

Review of the Use of Sustainable Materials in the Production of Building Units

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Article Info	Abstract
Received 12/10/2022	<p>The main goal of the technology is the minimizing of the huge consumption of energy specifically that arises because of burning clay bricks inside furnaces. An overall review of the available literature to determine the present knowledge and thinking level in unfired/fired clay bricks, and to establish an appropriate research context. Sustainable development has become the conversation of the age, and on this basis, searching for environmentally friendly materials has become a major element in this dialog. In this research, materials were prepared and ground to be downy with cement-like properties, and cement was the binding material in all mixtures. The results gained from the scrutiny showed that toting the reused material increases the compressive strength, with the highest compressive strength (33.8 MPa and the lowest being 1.9 MPa). Or shrink the difference in the impact factor and then conserve the environment from these materials and harness them for reuse in environmental resources.</p>
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1. Introduction

1.1. Fired Clay Brick

For almost 5000 years, bricks of burnet clay were an essential building substance on the face of the globe. Since hardened clay brick parades have superior forbearance to humid and ice climates, it is able to be behaved to create perpetual assemblies in mild ambiances. The Romans in the Old Testament were among the first to use baked bricks. This industrial and fabricating advantage motivated the Romans to transfer this industry and formulate it mobile with the Roman army throughout the empire. Brick was an important and major element in many installations, so medium and low-rise buildings took the largest share in construction with this feature at the end of the twentieth century. On other occasions, it was an architectural and decorative feature of many national buildings and edifices. Preparing and manufacturing these models was done by crushing the clay and mixing it with water to obtain the appropriate slurry consistency, then pouring it into the mold. A hydraulic urge is exploited to depress the clay into steel casts. The clay formed is fired at a temperature of up to 900 degrees Fahrenheit. After this also to stabilize the strength

bonds, the temperature is raised to 1000-1300. These works (heating and burning) are carried out continuously in modern brickworks. These kilns consume a lot of fuel and energy to produce bricks, and this is of course due to gaseous and liquid emissions that have a bad environmental influence. Throughout the element assembly progression, fumes such as fluorine, hydrogen, carbon, and solids are routinely released from brick kilns throughout the manufacturing progression. In many countries, especially developed countries, these emissions are treated with caution, and conditions that may be harsh in some cases are imposed to limit their emissions [1]. The bricks are moved gradually among the kiln on moving belts, trains, or kiln cars to obtain identical physical qualities for all bricks. To speed up the burning process, lime, ash, and organic materials are frequently added to the bricks [2].

A number of people have agreed to support sustainable development in all of their activities. Because environmental influences cause instant implications for civil engineering infrastructure operation, design and planning; it is very important to recognize the fact that good technology systems, services, and designs are crucial to improving environmental/social performance all over the world. For the

purpose of inoculating building materials with sustainable materials, there are many measures that must be considered both short and long-term during the design, construction, and operation of the structure. Despite significant attempts to reduce the consumption of energy and emissions related to burning clay brick by furnaces, such as the application of a recycled source of heat in order to dry the wet mixture of brick, and partial compensation of waste materials, such as silica fume, sludge of wastewater, diatomaceous earth, sludge of dewatered waste paper, waste of boron, colliery waste, waste glass, municipal incinerator bottom ash, and furnace ash, for conventional clay in burnt brick production, traditional k A appraisal of unfired clay brick was also conducted in order to give an intellectual background for the investigation[1].

1.2. Unfired Clay Brick

Mesopotamia was the first to employ unfired clay bricks around the third millennium BC [13]. The majority of the residents lived in dwellings made of unfired earth or clay bricks. For the most part, earth or unfired clay bricks were used to build walls and floors. When compared to modern brick walls, which are typically two thin leaves with an insulated hollow between them, the walls were thick and solid [3]. Traditional earth-building techniques for example brick, muck-block, wattle and daub, and rammed earth have a long and mainly successful history [4]. Equally weight impact and non-load impact constitute the use of jammed earth walls (which are built by pressing processed soil in successive layers in a stiff formwork [5].

Several waste kinds and secondary substances were utilized in the construction of unfired clay bricks as partial compensation for main clay and as stabilizing materials.

Energy inputs need to be developed to create fired clay bricks. Here it was necessary to correct the defects caused by the sunny clay. This research has indicated the usefulness and return of many elements that have a significant impression on construction, such as economic growth, enhancing construction methods, optimal use of resources, and reducing the use of fossil fuels [6].

The inkling of sourcing unfired bricks with fired bricks has altered many minds recently around the world. It is very important to understand the mechanism of soil stabilization and the applicability of various wastes. It is also very important to understand the mechanism and how to reuse recycled materials as fixing materials, or as stabilizers, as is the goal of this research [7].

2. Research Significance

The development of unfired brick to be used in sustainable constructions using waste substances with Portland Cement (PC) is the main significance of the research significance. The production of this type of brick supports the ability of cheap brick manufacturing, for constructing inexpensive housing, with an ability to provide an environmentally friendly construction material.

3. Sustainable waste material

There is an obvious lack in several places around the world of natural resources of the required substances to produce traditional bricks. For sustainable enhancement and environmental preservation, comprehensive research has been carried out to develop the manufacturing of construction bricks using waste and by-product substances. The following represents a detailed review of previous studies aimed at utilizing waste materials in brick production:

Gencil [8] studied the manufacture of lightweight and porous clay bricks using boosted thermal conductivity. To produce the required pores, pumice was added to the earthenware bricks. TG-DTA, XRF, XRD, and SEM-EDS analysis of raw substances were first carried out. At various ratios (reaching 40 wt %), mixes having raw substances of brick and pumice were prepared. By using an appropriate hydraulic press, the semi-dried mixes were pressed under a pressure of 20 MPa into the template, the wet parts must be dried, and after that, they were burned with high temperatures reaching approximately 900 and 1000 °C for a period of two hours. The values of loss by ignition must be determined. Moreover, apparent porosity, bulk density, and absorption of water calculations must be done by method of Archimedes. Mechanical strengths and thermal conductivities of fired specimens were determined as well. The obtained results revealed that the fired brick density was reduced by the addition of pumice.

Saleem et al. [9] used two waste substances of agriculture (i.e., ash of rice husk and bagasse of sugarcane). Elimination of the used wastes can be considered a completely hard job, and they cause hazards to the environment. The ash of rice husk and bagasse of sugarcane in this study were obtained locally from Wazirabad and Peshawar cities, respectively. Using three various mixing ratios, these waste substances were added to the mixture of clay brick, the ratios were 5, 10, and 15% by clay weight. Mechanical characteristics such as modulus of rupture and compressive strength, and durability characteristics such as freeze-thaw, sulfate resistance, and absorption of water of the resulting bricks were determined. The obtained experimental results showed that the resistance to sulfate attack and clay bricks efflorescence in the case of rice husk ash and sugarcane bagasse presence was raised considerably. On the other hand, there was no considerable influences on mechanical characteristics were noticed. Moreover, the resulting unit weight of brick lowered due to the addition of these materials which in turn minimized the entire structure's weight, thus leads a more economical building. Thus, one can conclude that the use of these waste substances in the production of brick is able to minimize the ecological burden providing more sustainable and economical construction.

Munir et al. [10] studied the production of environmentally friendly fired clay bricks containing recycled powder of waste marble. Marble powder wastes were obtained from the local industry of marble; they were used for manufacturing brick samples in local brick production factories using ratios ranging between 5 and 25% by weight of clay. The resulting durability and mechanical properties of bricks containing waste marble

powder (WMP) were studied. The addition of WMP created bricks of lighter weight and lowered the resulting linear shrinkage. Its addition increased the porosity significantly, as displayed using the analysis of scanning electron microscopy (SEM), so it accordingly lowered the resulting compressive strength. Furthermore, brick samples containing WMP with a ratio of up to 10% exhibited accepted values of compressive strength according to the dependent specification mentioned in the code of the local building. The examined samples of brick achieved the minimum required limits of flexural strength. The resulting efflorescence sulfate resistance of the control sample of brick (which did not contain WMP) was approximately the same as compared to the fired brick sample containing 5% WMP. Leaching experiments of brick samples showed that leached samples of waste marble powder bricks were lower than regulatory thresholds. The wide application of this waste in the manufacture of burnet bricks can reduce landfilling of WMP and develop economical, nonhazardous, and eco-friendly masonry buildings.

Gencil et al. [11] evaluated the use of concrete wastes to produce burnt clay bricks. The required clay was replaced by powder of ground concrete waste with ratios reaching 15% by weight. Specimens were prepared in the shape of cylindrical granules using an uniaxial hydraulic machine, and after that, they were placed in a furnace to be fired at 1000 to 1100 °C for two hours. Apparent porosity, bulk density, compressive strength, loss by ignition, capacity of water absorption, dilatometric, thermal conductivity, efflorescence analysis, and leach analysis were all carried out on samples of fired brick as well as microstructure studies. Basically, it was noticed that values of water absorption, porosity, and loss by ignition, porosity increased slightly, while values of thermal conductivity and compressive strength decreased due to the increase in concrete waste quantity. In spite of the sample having concrete waste with a ratio of 2.5% giving more appropriate results, samples having up to 15% exhibited compressive strength over 7 MPa, which can be considered the lower limit. The tested brick samples showed a relatively slight level of efflorescence. According to the obtained results, one can conclude that concrete waste is able to be utilized in the fabrication of animated clay bricks.

Loryuenyong et al. [12] revised the addition of glass wastes, which are produced from structural glass walls, with ratios reaching 45 % by weight to a mixture of clay used for the production processes of brick. In this research, mechanical and Physical characteristics of brick were studied as a function of firing temperature and content of wasted glass. The obtained experimental results showed that clay bricks of appropriate mechanical and physical characteristics can be produced using proper firing temperature and suitable content of wasted glass. For brick having a content of glass in the range between 15 and 30% by weight fired at a temperature of 1100 °C, the obtained water absorption was between 2 and 3%, and compressive strength was between 26 and 41 MPa. Water absorption and apparent porosity increase significantly when the percentages of glass is 45%.

Hassan et al. [13] used sludge of iron and arsenic in brick production and determined their effects on the resulting brick characteristics. The chemical composition of the sludge produced from water treatment plants is approximately similar to that of clay or brick. Thus, this sludge can represent a possible alternative to conventional brick. In the current work, sludge was added with quantities of 3, 6, 9, and 12% of the entire mass of the clay-sludge blend. Both chemical and physical characteristics of the resulting bricks were observed and then compared with the prepared control specimen that contained only clay. The obtained experimental results revealed that both firing temperature and quantity of sludge can be considered the governing factors in the determination of brick quality. The resulting compressive strengths were 14.1, 15.1, 9.4, and 7.1 MPa for brick samples containing sludge with quantities of 3, 6, 9, and 12%, respectively. One can conclude from the aforementioned results that the compressive strength of the produced brick enhanced firstly as the content of sludge increased but then decreased with the increment of sludge quantity. With pH variation at a fixed temperature, the leaching properties of fired brick were evaluated. 6% was the best sludge quantity that is able to manufacture high bonding of sludge-clay bricks.

Chidiac and Federico [14] studied the optimization of burnt clay bricks manufacture, it is considered substantial to keep the sustainability of this manufacture. In spite of there is room for developing the characteristics of the brick as it is dependent on harsh conditions, worries involving rising costs of energy, nonrenewable depletion of required resources, and management of waste materials have become more essential in global industries, especially in Canada. One of the possible strategies for addressing the aforementioned worries can be done by using additives of waste as fluxing factors in brick manufacture. The dependency of brick manufacture on depletable resources can be compensated, and the durability and strength of brick can be enhanced by using these additives. In the current research, the influence of the addition of recycled glass wastes on the mechanical, durability, and transport characteristics of burnt brick was studied. The studied variables were the quantity and particle size of the used glass wastes. Depending on mercury intrusion porosimetry, the microstructure was studied to determine the influence on the structure of pores. According to the obtained results, the optimum addition quantity was specified.

Cusidó and Cremades [15] carried out several toxicity and leachability experiments (offgassing and outgassing). These tests explain the environmental adequacy of certain products of ceramic to be depended on as construction substances and also in building deconstruction at the end of its life span.

Rezaie et al. [16] investigated the influence of shear span ratio and axial force on the structural behavior of the wall, especially on the strength and stiffness of the wall, and capacity of drifting. One can notice that at the beginning of the crack, the drift was 50% as compared to that by loading of stone walls; it is attributed to the plastering of only a single face for each wall which made the crack more apparent. Furthermore, one can conclude that the propagation of splitting cracks between leaves

of the wall played an essential role in the mechanism of collapse. New inputs for the analysis of collapse hazards relating to stone masonry constructions can be provided by testing walls till failure by loss of the axial load-bearing strength.

Kazmi et al. [17], used bagasse of sugarcane and ash or rice husk (waste materials) in brick manufacture, Figure (2-6) explains the materials. A quantity of 5% of sugarcane bagasse ash and ash of rice husk was added to the clay to evaluate the resulting durability and mechanical characteristics. According to the obtained results, one can notice that the addition of the ashes reduced the resulting modulus of rupture and compressive strength. However, in accordance with the guidelines of ASTM and the building code of Pakistan, the obtained modulus of rupture and compressive strength were acceptable. Moreover, lighter clay brick can be produced by the addition of the aforementioned waste materials. Clay bricks of lighter weight reduce significantly the overall weight of the structure making it more economical. The obtained experimental results revealed that the weather sensitivity of the brick containing these ashes was moderate. Furthermore, efflorescence resistance was enhanced significantly by the addition of the waste substances. By applying SEM analysis, the microstructure of the produced brick samples was studied. One can notice that the addition of the waste materials increased brick porosity to a great extent. According to the obtained results from this study, it was obvious that the use of rice husk ash and sugarcane bagasse ash was effective in reducing pollution of the environment and in producing economical and sustainable buildings.

Gencil et al. [19] studied the possibility of using water treatment sludge (WTS) in brick manufacture. The production of WTS around the world passes millions of tons per day, which causes several challenges for waste management, so their use in the brick industry can be considered an environmentally friendly solution. The influence of various WTS quantities on the brick behavior was evaluated. The engineering behavior of no-clay brick that contained wastes of marble, glass, and WTS was studied. Thus, bricks of WTS were produced using various waste contents of marble and glass (0 to 15%). In this study, empirical formulas were prepared to relate the density, thermal conductivity, porosity, and compressive strength of brick samples, the prepared formulas can be depended on to evaluate WTS brick behavior. Thus, samples of no-clay WTS brick containing wastes of marble and glass had the ability to provide sustainable, durable and strong constructions, this leads to the conservation of natural clay resources and better environment.

Muñoz et al. [19] studied the technological and mineral characteristics of brick produced by adding various quantities of residues of paper pulp at furnaces with a temperature of 900 °C. The experimental results showed that the mixture needed larger water quantities as the replacement ratio increased, which in turn led to increased shrinkage after drying. Despite mineral transformations were not affected by the addition of residue of paper pulp, the resulting porosity was directly raised, so the thermal conductivity and compressive strength lowered by 30% for a replacement percentage of 20%. Accordingly, when the replacement ratio was 10%, water absorption was 20%, toxicity

was within the mandatory requirement and compressive strength was 5 MPa.

Abbas et al. [20] studied in detail unfired clay bricks in which the essential substance is clay. The required clay quantity was obtained from a depth of 2 m below the ground surface to ensure its purity and cleanness. Various kinds of brick samples were by mixing various substances with clay to improve characteristics such as intensive deformations because of shrinkage. The used substances were divided into three classes. The first one consisted of natural fibers (husk of rice, sawdust, and straw), these fibers were added to improve the resulted tensile strength and reduce shrinkage cracks. The second consisted of coarse and fine sand acting as a stabilizer for lowering expected volumetric alterations. The third one was cement for enhancing the cohesion and adhesive of the clay mixture. The studied parameters were the flexural strength of bricks, and the compressive potency of grout, brick, and sandstone. Furthermore, the performance of unfired brick prisms was evaluated by comparing them with that of the conventional fired ones. The obtained results revealed that using the mixture containing straw, coarse sand, and clay exhibited higher compressive strength. On the other hand, the highest bricks' flexural strength was obtained using a mixture of sawdust and clay, while for prisms of unfired clay, the greatest compressive strength was achieved using a mixture of straw, coarse sand, and clay. Using the obtained experimental results, a formula was suggested for estimating the compressive strength of unfired bricks from that of mortar and brick.

Khitab et al. [21] studied the possibility of adding a combined mix of waste ceramic powder (WCP) and waste brick powder (WBP) as a compensation of clay in brick production to reduce the depletion of the natural resource. According to several previous researchers, the ratio of replacement must be at specific levels such as (4 + 5) %, (8 + 10) %, and (12 + 15) % for waste stoneware powder and rubbish brick triturate, individually. Modulus of crack, compressive strength, apparent porosity, density, efflorescence, fascination with water, freeze-thaw resistance, and resistance to sulfate and chemical attacks were the main studied factors. Test results showed that waste brick powder and waste ceramic powder were able to replace effectively 27% of the required clay, so resources of clay can be preserved without significant negative effects on the resulting compressive strength.

Kazmi et al. [22] studied the possibility of adding wastes of two agricultural crops (rice and sugarcane) to a clay mixture and determined their effect on the performance of the resulting clay. Basically, the added waste materials (i.e., rice husk ash (RHA) and sugarcane bagasse ash (SBA)) can be collected locally from bull's trench furnaces and sugar mills, respectively. By adding different quantities of RHA and SBA (15, 10, and 5%) samples of brick were produced at a brick factory. The research involved studying the durability and mechanical characteristics of the produced brick samples. The obtained results showed that lower compressive strength was achieved for brick samples containing RHA and SBA compared with the compressive strength of the control sample (without additives). However, samples containing RHA and SBA with a ratio of 5% showed

compressive strength of 5 MPa, which is acceptable according to Building code requirements in Pakistan.

The microstructure of the brick samples containing RHA and SBA was studied using SEM, it was observed that it exhibited higher porosity than that of traditional clay brick, this reduced the weight of the resulting brick and led to lightweight, and more economical constructions. Moreover, the addition of wasted reduced significantly the efflorescence of the resulted brick. According to the obtained results, one can notice that the addition of low percentages of RHA and SBA (approximately 5%) was able effectively to reduce the environmental problems and to produce more economical and sustainable constructions.

Pinto et al. [23] studied the mechanical properties of eight different debris stone brick walls obtained from various parts of a Portuguese statue. According to the Italian Building Code Commentary IBCC 2019, their performance was estimated [24]. Tests of flat-jack were applied to determine the mechanical characteristics of the brick walls, while tests of Rebound hammer were carried out to assess the performance of mortar joints and stone units. The obtained experimental results aimed to suggest modern criteria for rating the stones and mortar quality for supporting the depending on the reduplication factors concerning mortar quality in the methodology of IBCC 2019. Processing of images was applied to quantifying many properties of brick walls and introducing modern criteria. The results identified the amount of mortar, stone shape features, mortar quality, and joints' horizontal alignment as governing factors in the mechanical properties of debris masonry consisting of lime-based mortars and unequal tough stones. The obtained mechanical characteristics according to tests of double flat-jacks and IBCC 2019 revealed adequate correlations and highlighted the merits that resulted from the masonry quality estimation for evaluating mechanical characteristics of masonry.

Ukwatta et al. [25] studied the appropriateness of fired-clay brick when its clay was partially replaced by waste materials. Classification experiments were carried out, involving sieve analysis, plastic limit, and liquid limit, the obtained results showed that there were three specimens of biosolids, which were poorly graded silty sand and clayey sand. The specimens of biosolids exhibited linear shrinkage ranging between 10 and 15% while the used organic content ranged between 6 and 14%. Brick samples contained biosolids with a ratio of 25% and control samples (without biosolids) were prepared in this study. The studied characteristics were density, shrinkage, compressive strength, water absorption, and initial rate of absorption (IRA), while thermal conductivity was assessed using an empirical formula. Moreover, SEM analysis was used in order to evaluate the influence of biosolids addition on the brick's microstructure. According to the obtained results, the achieved compressive strengths were 25.9, 17.4, and 16.2 MPa for brick samples containing the added three various biosolids types. The achieved compressive strength of the prepared control specimen was 36.1 MPa. The obvious decrement in the compressive strength and also in the density can be attributed to the increased apparent porosity because of the addition of biosolid materials with three various organic contents.

To improve the properties of brick, Chen, et al [26] investigated the addition of hematite tailings and fly ash to the traditional mixture. The production procedure of bricks involved blending, formation, drying, and burning. The inclusion of hematite tailings with a ratio of 84%, the application of forming pressure ranging between 20 and 25 MPa, the addition of water content between 12.5 to 15%, and burning of the mixture at a temperature of 980 to 1030 °C for two hours were the best conditions for production. According to the aforementioned circumstances, the resulting reddish bricks exhibited water absorption and compressive strength in the range between 16.54-17.93% and 20-22.9 MPa, respectively. Furthermore, the durability and remaining physical characteristics were compatible with the standards of Chinese Fired Common Bricks (GB/T5101-2003) [27]. The morphologies and phases of the burnet sample and green tailings were determined by SEM and XRD, while the obtained experimental results revealed that tridymite, anorthite, quartz, and hematite formulated the essential mineral phases of tested samples, they basically generated the high mechanical properties.

Maximino et al. [28] used sustainable building substances obtained from wastes to produce brick samples with the addition of mycelium to cat as the required binders. Mycelium capability, which is the fiber of fungi's root, that is achieved from microorganisms can be depended on to stabilize and bind materials of brick. In this experimental work, 48 brick specimens were prepared using six different mixtures, the dimensions of the prepared brick samples were 200×90×60 mm. The carried-out tests were flexural and compressive strength. For monitoring the growth progression of mycelium inside the sample, weight alterations were determined against time. According to the results, samples containing rice bran and sawdust exhibited mean compressive strength higher than that of samples without mycelium by 38.5 and 31.0, respectively. Moreover, for all kinds of brick (clay, sawdust, and, rice bran), samples containing mycelium exhibited high midpoint displacement and flexural strength. As a final conclusion, the use of mycelium in the brick industry is able to improve the mechanical characteristics and minimize the consumption of conventional building materials.

Gencil et al. [29] considered the influence of zeolite, slag, ferrochromium, and groupings on systematic and physical properties, microstructure characteristics, and thermal conductivity of brick samples. This material was added as a partial replacement for traditional raw substances. The partially dry blends were pressed at a pressure of 20 MPa. Specimens were burnet at 900 °C for a duration of two hours, rate of temperature increment was 5 °C per minute. The determined properties of the burnet brick were weight loss, absorption of water, porosity, density, thermal conductivity, bending and compressive strength, phase analysis, and microstructural properties. Thermal conductivity was reduced by 42.3%, and compressive strength was more than 7 MPa. The obtained experimental results explained that samples containing slag and zeolite can be dependent as building substances.

Sutcu et al. [30] studied the characteristics of brick samples containing clay, bottom ash (BA), and fly ash (FA). For

determining the absorption of water, thermal conductivity, compressive strength, apparent specific gravity, apparent porosity, and bulk density, 12 mixtures were prepared, and samples were divided into two groups, the first one was fired at 950 °C and the second at 1050 °C. To explain the deep reason for the obtained results, microstructural analysis was carried out. The obtained results revealed that the water absorption and apparent porosity of samples burnet at a temperature of 1050 °C were slightly lower than those of when burnet at 950 °C, but thermal conductivity and bulk density were slightly higher. Furthermore, the increment of fly ash ratio increases the resulting absorption of water and apparent porosity but decreases thermal conductivity and bulk density. On the other hand, there were not any noticeable effects on the resulting properties according to the inclusion of BA. It was obvious that samples containing 5 to 10% bottom ash and 5% fly ash exhibited compressive strength similar to that of the samples containing clay only. According to leaching test results, heavy metals leaching from burnet samples were greatly smaller than standard concentrations. The obtained concentrations of leaching for all the tested specimens explained that the existing heavy metals within the ceramic structure were effectively immobilized. These results indicated that the replacement of

30% of traditional materials by ashes was able to produce effective and environmentally friendly bricks and to reduce the depletion of clay resources.

3. Argument

Different types of waste were used in different proportions [31, 32], as shown in Tables 1 and 2. Bricks were made according to different mechanisms as well. Many researches indicate that the two most significant criteria in regulating brick strength are pressure strength and water absorption and in different mixing ratios of the reused materials the compressive strength of the bricks produced and in different proportions for each material varies according to the materials and it was obtained a different resistance compared to the local brick. The selection of reused materials in addition to enhancing the resistance of the bricks produced works to reduce the proportion of pollutants through the use of reused materials. For the purpose of achieving the principle of sustainability and for the benefit of future generations, it was concluded that bricks produced without burning process and from sustainable materials reduce climate-affecting carbon dioxide gas and are also highly resistant to pressure.

Table 2. The Standard specifications

Code	Size of brick (mm)	Compressive Strength (MPa)	Class of Brick
Iraqi Standard	240x115x75	18	A
		13	B
		9	C
ASTM C62-08	203x92x57	20.7	SW
		17.2	MW
		10.3	NW
ASTM C 216	203x92x57	20.7	SW
		17.2	MW
BS 3921	215102.5x65	≥70	A
		≥50	B
		35	35
		30	30
		25	25
		20	20
Indian Standard (IS 1077)	190x90x90	17.5	17.5
		12.5	12.5
		10	10
		7.5	7.5
		5	5
		3.5	3.5
		7.5	7.5
TS EN771- 1	250x125x100	5.0	5.0
		50	2.5
		2.5	
		25	

Table 1. The limits of substantive and compressive strength for brick [33-62]

No.	Name of research	Material	The range of material	Compressive strength
1	Characteristics of fired clay bricks with pumice additive	pumice	the ratio of 10 %, 20 %, 30 % and 40 % by weight	Pumice addition decreases the compressive strength of the reference element which is 31.7 MPa at 900°C and 32.9 MPa at 1000°C. whereas, all units with pumice have potencies over 18 MPa
2	Clay units equipped with sugarcane bagasse and rice husk ash – A supportable explanation	Clay was achieved from a brick furnace RHA and SBA	(5,10,15)% From RHA (5,10,15)% From SBA	Brick with RHA and SBA showed less compressive an addition of 5% of waste in burnt clay
3	Development of Ecological Fired Clay Bricks Featuring Reprocessed Toy Ash	Clay and WMP	A watery combination was arranged after complementing malleability water (21.4–18.2%) (Lumps for each brick	Adding WMP lessened the element compressive of bricks integrating up to 10% WMP satisfied.
4	Effects of concrete waste on characteristics of structural	The concrete wastes, milling process	Concrete waste was replaced with clay up to 15%	The compressive strength of the bricks is 23.4 MPa. It will decrease to 14.7 MPa when the concentration of concrete in the total brick content increases
5	Influences of cast-off glass swap on the pure and systematic estates of clay bricks	lost glasses after basic glass walls up to 45 wt.%	Merging the underdone constituents (glass powders/rice husk and ball clays) in different proportions. The Water was complemented, in the quantity of 30 wt%.	When the concentration of glass losses used in the clay brick content increases, it will lead to a reduction in the compressive strength and modulus of rupture of the clay bricks
6	Possessions of using arsenic–iron mud dissipate in brick-producing	The arsenic–iron sludge waste used	Clay blend percentages of 3%, 6%, 9%, and 12% were organized in the workroom.	The compressive strength of bricks will increase as the sludge is added the first time, and then it will decrease as the sludge addition rate increases
7	Influences of waste glass supplements on the estates and resilience of aflame clay brick	.Clay .Waste glass Baco3 .Water .Chemical admixture	particle sizes for glass were nominated lesser than 300µm and larger than 45 µm	The percentage of waste glass was an increased in compressive strength.
8	Investigative Report on the Consequence of Waste Rice Husk and Sugarcane Bagasse Ashes in Burnt Clay Bricks	.clay, Rice husk ash .whereas, sugarcane	, RHA (5% by clay weight) and SBA (5% by clay weight)	Compressive potency and modulus of break decrease next accumulation of RHA and SBA in brick clay.
9	Probability of exhausting clay-permitted bricks synthetic from Marble processing residues, glass, and water: An exploratory feedback	water handling, glass, and granite	Different dosages of glass and marble wastes (i.e. 0–15%).	the peak compressive strength of 33.8 MPa among all the specimens having WTS, glass, and marble.
10	Investigation of Compressive Strength of Straw For reinforced and unburned clay bricks to build sustainable buildings	soil, cement, sand, and water	The liquid boundary of this soil was 37 %, and the plastic limit was 21 % . The ordinary Portland cement type I And the recollected sand on sieve No. 4 was	The unfired bricks gave a compressive strength of 1.9 MPa and were made of clay, coarse sand, and straw. While the compressive strength of stone bricks was close to that of unfired bricks.
11	Manufacturing of Clayey Bricks by Synergistic Use of Waste Brick and Ceramic Powders as Partial Replacement of Clay	fresh clay, waste bricks, and waste ceramic from broken ceramic pottery	(4 + 5)%, (8 + 10)%, and (12 + 15)% of waste brick powder (WBP) and waste ceramic powder (WCP).	• Bricks have 9% (5% WBP + 4% WCP) waste materials had a compressive potency of 11 MPa, above the head samples with 9.8 MPa power. However, bricks with 27% waste ingredients had a strength of 8.1 MPa.

12	Manufacturing of sustainable clay bricks: Utilization of waste sugarcane bagasse and rice husk ashes	Clay, dry sugarcane bagasse, and rice husk ashes.	Using various dosages (5%, 10%, and 15% by clay weight) of SBA and RHA.	The compressive and flexural strengths subsided with amplified proportions of RHA and SBA. However, brick samples incorporating 5% by clay weight of RHA and SBA showed a compressive strength of 6.62 MPa and 7.18 MPa respectively,
13	Preparation of eco-friendly construction bricks from hematite tailings	Along with hematite residue, fly ash, and clay additives	The hematite tailings concentration was 84%, while the water content and formation pressure were respectively in the range of 12.5-15% and 20-25 MPa.	The computerized power and water absorption of the reddish fired specimens were 20.03–22.92 MPa and 16.54–17.93%, respectively, and the other physical characteristics and stability were well.
14	Creation of Workable Clay Bricks Handling Waste Fly Ash: Mechanical and Durability features	clay, fly ash, and water.	plasticity water (20.8 – 18.7%) was enhanced	The compressive power of bricks joining fly ash was dropped as linked to that of clay bricks deprived of fly ash.
15	features of bricks with waste ferrochromium slag and zeolite	clay and additives containing ferrochromium slag and natural zeolite	. Partial-dry fusions were crushed with a pressure of 20 MPa.	Adding zeolite in different proportions between 10%, 20%, and 30% to the clay, which is the raw material for the bricks, will give a compressive strength of 14.3e22.3 MPa, respectively. However the compressive strength when adding the slag and zeolite mixture will be 17.4 and 27.7 MPa. The presence of chromium, iron, and zeolite in some industrial slag and waste will raise the compressive strength to more than 14 MPa, which meets the requirements of TS EN 771.
16	Reusing of underneath ash and fly ash wastes in ecological clay brick creation	clay, fly ash (FA), and bottom ash 5 (BA).	5% FA, 5% BA, and 10% 15 BA	Bricks comprehending 5% FA, 5% BA, and 10% BA display a similar compressive strength to the control bricks.
17	Reutilizing The remains of sugarcane and its leaves, in addition to the remains of ash in the formation of clay bricks	It is possible to make use of clay and waste by crushing sugarcane residue into a powder of a special nature	Nominated blends comprising 0, 5, 10, 15 and 20 wt.% waste was equipped	Increased water retention and loss of routine bonds will lead to the production and increased incorporation of waste bagasse into clay bricks, as they are called.
18	Synergistic effect of rice husk, glass, and marble sludge on the manufacturing features of environmental bricks	Clay, GS, MS, and RH were used as raw resources	Factors of clay, GS, MS, and RH are detected at 7.5, 3.5, 3.0, and 4.5, individually.	• Tests have proven the effectiveness of brick samples containing various wastes, the minimum compressive strength, and modulus of tear required for building bricks.
19	Consumption of unused glass to improve material systematic estates of launched clay brick	flamed by fire clay brick by integrating surplus glass	. The ground waste glass was incorporated into the clay body at the dosages of 0, 5 and 10% by weight	The compressive strength of the bricks was increased by adding waste glass in proportions ranging from 0 to 10% by weight. Temperatures varied between 900 to 1000 degrees Celsius. The results showed that increasing glass waste and temperatures will lead to a decrease in porosity values and the amount of water retention. Having a concentration of 10% by weight of glass will help the brick burn at low temperatures.

4. Outcomes and Discussion

According to what has been reviewed and concluded, the production of bricks from waste materials gives the following conclusions: any groups of researchers have been studied for materials reused for brick production.

The diverse systems reviewed for the production of bricks from reused materials can be separated into common sorts: thermal bricks, and cement, besides geographical polymerization. Still, release and cement methods (especially cement based on cement additives) Despite the numerous research involved in brick production, brick production from sustainable the production of bricks from sustainable materials is still restricted by many factors. Although it raises the level of the environment in terms of eliminating waste, it is still not completely accepted by the public. There are also concerns about restricting the production of bricks from recycled materials, as this mechanism still lacks standards and specifications. The procedure of creating bricks from maintainable supplies shows us that more research and development is needed, to benefit from them in several aspects, including technical and economic.

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Conflicts of Interest:

The authors declare no conflict of interest.

Authors contributions

All authors conducted the work equally.

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