waste product from the industries as admixture for making bricks. In this project, 200 bricks are cast with partial replacement of marble sludge powder. The result focuses on comparison of properties of bricks to achieve better results. These bricks are tested at varying proportions of marble sludge powder. Marble sludge dust is environment friendly that reduces the pollution and prevents the waste disposal.

Angel Daniel et al. (2015) researched on the sawdust (49%) and plastic waste (49%) products can be used as raw materials to create wood plastic composite (WPC) with 2% fusa bond for making the brick. The brick is made of in different shapes (Hexagon, Rectangular, Octagon and Triangular) and of internal geometry holes are designed to increase sound absorption together with an improvement in structural strength. The brick design with the structure of triangular holes has the best performance and which gives better sound absorption.

Ahsan Habib et al.(2015) his study was conducted on to determine the effect of the proportion of the soil and the stabilizers (such as cement and stone dust) on stabilized earth blocks durability. Adobe brick was prepared with different volume fractions of stone dust varying 5%, 10%, 15%, 20% and 25%. The result has shown that the use of stone dust increases the compressive strength by 10% to 20 % respectively. The water absorption of the adobe (dredge soil and cement and stone dust) also calculated which is very similar and slightly changed the percentage of stone dust. The author concludes that the use of stone dust of (10 % to 20 %) with 5% of cement-based adobe enhances the mechanical properties and optimization of the stone dust is required to get the best performance.

Bwayo and Obwoya,(2014) discussed on the effect of particle size of a mixture of ball clay, kaolin and sawdust on thermal diffusivity of ceramic bricks. A mixture of dry powders of ball clay, kaolin of the same particle size, and sawdust of different particle sizes mixed in different proportions and then compacted to high pressures before fired to $950^0$C. The thermal diffusivity is determined by an indirect method involving measurement of thermal conductivity, density, and specific heat capacity. The study reveals that coefficient of thermal diffusivity increases with decrease in particle size of kaolin and ball clay but decreases with increase in particle size of sawdust.

Gauravkumar and Barot (2014) researched on different proportions of Sugarcane bagasse ash, cement and stone dust are used to prepare brick. The Compressive strength and water absorption tests are conducted on samples. It showed that only minimum 8% of utilization of cement can satisfy both the compressive strength and water absorption test and maximum 30% of utilization of bagasse ash satisfies both the compressive strength and water absorption test of IS code provision for burnt clay brick.

Maneeth et al. (2014) in his research an attempt has been made to produce bricks by using waste plastic (PET bottles) in range of 60% to 80% by weight of laterite quarry waste in molten form, which acts as a binder. When this molten plastic was not sufficient for binding capacity, to overcome this problem a little quantity of 60/70 grade bitumen is added in a range of 2% to 5% by weight of soil and this bitumen-plastic resin was mixed with laterite quarry waste to manufacture bricks. Based on the tests, the compressive strength for plastic-soil bricks with 70% plastic content by weight of soil with the binder(bitumen) content of 2% by weight of soil gives a compressive strength of 8.16 $N/mm^2$ which is higher than laterite stone (3.18$N/mm^2$) and has a lesser water absorption(0.9536%) than laterite stone (14.58%).

Prakash et al. (2013) studied on the feasibility of using aerated concrete block (ACB) as an alternative to the conventional masonry units. These blocks are prepared by mixing of Portland cement, sand, water and pre-formed stable foam.ACB blocks weigh lesser, the dead load is lesser on the structure, can be designed more efficiently for a lower load. As per the test results, Aerated concrete block units have the least compressive strength when compared to any other type of masonry unit. Hence, it is not favourable.

Bilgin et al. (2012) researched on the utilization of waste marble powder as an additive in industrial brick mortar with proportions of 0% to 80% wt. It has been observed that when an increase in the temperature and proportion of marble waste ratio in the mixture caused expanding the samples but clay mineral shrinks after the sintering process. The disadvantage is that increasing the size of the samples, bricks cannot maintain their shapes. The author concludes that adding waste marble more than 10% wt. increases the water absorption and decreases the mechanical properties.

Swaminathan Dhanapandian et al. (2009) in his research, aimed to characterize and evaluate the possibilities of using the granite and marble sawing wastes, generated by the process industries. Chemical tests are carried out for determination of chemical composition, mineralogical and petrological analysis, particle size, plasticity, FTIR and Mossbauer measurements. As per the physical tests, bulk density, compressive strength, flexural strength are found to increase due to the addition of the granite and marble sawing wastes. Technological tests are also conducted on wastes incorporated brick specimens in order to evaluate the suitability of addition of wastes in the production of bricks. From the results of technological tests, the author suggested that granite and marble wastes can be incorporated up to 50% wt. into clay materials for the production of bricks.

**2.3 Development of eco-friendly Bricks from other waste materials**

Safeer Ahmad et al. (2017) studied on manufacturing of brick made of various proportions of wheat husk and coal separately as additive along with the ingredients of clay earth. Clay bricks are prepared by mixing 5%, 10%, 15%, 20%, 30%, 40% and 50% wt. of coal and wheat husk individually with initial ingredients. Different tests are conducted like micro-structure, thermal conductivity and coefficient of thermal diffusivity, water absorption, shrinkage, compressive strength and bulk density of fired clay bricks with and without additives are investigated. Hence, clay brick containing 5%–15% wt. in which wheat husk and coal added to it that shows good results are found to be within the permissible limits.

Gaurav Goel and Ajay Kalamdhad (2017) investigated on experimental study of manufacturing eco-friendly lightweight bricks through binary mix of paper mill sludge (PMS) and soil. The mix ratio between PMS and soil vary (0%, 5%, 10%, 15% and 20%) and two firing temperatures at 850°C and 900°C are tested in a kiln. The performance of incorporating PMS, into the mix, tested by evaluating properties such as linear shrinkage, compressive strength, water absorption, mass loss on ignition, and bulk density of bricks as recommended by the relevant Indian and ASTM standard codes. Based on the results, an optimum mix of 10% PMS with both soil types are found suitable for brick production at a firing temperature of 900°C.

Kazmi et al. (2016) researched on brick specimens manufactured by using various proportions of Sugarcane Bagasse Ash (SBA), Rice Husk Ash (RHA) and clay earth. Based on the test results, the author observed that clay bricks mixed with SBA and RHA (separately) exhibited lower compressive strength compared to that of clay bricks without SBA and RHA. Hence, it can be concluded that the brick specimens incorporating 5% by clay weight of SBA and will not only relieve the environmental degradation but also results in a more sustainable and economical construction.

Sodupe-Ortega et al. (2016) studied on the use of Crumb Rubber (CR) that is obtained from the tyres industry, as fine aggregate in dry mix to produce rubberized long hollow blocks and bricks. CR is incorporated over a range of 10%–40% with water/cement ratio varying from 0.7 to 0.9.The rubberized bricks exhibited better performance than long hollow blocks. This research reveals that the building product is appropriate only for very low percentages of rubber replacement at high water/cement ratios. As the test results shown important deformations and drastic reduction in compressive strength, the crumb rubber percentage is greater than 20%.

Eliche-Quesada et al. (2016) investigated on the feasibility of using biomass combustion ash waste (rice husk or wood ash from boards) as secondary raw materials in the manufacture of clay bricks. Either rice husk ash or wood ash is used to replace different amounts (10%–30% wt.) of clay in manufacturing of bricks. Based on the results, the bricks containing 10% wt. of rice husk ash and 30% wt. of wood ash fulfilled standard requirements for clay masonry units at an optimal firing temperature of $1000^{0}$C.

Padmapriya and Mrs. Pandeeswari (2016) studied the properties of various strengths of M40 grade concrete by using PET (Polyethylene Terephthalate) and Carbon Black. The PET percentage ( 0%,10% and 20%) is taken as constant, the Carbon Black as a partial, which replaces cement by 0%, 10%, 20%, and 30%. Based on the strength test results, the author concludes that the carbon black up to 30% as a partial replacement of cement will be very effective in concrete.

Nitin Goyal et al. (2016) investigated a new concept of eco-bricks also known as bottle bricks used as a construction material. These bricks are manufactured by using the non-bio-degradable wastes such as plastic bottles, plastic bags and other non-bio-degradable substances are used to construct garden partition walls and school buildings and houses. By consideration of cost of construction, these bricks are less cost effective and can be a shelter home for the poor. The houses that are constructed with these bricks are bulletproofing and less prone to attack. Hence, the author concluded that the cost and resource efficient building material which can be used in order to deal with the various environmental problems as well as in the reduction of cost of construction.

Susana Serrano et al. (2016) researched on six types of additives with two different shapes (fibres and pellets) are added into adobe bricks. The fibres used are straw "S" (used as the reference material), corn plant "CP and fescue "F", on the other hand, the pellets used as additives are olive stones "O, polyurethane "PU" and rubber crumbs “R”. Four of them are agricultural by-products and the others, transport and appliances wastes. In order to evaluate how additives effect on the flexural and compressive strength of adobe bricks, a design of experiments carried out using Design Expert-software. The author concludes that flexure strength can be improved by the addition of S and CP but in contrary F and O are not recommended to increase flexural strength of the adobe bricks.

Gabriela Calatan et at. (2016) an experimental research conducted to explore the clay material recycling possibility of the adobe bricks type masonry units. The bricks are prepared with the paste obtained from recycled clay material allows the dispersed reinforcement with vegetable fibres (straw or hemp fibres). Based on the experimental result, the compression strength increased by about 50% compared to the conventional clay brick. The author concludes that after drying specimens showed physical and mechanical performance similar to those recorded when using fresh clay extracted. This phenomenon takes place only once in the matter of non-recyclable clay-based paste. However, where as in the aspect of pulp based material recycled clay, this phenomenon takes place twice.

Yassine Taha et al. (2016) this study presents a feasible approach to recovering residual coal from coal mine waste rocks (CMWR) and reusing the derived tailings to produce eco-friendly fired bricks. The first step aims at the production of high-grade anthracite coal concentrate using a physical treatment method, which consists of consecutive stages of crushing, grinding and froth flotation. The second step of the process consists of the mixture of the decarbonated tailings, called treated coalmine tailings (TCMT), with a small amount of water, pressed and fired at an optimal temperature of $1020^0$C for the production of eco-friendly bricks at a laboratory scale. The study assessed the effects of removing coal from CMWR on the physical and technical properties of the derived fired bricks. The removal of coal from CMWR enhanced the quality of fired bricks by increasing its flexural strength and decreasing the open porosity and water absorption. According to the results of this study, two main scenarios may be proposed to best manage the coalmine wastes in a sustainable and efficient way. The first scenario aims at the production of bricks directly from CMWR while the second scenario consists of the production of two value-added potential products, fine coal concentrate and high mechanical strength bricks.

Rohit Kumar Arya and Rajeev Kansal (2016)this research is to determine the weight, compressive strength, water absorption capacity, fire resistance, hardness etc., of Papercrete brick by using waste papers (newspapers, invitation cards, magazines etc.) in order to determine their aptness for use as a building construction material. While using paper pulp with cement and sand the weight of the brick is approximately 50% lesser than the conventional clay brick. Therefore, papercrete bricks will decrease the dead weight of the structure to a significant amount. Based on the test results, the compression test showed that Papercrete bricks are acceptable for non-load bearing walls only. The water absorption capacity of papercrete brick is more than 20%, which makes it not suitable for water logging and external walls. The total cost of building construction is reduced from 20% to 50% by using these bricks.

Siva Prasad et al. (2015) investigated for utilization of waste paper used as a construction material constitutes a step towards sustainable development in the manufacturing process of bricks. For this effort two different mix proportions [1:1:1], [1:1.25:1.5] are used to make bricks. The bricks are made of normal mix and aggregate based mix in above two proportions. For normal mix, Portland cement, sand, sludge is used. In case of aggregate based mix, paper sludge is replaced by coarse aggregate by 5%,10% and 15% respectively to the investigation of properties. The weight of this brick is 2/3rd to 3/5th lesser than conventional clay brick. Finally, the author concluded that the Papercrete brick for a building construction and its total cost will be decreased from 20% to 25%,and these bricks are not suitable for water logging and external walls.

Sami Masadeh (2015) researched on the effect of carbon black to the concrete mix on corrosion of steel reinforcement. It achieved by inserting steel bars in different concrete mixes containing 0.1, 0.2, 0.3, 0.4, and 0.5, carbon black/cement ratios. Samples are cured, immersed in 3.5% chloride solution for 6 months. Based on the tests, the author concludes that corrosion rate and chloride ions penetration decreased with increase in carbon black content. Carbon black addition to concrete mix is an easy and cheap method of reducing corrosion of steel in concrete. It is stated that carbon black addition in carbonation corrosion of steel reinforcement in concrete has a positive effect. If Carbon black addition to concrete mix is used in combination with any other corrosion protection methods, it enhances protection and reduces cost.

Dr. Chitraet al. (2014) attempted to minimize the presence of pores in conventional concrete by using carbon black powder, which is a waste material from rubber industry as filler. The research reveals that concrete specimen with 2% and 5% carbon black showed good performance with respect to conventional concrete. The author concluded that the addition of carbon black up to 5% as filler is very effective in concrete.

Mohammad Shahid Arshad et al. (2014) researched on reducing the quantity of clay with natural waste material. The orange peels and coconut waste have been utilized to make construction of bricks that serve a purpose of solid waste management. The bricks prepared with orange peels and coconut waste with varying compositions of clay reduced the quantity of clay by 10% - 40% wt. and 10% - 60% respectively. Based on the experiment results, it is observed that waste create bricks (WCB) making lightweight, shock absorbing and meets compressive strength requirements of ASTM and BIS. The soil content is only 30%, then the waste material comprises of paper mill waste and orange peel do not make a good bond with each other and it crumbles only when it is totally dried. Orange peel does not make bond with paper mill waste and soil and thus, it is not a good binding agent and it cannot be used as an ingredient for construction purpose. Coconut waste is more efficient than orange peels and paper mill waste. Finally, the author concludes that coconut waste can easily be handled and utilized for making lightweight bricks.

Darweesh and El-Meligy (2014) the main objective of this work is to study the reutilization of Kraft pulp waste (KPW), which is the primary waste of the paper industry, in clay brick. For preparing these bricks, increasing amount of residue (0%, 2%, 4%, 6% and 8% wt.) is mixed with clay (TC) and homra waste (H). The addition of 2% to 6 % pulp waste found to be effective for pore-forming in clay body with acceptable mechanical properties. The author concludes that kraft pulp wastes can be used safely as an organic pore-forming agent in the manufacturing of clay-bricks, the optimum batch composition was 6 % KPW fired at 1000ºC.

Dr.Ruhul Amin et al. (2013) investigated on developing environment friendly and energy saving brick from rice husk ash (RHA). The main components of these brick are rice husk ash, lime, sand and binder. Five batch experiments carried out with different composition of above components to get the desired compressive strength of the brick. Maximum attained compressive strength is 2.1N/mm$^2$. If an increase in the amount of binder & lime, the compressive strength and maximum load of the brick can be improved. Finally, it will not be feasible because the cost will increase. The author concludes that the use of this brick should be limited for building only one-storied low-cost house.

Rajput et al. (2012) researched on the Waste Crete Bricks can be prepared by recycled Paper mills Waste (PW) and cotton waste (CW). Waste Crete Bricks with varying content of cotton waste (1%–5% wt.), Recycle Paper Mills waste (89%–85% wt.) and fixed content of Portland cement (10% wt.) have been prepared and tested as per IS 3495 (Part 1–3): 1992 standards. The brick samples with PW, CW, which have physical and mechanical properties and cement are investigated. By testing observations it is revealed that the bricks with 1%–5% addition of CW and 10% cement to PCW exhibit a compressive strength of 21–23 MPa (with 30% shrinkage) which is several times greater than the conventional clay bricks. The author concludes that the PCW–cement combination can be potentially used in the production of lighter and economical brick material, which can be used as internal partition wall and also concludes that 85% PW–5% CW–10% cement is the optimum composition.

Badr El-Din E et al. (2012) researched on the complete substitution of brick clay by water treatment sludge incorporated with rice husk ash (RHA). Three different types of sludge to rice husk ash (RHA) ratios of 25%, 50%, and 75% of the total weight of sludge-RHA mixture are studied. Each brick fired in series at 900$^0$C, 1000$^0$C, 1100$^0$C, and 1200$^0$C. Based on the test results, the author concludes that by operating at the temperature commonly practiced in the brick kiln, 75 % was the optimum sludge addition to produce brick from sludge-RHA mixture. The produced brick should meet the required values of compressive strength, water absorption, and efflorescence. Therefore, the author concludes that the produced bricks properties are obviously superior to the clay control-brick and to those, which are available in the Egyptian market.

Mohan et al. (2012) in this study, rice husk ash has been utilized for the preparation of bricks in partial and full replacement of clay. Engineering properties like compressive strength, water absorption and size and shape have been studied. Based on the observations the author concludes that optimum proportion for (RHA + Clay) bricks is observed as 30% (maximum) RHA and 70% as the bricks exhibited high compressive strength and low brick weight. In full replacement of clay for 40% RHA, 40% Lime and 20% gypsum by 50% RHA; 30% lime and 20% gypsum gives more strength (41 kg/cm2) after 28 days curing period.

Raut et al.(2011) investigated on the brick prepared with Recycle paper mills waste (RPMW) and cement which is known as waste-create bricks (WCB). RPMW with cement combination and low carbon footprint bricks with varying composition of cement (0%–20% wt) have been prepared and tested as per standards. In this investigation, the author observes that waste-create bricks (WCB) prepared by using RPMW-cement combination is lightweight, shock absorbing and meets compressive strength requirements of ASTM.

## III. CONCLUSION

It is apparent from the above researches that various types of waste materials from the different industries have been used in different proportions and different methods are adopted to produce bricks. Based on the literature review, the researchers have revealed that many successful attempts are made to incorporate waste materials in the manufacturing of bricks. They have positively influenced and enhanced the performance in terms of making them environment friendly and manufacturing economical bricks leading to the design of green building. Certain bricks are made without firing which is an advantage over other method of manufacturing of bricks in terms of low embodied energy material. It also offers a solution to the problem of waste disposal as well as eco-friendly environment in construction industry.

The use of eco-friendly bricks made-up of waste materials is still very limited and there is a scope of further research in manufacturing reinforced bricks using waste materials. Further research and development is needed to promote wide range of production of eco-friendly low cost bricks from waste materials in the absence of relevant standards, which have semi acceptance by the industry and the public.

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