THE CURRENT TREND OF CONVERTING AGRICULTURAL/SUGARCANE BAGASSES WASTE IN TO BRICK

Nitin*[1], VeenaChaudhary[1], Yeshpal[2#], Nancy[2], Gaurav Kumar[2], Amrish Soam[2], Anandveer Sindhu[3]

ABSTRACT
Bricks are a popular building and construction material used all over the world. Historic bricks are made of clay and fired at high temperatures, or from ordinary Portland cement (OPC) concrete, and have a high embodied energy and a hugecarbon footprint. There is already a scarcity of natural source material for theproduction of traditional bricks in many parts of the world. Bricks remain to be an important element in the infra structure development sector for hundreds of decades. Despite of having a wide variation of manufacturing methods, bricks are well known for their energy intensive firing-based manufacturing process which includes a huge environmental footprint. Several innovative techniques towards producing sustainable bricks and many investigations were attempted to reduce the carbon emission while manufacturing bricks. Extensive study on the bricks made from agro waste materials has been performed for environmental protection and sustainable development. This document provides an up-to-date research of research on the use of agro waste materials to make bricks. Although a wide range of agro waste materials have been investigated for use in the production of bricks using various processes, commercial production of bricks from agro waste materials is still quite limited. The methods for creating bricks from agro waste materials, the potential contamination from the agro waste materials utilized, and the lack of necessary information are all possible factors.
However, commercial production of agro waste-derived bricks is currently quite limited. The processes for creating agro waste-based bricks, the potential contamination from the agro waste materials utilized, the lack of applicable standards, and the tardy acceptance of trash-based bricks by industry and the general public are all possible explanations. Further research and development isrequired for widespread production and application of agro waste-derived bricks, not only in terms of technical, economic, and environmental aspects, but also interms of standardization, government policy, and public education related to waste recycling and sustainable development.

Keywords: Bricks, Agro Waste materials, Energy efficiency, Lightweight, Sustainability

[1*]Research Scholar, Department of Chemistry, Meerut College, Meerut, Utter Pradesh (nitinkumar371996@gmail.com)
[1]Professor, Department of Chemistry, Meerut College, Meerut, Utter Pradesh
[2#]JRA UPCST Project, Department of Chemistry, Meerut College, Meerut, UtterPradesh
[2]ResearchScholar, Department of Chemistry, Meerut College, Meerut, Utter Pradesh
[3]Professor, Department of Chemistry, Meerut College, Meerut, Utter Pradesh

***Corresponding author: -** NITIN
*Email:nitinkumar371996@gmail.com

DOI: 10.53555/ecb/2022.11.10.61

1. Introduction

India is one among the fastest growing economies in the globe, which in turn makes India, being one of the top waste generating nations. Many government policies, schemes, programs and missions are launched to handle the solid waste management issues in India effectively. The Basic Services to Urban Poor (BSUP), Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Urban Infrastructure and Governance (UIG) were the notable initiatives which brought up some serious changes in the existing scenario [1]. Despite of Government initiatives in managing waste, India still emerges sal and of encountering versatile waste streams that are generated from different industrial sectors. Construction and demolition waste (C&DW) is growing as a significant urbancontributor to the overall solid waste generation in India. C&DW generation in Indian cities hits up to 1300 kg/m2 which is almost equal to that of a Chinese citywith C&DW generation of 1360 kg/m2 thus needs more attention [2]. Regarding the handling of waste water generation in India, majority of the waste water treatment plants are disposing their generated sludge in dump yards and in landfill sites. In fact, a gap is noticed between the effective management of the sewage sludge produced and the recovered energy from them. However, energy recovery from the sewage sludge has a huge potential to reduce the cost of land filling and transportation operation [3]. Around 620 million tones of agricultural waste are generated annually, of which, only up to 30% is effectively utilized in energy generation and in lives to ck feeding. Remaining 70% (434million tones) of annually produced agricultural waste becomes a part of municipal solid waste that either goes to landfill or burnt [4]. Considering the different waste related sectors and the deficiency in between waste generation and its effective management, considering utilization of the waste streams in the alternative construction brick development becomes a bright strategy [5]. Burnt and unburnt bricks are the basic and primarily adopted construction material in masonry works. Bricks are manufactured either by burning the dried clay mass or by compressing cum curingthe cementitious mass. Under the umbrella of sustainable brick development, along with the economic and environmental concerns, focus on the people typically involve in different brick manufacturing processes should also be given. A typical brick industry promotes employability to both skilled and unskilled labors. Onaverage, a brick manufacturing plant employs 980 labors in Eastern India with the wages fixed either monthly or per 1000. For a long time, bricks have been a popular building and construction material. The first usage of dried clay bricks was in 8000 BC, while the first use of burnt clay bricks was around 4500 BC. Brick production is currently over 1391 billion pieces per year worldwide, with demand expected to continue to rise. Ordinary Portland cement (OPC) concrete or clay is used to make traditional bricks. Quarrying forclay uses a lot of energy, has a negative impact on the environment, and produces alot of waste. Kiln burning at high temperatures consumes a lot of energy and emits allot of green house gases [52].

1.1. Scope of the Problem:-

The global use of natural clay in the brick manufacturing sector has resulted in asignificant depletion of clay resources. The scientists were motivated to seek outnovel materials and/or harness and capitalize on the byproducts generated fromvarious environmental activities [1, 2]. The qualities of the raw materials and the procedures and techniques used have a substantial impact on the quality of bricks. The characteristics of bricks are influenced by the presence of numerous ingredients, such as SiO_2, Al_2O_3, CaO, and iron oxide, which are found in clay indifferent proportions [3]. Various agricultural and industrial byproducts, such asrice husk ash (RHA), sugarcane bagasse ash (SCBA), water sludge (WS), high pulverized fly ash (HPFA), sawdust ash (SDA), sunflower ash (SFA), wheat stalk ash (WSA), Corn Straw Ash (CSA), Physalis Pith Ash (PPA), and Coir Pith Ash (CPA), among others, have been identified as potential pozzolanic materials [4–13]. Numerous scientific studies conducted in the United States, China, Brazil, andEgypt have examined the potential use of water treatment sludge or alum sludge, which has significant clay content, in various industrial contexts.

Several studies have explored the potential use of sludge in the production process of bricks [14, 15].The inorganic constituents found in alum sludge have resemblance to those found in clay, therefore enabling the incorporation of alumsludge into the production of bricks [16]. The addition of unfavorable glass sludge results in a significant increase in compressive strength, with improvements ranging from around 20–24%. According to reference [17], it has the potential to reduce overall porosity and decrease expenses. Several studies [14, 15] have explored the potential use of alum sludge as a substitute or complete replacement for clay in the brick-making sector. Several studies have examined different percentages of sludge mixed with clay in certain scenarios. The findings indicatedthat a sludge concentration of 50% was determined to be the optimal proportion forthe production of bricks using sludge-clay mixtures [15]. Studies have shown that one way to make better use of sludge from water treatment plants is to see if it canbe used instead of other waste materials with a high silica concentration, like ricehusk ash, to make bricks [18, 19]. A substantial volume of dredged sludge may beacquired by the process of dredging rivers, oceans, and reservoirs. The dredgedsludge has similarities to sludge obtained from several facilities. Various forms of waste materials have been identified as potential resources for the manufacturing of red clay bricks [20–22].The integration of waste by-products into the manufacturing process of clay bricks effectively reduces environmental pollution, namely air pollution resulting from the dumping of agricultural and other waste materials in open landfills. Moreover, it often offers the opportunity to achieve asuperior level of brick performance. As a result, the use of agricultural by products such as sugarcane bagasse and rice husk ashes has been shown to enhance the process of brick manufacturing [23]. The global annual rice output is estimated tobe between 800 and 1000 million tons [24]. Globally, bricks serve as a prominent construction material, possibly dating back to ancient times. Since around 3000 BC, with the advent of human settlement, bricks have emerged as a note worthy construction material because of their durability, malleability, and practicality. This development allowed people to successfully shield themselves from environmental factors such as rain, wind, and potential threats from animals. Historically, the production of bricks included manual molding and sun-drying, resulting in bricks with rather delicate characteristics. However, a significant development occurred circa 2500BC with the introduction of burnt bricks, enabling the construction of larger-scale structures [25].

The progression of brick development has persisted in several nations throughout time, particularly with the onset of industrialization in 1830. The invention of abrick press by Augusta Virebent sparked this advancement. The emergence ofbrick industries occurred in conjunction with the Industrial Revolution, when theybegan to consolidate into factory settings, resulting in a significant expansion of production [26].

Bricks have been consistently used in the construction of structures due to their notable physical, mechanical, and thermal characteristics, particularly their robustness, longevity, and density [27, 28]. Hence, it is essential to develop a novelmaterial that exhibits enhanced performance in terms of thermal and mechanical properties. To make it easier to get these improvements, one could add particles tothe clay mixture. These particles would create holes while the clay is being burned, which would change the bricks' properties in a good way.

In contemporary times, and particularly over the last two decades, there has been anotable prevalence in the use of waste materials for this specific objective [29].This proposed approach presents an alternate method for repurposing waste materials rather than disposing of them via dumping or incineration, with the added benefit of improving the thermal and mechanical characteristics of bricks. Furthermore, given the growing prevalence of eco-friendly goods, the reins a potential interest in developing a material that not only contributes to environmental well-being but also maintains the necessary performance standards [30].

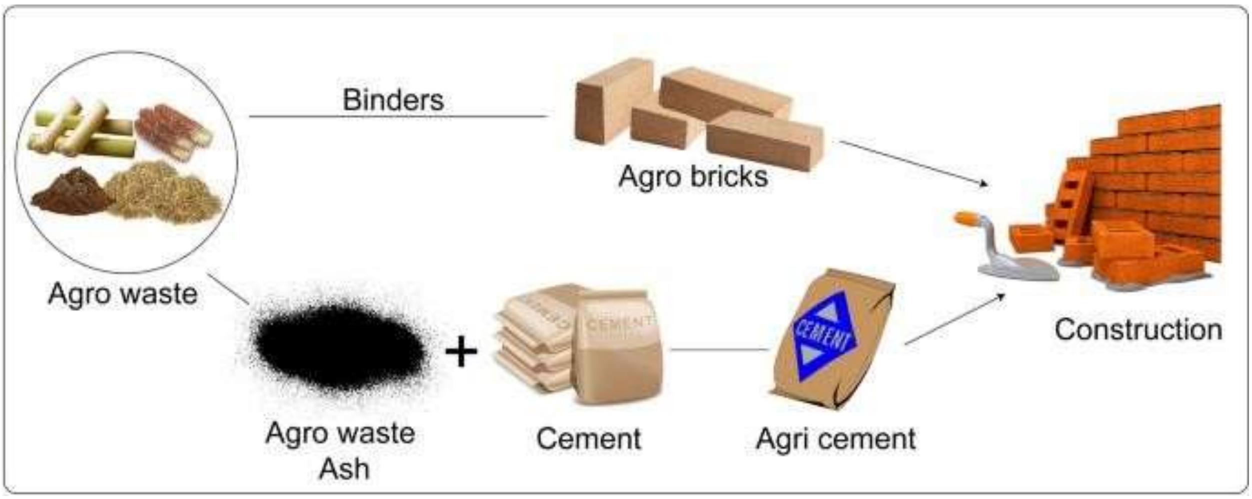

Fig.1.conversionprocessofagrowasteinconstructionmaterials

2. The Conversion Process:-

There are many techniques for the conversion of agricultural waste into bricks.These procedures may be categorized into three distinct steps: The process has three main stages: preparation of raw ingredients, proportioning and mixing, and molding and curing.

The first phase of the process is the collection, categorization, and preparation of the agricultural waste materials. In order to eliminate excessive moisture, it is necessary to dry organic wastes such as crop stalks, bagasse, straws, and husks. Additionally, these residues may need fragmentation via the use of a crusher or grinder to achieve smaller particle sizes.

The process of proportioning and mixing involves the combination of agricultural waste and a binder, such as clay or cement, in predetermined ratios. The use of agricultural waste serves as a source of fiber reinforcement, with the binder playing a crucial role in binding these fibers together. The mixture ratio exhibits variability; however, it is customary to use an agro-waste to binder ratio of either1:2 or 1:3.

The process of molding and curing involves shaping a combination of agriculturalwaste and binder into bricks using a mold. The green bricks that are obtained as aconsequence are either air-dried for a fewdaysor subjected to kiln drying. After the drying process, it is possible to enhance the strength and durability of these bricks by subjecting them to an optional firing in a kiln. The research has also investigated the use of bio-enzymes, natural fillers, and bacterial agents to augment the characteristics of the bricks. The selection of the appropriate process is contingent up on the exact kind of agricultural waste used and the intended characteristics sought in the resultant bricks. However, it is important to align the chosen approach with the established norms and standards for building materials in order to guarantee the safety and efficacy of the end products.

Table 1 Summary of previous research works about bricks with alternative materials [49].

S.No	Waste materials focused	Time line Coverage	Summaryoffindings	Review Works
1.	Fuelwastes:sewagesludge,paperindustrysludge, saw dust, woolwashwatertreatmentsludge,wastefromtanningindustries,coconutpith,coal miningwastes,petroleumcokes;flyash;Fluxingwaste:waste from ceramic tileandplatingindustries;Plasticityreducingwaste:basaltdust,brick chamotte, cementdust,gravelwashingsludge,refractorychamotte,cementwaste;Plastifying waste:drillingmuds,sandwashingsludge ,miningwaste,bauxiteprocessingwaste	1977–1997	• Duetosavingsincombustion energy,carbonrichwastematerialsaremostpreferable.•Utilizingwastematerialsalsoinduces toxicity leachingandadditionalcostfortransportation.	[50] 91references
2.	Glass Plastic wasteMunicipal waste SludgeSlagCoalash	1934–2017	• Brickmanufacturingmethodswereclassifiedintofiring,	[55] 137 references
	Biomassash		geopolymerizationandcementing.•Regardingsustainabilitypointofview,geopolymerizationscoresmorethanremainingtwomethods. • Geopolymerizationbasedclaybrickresearchwas said to be promisingleads.	
3.	SludgeResiduesofpulpTobaccoPaperwaste.	1980–2010	• Reusingsolidwasteissuggestedascosteffective replacement forfiredclaybricks.•Thebricksmadewithrecycledcontentshownenhanced physicalpropertiessuchasthermalbehaviour,lowdensity,waterabsorption andporosity.	[51] 53references
4.	PaperwasteTobaccoresidueGrassCottonwasteSawdustandRicehusk ash.	1983–2012	• Wastematerialsfromagroprocessespossesslesserthermalconductivity, durable butcheaper,lightinweightandecofriendly.• Agrowastematerialsarehavingsignificance regardingpracticalityofreusing.	[54] 63references
5.	Solidwastesfromagriculturalandindustrialwastestreams	1977–2010	• Fornon-structuralandstructural wallapplication,minimumcompressives	[52] 66references

			trengthrequiredforfiredclaybricks ranges between 3and5MPaand5–10MPa.•Wastepaperpulp incorporated bricks showed highestcom pressive strength andcrumbrubberwasteincorporated bricksshow edleastwaterabsorptionamongthe otherwastesreviewed.	
6.	Solid wastes frommunicipal and industrial wastestre ams	1951–2015	• When producing unfiredbricks,thedemandforraw material reconstitutionresultsinbetterdensityandstre ngth.•Bricksthathavebeenautoclavedhaves howedpromisingoutcomesintermsofweigh t reduction, energyefficiency, and insulatingqualities.•Stabilizedearth blocks were shownto be a superior substituteforburntbricks,butonlywhenthey containednomorethan10%cement.	[56] 138 references
7.	Solidwastesfromagricultural andindust rial wastestre ams	1996–2013	• Possibilityofrecyclingwasteintobrickma nufacturingiseasierbutharderincommercial ization. • Cementingmethodremains better than firingmethod in view of globalwarmingissue. Hydration, porosity andstrengthofcementitiousmaterialsdecide sthequalityofbricksincementing andtemperature, loss on ignition and ratio ofwastematerialsinfiringprocess.	[53] 98re ferences

3. Production of bricks by achieving waste incorporation

In this section, brick manufacturing methods using various wastes including sludge, agro waste, plastic waste, industrial waste-solid waste emerging from different industrial activities and construction and demolition waste were reviewed. The research includes the material choices, mix and waste replacement ratio, impact of waste addition on physico-mechanical characteristics of the manufactured bricks.

The residues that are generated in crop cultivation processes are termed as agro waste. Due to the diverse practicesin agricultural activities, India stands as thenext largest country to China, second on the globe, with over 500 million tons of annual agro waste generation [57]. Due to the increased load to municipal wastestream on one hand and the caused air pollution through burning of crop residueson the other, increased the agricultural sector demand for more efficient practices for their waste handling and management. Comparative study was performed to assess the recycling potential of wheat husk and sugarcane bagasse in producing the bio-bricks and bio- brick panels [58]. The study was focusing more on product design aspect for developing eco-friendly building material with agro wastes rather than assessing the structural suitability of the bio bricks in load bearing. The results explained that sugarcane bagasse waste-based bio-bricks and bio-panels are better than wheat husk-based bio-bricks in compression strength and water absorption. However, the research clarified that the bio products made from wheat husk and sugarcane bagasse exhibited similar thermal insulation property. Alternative fly ash brick manufacturing method was investigated by partially replacing corn cobash with cement [59]. The partial replacement ratios attempted were 10%, 20% and 30%. Physical characteristics of the produced ricks were assessed. The presence of Al2O3 and SiO2 in corn cob ash helped to replace the cement suitably. The results proved that 10% corncob ash can successfully replace the cement in makingfly ash bricks. It was noted that the replacement ratios beyond 10% resulted in decreasing compressive strength and increasing water absorption. Sugarcane bagasse ash (SBA) in fused energy efficient bricks were made and analyzed for their suitability for load bearing units [60]. Mix ratios (in %) attempted were: 80–0–20, 75–5–20, 70–10–20, 65–15–20, 60–20–20, 55–25–20 and 50–30–20 as SBA-quarry dust-lime respectively. The bricks were made and tested as per Indian standards. Physico-chemical properties confirmed the suitability of SBA for pozzolanic material replacement. Further, thermo gravimetric analysis showed thatSBA can be stable at higher temperature up to 650°c. The mechanical properties of bricks proved that mix ratio of 50–30–20% (SBA-quarry dust-lime) satisfied the requirements of IS: 2185 (Part 1) SP:21 for building materials.

Table.2.Different compositions for constructive materials:

S.NO	Composition	Water absorption rate (%)	Compressive strength (MPa)	Ref.
1.	Cement,Sand,PaintWaste,Water	13.8-20.0	8.74	[32]
2.	Small pieces of SCB, SAND	24-30.5	2.09-2.12	[33]
3.	Parali,Recycledaggregates,Sand,Cement	27	1.38	[34]
4.	Parali,Sand,Cement,PET	16.86	0.71	[34]
5.	Recycled Aggregates, Sand,Cement,LDPE	12	-	[34]
6.	SCBA,Cement,Aggregates	-	1.68-3.04	[35]
7.	Clay, Sludge, Saw dust, sugarcanebagasse(SCB),andCornStalk(CS)	27.40-27.80	47.5-48.5	[36]
8.	Desertclay,Wastebuildingbricks,Wasteglass,Agricultura lresidueobtainedfromWheat&Sugarcanecultivation.	13.32-20.08	19.12	[37]
9.	Bagasseash,Clay,Water,Sand,Admixture	13.89-16.26	2.35-4.55	[38]
10.	Clay, Sand, Oat Husk (OH),BarleyHuskMiddlings(BHM)	7.3-49.2	0.8-29.5	[39]
11.	Clay, SCBA	13.1-22.7	10.53-24.47	[40]
12.	Clay,Sugarcanebagasse	27	7.96	[41]
13.	Clay,Coconut husk	34	10.4	[41]
14.	Clay,Grass	32	9.84	[41]
15.	Clay, Sand, Olive core flour,Wheat straw	25-32	2.5-7.2	[42]
16.	Claysoil,Coconutfibre(CF)andEmpty fruit bunchofpalmoil	21.82-34.43	0.96-697	[43]
17.	Wastewater treatment sludge,Limemud,Grits	22-27	1.51-3.23	[44]
18.	Clay, Sand, Water, Wheat straw,SunflowerseedcakeandOlivestoneflour	17.8-24.1	-	[45]
19.	Clay, SCBA, an alternativefluxing agent	11-18	3.5-15	[46]
20.	Cementdust,Clay,Ricestraw	-	1.3-2.5	[47]

Additionally, the bricks were attaining 60% energy efficiency and passed the TCLP test for environment compatibility. Impacts of addition of agricultural solid wastes on the physico-mechanical and porous properties of fired ceramics were studied [61]. Barley husk, oat husk and millings were mixed in place of clay indifferent proportions 5%, 10% and 20%. It was found that addition of agriculturalsolid waste helped in reducing the drying shrinkage and post firing shrinkage. Micro structural analysis confirmed that due to stabilization of drying process and the pore structure formation, initial water absorption is reduced and early compressive strength is improved. Results stated that the replacement of 10% produced eco-friendly clay bricks confirming to standards. With the aim of developing sustainable construction material, recycling of agro-industrial wastes in the manufacturing of bricks were investigated [62].Coco a shell saw dust, sugarcane and rice husk were added in different proportions in place of clay (5%, 10% and 20%) to assess the influence on physico-mechanical properties of produced bricks under sintering. It was noted that the open porosity of the ceramicbodies increased due to the fact that agro wastes are highly organic in nature. Theresults confirmed that 10% cocoa shell and 90% clay produced sustainable bricks which was claimed to meet the standards. The reason found to be was the emergence of oily films from cocoa shells acted as lubricants and supported the development of denser clay product, increased the compression strength. Fibroustea waste replaced the raw clay in the manufacturing of sintered and unborn bricks [63]. The impact of tea waste in the development of pore spaces in case of firedbricks and bonding characteristics in case of unfired bricks were assessed. Thereplacement ratios were 2.5% and 5% on weight basis. While the presence of waste was increasing, the brick's density was reported to be decreased due to loss on ignition. The waste added bricks exhibited increased water absorption beyond 18% but no black coring was reported. Compressive strength of fired bricks is more (22.7 MPa) than unfired bricks (7.5 MPa). The physico-mechanical characteristics of the final produce concluded that the processed tea-waste can be utilized as an effective porous substance in the production of burnt bricks. Sugarcane bagasse ash (SBA) and rice husk ash (RHA) were assessed for their effective utilization inthe development of clay bricks [64]. SBA and RHA were mixed partially with clayin the ratio of 5% each by weight. The modified bricks were tested and compared against the control bricks. The modified bricks yielded 6% lesser weight comparedto control bricks. Even though the compressive strength of modified bricks was reported to be reducing with the addition of SBA and RHA, the final produced bricks met the standards of Pakistan for least requirement of compression strength (5MPa). Similarly, the flexural strength of modified bricks met the ASTM standards for masonry units. Water absorption test indicated that the final producecan be only utilized in moderate weather regions due to its higher water absorption. Since the addition of SBA and RHA helped in reducing the calcium (Ca) and ironoxide (FeO) levels in the bricks, the efflorescence has significantly reduced too.The modified bricks have also showed environmental compatibility. Crystalline silica rich sugarcane bagasse ash (SBA) was attempted to replace the clay in the development of sustainable bricks [65]. The mixing ratios were kept as 5%, 10%, 15% and 20%. The proportions [66] Mix ratios kept were 5%, 10%, 15%. The modified bricks were tested for durability and mechanical characteristics. The outcomes confirmed that the 5% replacement of clay with SBA and RHA coincide with the statutory limits of Pakistan for masonry bricks. Waste biomasses from agricultural activities such as wheat straw (WS), sunflower seed cake (SSC) and olive stone flour (OSF) were partially mixed in different proportions, 4% and 8%, in place of clay for the development of sintered bricks [67]. The physico-mechanical characteristics of the produced bricks have shown that 4% addition ofSSC and OSF resulted in increased porosity (23%), reduced bending strength (<10MPa) and reduced thermal conductivity (0.38W/m.K). SSC and OSF were recommended as the sustainable additives in clay brick manufacturing if life cycle analysis of the bricks is performed. Woody agricultural biomasses such as grapes, cherries seeds, saw dust and sugarcane ash were added in place of clay in different proportions and tested for its suitability as construction bricks [68]. The technological tests conducted on the modified bricks highlighted that the addition ratio up to 5% gave positive results. Grapes and cherry seeds provided improvements in mechanical properties where sugarcane ash helped to reduce theshrinkage and led to no weight loss. New type of fired clay bricks was investigated for the enhanced thermal performance by the addition of waste tea (WT), corn cob (CC) and rice husk (RH) separately [69]. The mixed ratio of RH, CC, WT attempted were 2.5%, 5% and 10%. The produced bricks were manufactured andtested according to relevant ASTM standards. The shrinkage test revealed that theaddition of waste did not help in reducing the shrinkage but in contrast it increased, which was due to the high requirement of water content. The agricultural wastes helped in making the bricks less dense. Corn cob with 10% mixing proportion produced bricks with lowest density, 1186 kg/m3. Straight correlation between increasing waste addition and decreasing water absorption was noticed. CC brickswith 2.5% addition showed lowest water absorption of 12.62% compared to the11.59% of control bricks. Increasing of waste addition eventually decreased the compressive strength of the modified bricks. 2.5% addition of all the selected waste materials produced bricks with the required minimum compressive strengthof 5 N/mm2. Thermal conductivity of all the modified bricks with all the mix proportions resulted in satisfied thermal conductivity. Out of the mix propositions, 2.5% addition of RH, CC and WT resulted in thermal conductivity which wasalmost equal to those of control bricks. Fired clay bricks were investigated for theenhanced structural performance by the addition of sugarcane bagasse (SB), emptyfruit bunch (EFB) and coconut fiber (CF) separately [70]. The mixed ratio for EFB: CF: SB attempted were 2.5%: 5%: 10%. The produced bricks were manufactured and tested according to ASTM C 518, BS 3921: 1985. Physico-mechanical test results revealed that modified bricks had lesser density, increased water absorption, lesser compression strength and almost equal thermal conductivity. The reasons constituted were pore formation, higher moisture requirement, reduced presence of silica and higher porosity respectively. It was concluded that 5% addition of EFB and SB was recommended for non-load bearing wall construction bricks.

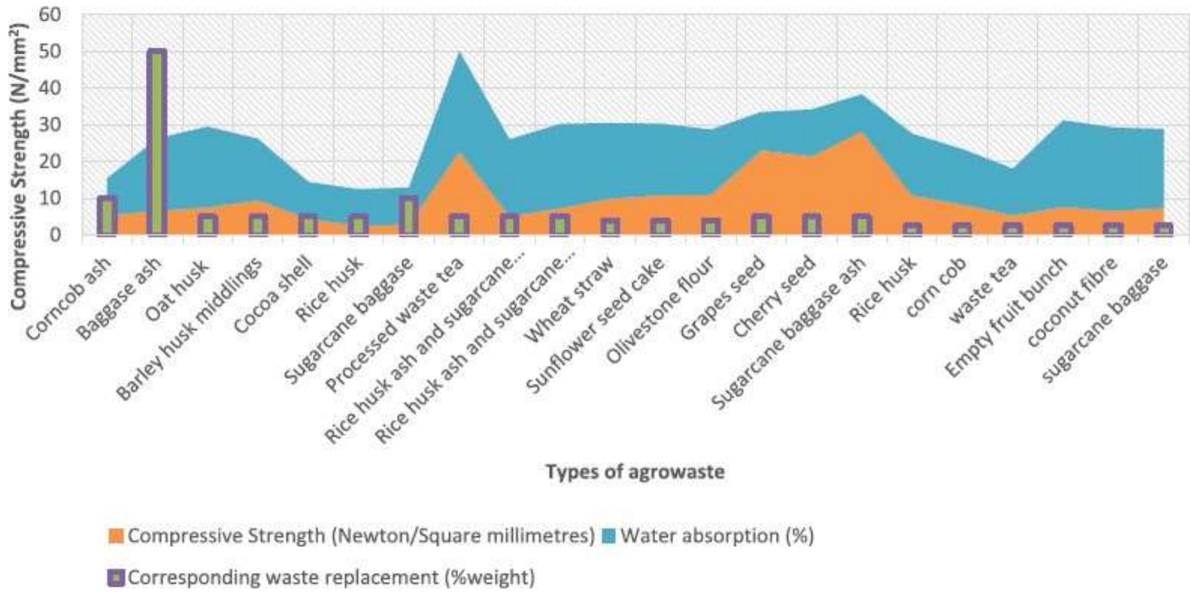

Fig. 2. Compressive strength and water absorption of bricks made with different agro waste [49].

4. Impact of incorporation of agro waste materials for brick production on environment

Unlike sludges, being completely organic in nature, agro wastes yet exhibited morepositive impacts on sustainable brick production. Biobricks which are prepared with agro wastes such as corncobs, sugarcane bagasse, rice husk and wheat husk as major ingredient shown better results regarding reduced thermal conductivity. This was due to the increase in total mass to volume of binder ratio. Furthermore, as the utilization of agro waste in brick production, the pre-existing practice of burning the agro waste is majorly prevented and thus led to carbonation aided atmospherecarbon fixation.

5. Future Prospects of Agro-Waste Bricks/SCB in the Construction Industry

The potential outlook for agricultural waste bricks in the building sector is favorable due to many factors. The construction sector as an ongoing need for eco-friendly and sustainable building materials. Agro-waste bricks are an ideal solution that alignswell with the current need, therefore positioning them as a material with significant future prospects.

Technological Advancements: Due to continuous advancements in technology, it is anticipated that the conversion of agricultural waste into bricks will see enhanced efficiency and cost-effectiveness, making this alternative more appealing for wide spread implementation.

Policy Support: Governments worldwide are increasing gly prioritizing environmental sustainability, resulting in policy reforms aimed at promoting the use of sustainable construction materials. These policies are expected to prioritize the use of agricultural waste bricks.

Increasing Consumer Awareness: Consumers are becoming more aware of the environmental consequences associated with building operations. The fore mentioned phenomenon leads to a rise in the need for sustainable construction materials and procedures, such as theuse of agricultural waste bricks. However, the widespread implementation of agro-waste bricks is contingent upon effectively overcoming the obstacles related to their use. These factors include the maintenance of uniform quality, the establishment of effective manufacturing methods and procedures, the verification of long-term resilience, and the attainment of recognition fortes bricks within the building industry and regulatory entities. In summary, considering the continued need for sustainable building methods with improvements in technology and evolving legislative frame works, the use of agro-waste bricks in the construction industry has considerable prospects.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The author would like to acknowledge University Grant Commission (UGC), New Delhi (NTARef. No.211610130318) for financial assistance.

References:-

[1] Agwa IS; Omar OM; Tayeh BA; Abdelsalam BA (2020) Effects of using rice straw and cotton stalk as heson the properties of light weight self-compacting concrete, Journal of

Construction and Building Materials, 235, 117541.doi:http://dx.doi.org/10.1016/j.conbuildmat.2019.117541.

[2] Kazmi MS; Abbas S; Saleem MA; Munir MJ; Khitab A (2016) Manufacturing of sustainable clay bricks: utilization of waste sugarcane bagasse and rice huskashes, Journal of Construction and Building Materials, 120,29–41, doi:http://dx.doi.org/10.1016/j.conbuildmat.2016.05.084.

[3] Riaz MH; Khitab A; Ahmed S (2019) Evaluation of sustainable clay brick sin corporating brick kiln dust, Journal of Building Engineering, 24, 100725. doi:http://dx.doi.org/10.1016/j.jobe.2019.02.017.

[4] De Silva GS; Surangi MLC (2017) Effect of waste rice husk ash on structural, thermal and run-off properties of clayrooftiles, Journal of Construction and Building Materials, 154,251–257. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.07.169.

[5] Eliche-QuesadaD;Felipe-SeseMA;Lopez-PerezJA;Infantes-Molina A (2017) Characterization and evaluation of rice huskash and wood as hinsustainable clay matrix bricks, Ceramics International, 43,1,463–475, doi:http://dx.doi.org/10.1016/j.ceramint.2016.09.181.

[6] Darweesh HHM; Abo El-Suoud MR (2019) Palm Ash as a Pozzolanic Material for Portl and Cement Pastes,To Chemistry Journal, 14,72-85. http://purkh.com/index.php/tochem.

[7] Darweesh HHM; Abo El-Suoud MR (2019) Influence of sugarcane bagasse ashsubstitution on Portland cement characteristics, Indian Journal of Engineering, 16,252-266. www. discovery journals.org.

[8] Li1Q; Zhao Y; Chen1 H; Hou P; Cheng X (2019) Effect of cornstalk ash on themicro structure of cement-based material under sulfate attack, IOPConf. Series: Earth and Environmental Science, 358, 052010. doi:10.1088/1755-1315/358/5/052010.

[9] Darweesh HHM (2020), Specific characteristics and microstructure of Portland cement pastes containing wheat straw ash (WSA), Journal of Engineering, 2020, 17,48,569- 583.www.discoveryjournals.org.

[10] Darweesh, HHM (2020) Saw dust ash substitution for Portland cement pastes-Part II: Chemical resistance against sulfate attack, Indian Journal of Engineering,17,48,396-407.www.discoveryjournals.org.

[11] Darweesh HHM (2020) Influence of sun flower stalk ash (SFSA) on the behavior of Portland Cement, Results in Engineering, 8,100171.https://doi.org/10.1016/j.rineng.2020.100171.

[12] DarweeshHHM(2021)UtilizationofPhysalisPithashasapozzolanicmaterialinPortlandcementpastes,JounalofBiomaterials.5,1,1-9.http://www.sciencepublishinggroup.com/j/jb.

[13] Darweesh HHM (2021) Characterization of Coir Pith Ash Blended CementPastes, Research & Development in Material science, RDMS.000851. 15, 1, 1630-1630. DOI:10.31031/RDMS.2021.15.000851.

[14] Hegazy BE; Fouad HA; Hassanain AM (2012) Brickmanufacturing fromwater treatment sludge and rice husk ash,Aus. J. Bas. Appl. Sci. 6 (3) 453–461. https://sswm.info/node/4027.

[15] Ramadan MO; Fouad HA; Hassanain MA (2008) Reuse of water treatment plants ludgein brick manufacturing, J.Appl.Sci. Res.4,10,1223-1229. https://www.researchgate.net/publication/295548404.

[16] DarweeshHHM;El-MeligyMG(2014)Non-ConventionalLight-WeightClayBricksfromHomraandKraftPulpWastes,JournalofChemistryandMaterialsResearch,1,4,123–129.www.oricpub.com.

[17] Kazmi SM; Abbas S; Nehdi ML; Saleem MA; Munir MJ (2017) Feasibility ofusing waste glass sludge in production of eco-friendly clay bricks, J. Mater. Civ.Eng. 29,8,04017056.doi:http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0001928.

[18] Esmeray E; Atis M (2019) Utilization of sewage sludge, oven slag and fly ashinclay

[19] Hegazy BE; Fouad HA; Hassanain AM (2012) Incorporation of water sludge,silica fume, and rice husk ash in brick making, Adv. Environ. Res. 1, 1, 83–96. doi: http://dx.doi.org/10.12989/aer.2012.1.1.083.

[20] Lang L; Song C; Xue L; Chen B (2020) Effectiveness of waste steel slagpowder on the strength development and associated micro-mechanisms of cement-stabilizeddredgedsludge,Constr.Build.Mater. 240,117975.doi:http://dx.doi.org/10.1016/j.conbuildmat.2019.117975.

[21] Lang L; Liu N; Chen B (2020) Strength development of solidified dredgedsludge containing humic acid with cement, lime and nano-SiO2, Constr. Build. Mater. 230,

116971. doi:http://dx.doi.org/10.1016/j.conbuildmat.2019.116971.

[22] Lang L; Chen B; Li N (2020) Utilization of lime/carbide slagactivated groundgranulated blast-furnace slag for dredged sludge stabilization, Mar. Geore sources Geotechnol.,1–11. doi:http://dx.doi.org/10.1080/1064119X.2020.1741050.

[23] Kazmi MS; Abbas S; Munir MJ; Khitab A (2016) Exploratory study on theeffect of waste rice husk and sugarcane bagasse ashes in burnt clay bricks, J. Build.Eng.7,372–378,doi:http://dx.doi.org/10.1016/j.ceramint.2014.10.102.

[24] IRRIInternationalRiceResearchInstitute.(Accessed28.7.16).https://www.irri.org/rice-straw-management.

[25] Chabat, P., 1881. La brique et la terre cuite: _etude historique de l'emploi decesmat_eriaux, fabrication etusages, motifsde construction etded_ecorationchoisis dans l'architecture des diff_ erentspeuples. In: par Pierre Chabat.,..; avec lacollab.deF_elixMonmory,S_erie 1.May et Motteroz (Paris).

[26] Brongniart, A., 1844. Traite des arts ceramiquesou Des poteriesconsidereesdansleurhistoire,leurpratiqueetleurtheorie.In:parAlexandreBrongniart, Tome1.A.Mathias(Paris).

[27] Kadir, A.A., Sarani, N.A., 2012. An overview of wastes recycling in fired claybricks.Int.J.Integr.Eng.4,53e69.

[28] Sutas, J., Mana, A., Pitak, L., 2012. Effect of Rice husk and Rice husk ash to properties of bricks. Procedia Eng.32,1061e1067.

[29] Devant, M., Cusid_o, J.A., Soriano, C., 2011. Custom formulation of redceramicswithclay,sewagesludgeandforest waste.Appl.ClaySci. 53,669e675.

[30] Dhanapandian,S.,Gnanavel,B.,2010.Using granite andmarble sawingpower wastes in the production of bricks: spectroscopic and mechanical analysis.Res. J.Appl.Sci.Eng.Technol.2,73e86.

[31] SatputePratiskhaVaijnath1,MaliPrajaktaSiddheshwar2,MahashikareSakshi Pradip3 , Dr. Kazi Kutubuddin Sayyad Liayakat4 International Journal of Aquatic Science ISSN:2008-8019 Vol13,Issue01,2022

[32] DhruvAnand1,TabishQuadri2Volume11,Issue1,January2022,DOI:10.15680/IJIRSET.2022.1101034

[33] Amany Micheal [1],RaniaRushdyMoussa [2,*]Civil Engineering and Architecture Vol.10 (1),pp.71-78DOI:10.13189/cea.2022.100106

[34] Dr. Vishal Puri1 , Satyam Kumar2 , Khushi Grover2 , Mukul Sharma2 ,Materials Science and Engineering 1248 (2022) 012109 doi: 10.1088/1757-899X/1248/1/012109

[35] Nancy T. Hussien&Ahmed F. Oan, Journal of Engineering and AppliedSciencevolume 69,Articlenumber:31(2022)DOI:10.1186/s44147-022-00076-6

[36] Hassan Hassanien Mohamed Darweesh, Journal of Biomaterials Volume5, Issue2, December 2021, Pages:16-22 doi:10.11648/j.jb.20210502.11

[37] Mai Hassan,March 2021, WSEAS TRANSACTIONS ON ENVIRONMENT AND DEVELOPMENT17:192-200, DOI: 10.37394/232015.2021.17.19

[38] Vol-4Issue-42018IJARIIE-ISSN(O)-2395-43969042www.ijariie.com1306"BAGASSE ASHBRICK"MANISHCDETROJALecturer, Civil,S.B.Polytechnic,Gujarat,India

[39] olga.kizinievic@vgtu.lt(O.Kizinievič).Availableonlineatwww.sciencedirect.com Science Directjournal home page: http://www.elsevier.com/locate/acmehttps://doi.org/10.1016/j.acme.2018.03.003

[40] NonthaphongPhonphuak [a] and PrinyaChindaprasirt* [b]Chiang Mai J. Sci.2018;45(4):1855-1862,http://epg.science.cmu.ac.th/ejournal/ContributedPaper

[41] AnuwatSrisuwan1*,NonthaphongPhonphuak2,andChiawchanSaengthong1Received: November 06, 2017; Revised: December 26, 2017; Accepted: December27,2017

[42] Sani, R.; Nzihou, A. (2017). Production of clay ceramics using agriculturalwastes: Study of properties, energy savings and environmental indicators. Applied Clay Science, 146(),106–114. doi:10.1016/j.clay.2017.05.032

[43] The Potential of Agricultural Waste as Pore Forming Agents in Production ofLow Thermal Clay Brick Rafikullah Deraman1,*, Abd Halid Abdullah, ShahironShahidan1,SasitharanNagapan1,,MohamadHazmiHamzah1https://www.researchgate.net/publication/317386100

[44] Sarkaretal.,CogentEngineering(2017),4:1405768https://doi.org/10.1080/23311916.2017.1405768

[45] Cecile Bodes, Laila Aouba, Emeline Vedrenne, Gerard Vilarem. Fired claybricks using agricultural biomass wastes: Study and characterization. Constructionand Building

[46] Green Building Bricks Made with Clays and Sugar Cane Bagasse AshD.Tonnayopas,

Department of Mining and Materials Engineering, Prince of Songkla University, Thailande-mail:danupon.t@psu.ac.th

[47] USINGADHESIVEMATTERFORAGRICULTURALWASTESASBUILDING BRICKS 1. Tayel S.A. 2- Khairy M. F. A. 3- EL-Soaly I. S. 4-MoussaA.M.

[48] Zhang,L.(2013).Productionofbricksfromwastematerials–Areview.Constructionandbuildingmaterials,47,643-655.

[49] ContentslistsavailableatScienceDirectSustainableChemistryfortheEnvironmentjournalhomepage:www.editorialmanager.com/scenvhttps://doi.org/10.1016/j.scenv.2023.100030

[50]M. DONDI, M. MARSIGLI, B. FABBRI, Recycling of industrial and urban wastes in brick production: a review, Tile Brick Int.13 (1997)218–225.

[51]A.A.Kadir,A.Mohajerani,Bricks:Anexcellentbuildingmaterialforrecycling wastes - a review, Proc. IASTED Int. Conf. Environ. Manag. Eng. EME2011 (2011)108–115,https://doi.org/10.2316/P.2011.736-029.

[52]S.P. Raut, R.V. Ralegaonkar, S.A. Mandavgane, Development of sustainable construction material using industrial and agricultural solid waste: A research of waste-create bricks, Constr. Build. Mater. 25 (2011) 4037–4042, https://doi.org/10.1016/j.conbuildmat.2011.04.038.

[53]L. Zhang, Production of bricks from waste materials - a review, Constr. Build. Mater. 47 (2013)643–655, https://doi.org/10.1016/j.conbuildmat.2013.05.043.

[54]M.V. Madurwar, R.V. Ralegaonkar, S.A. Mandavgane, Application of agro-waste for sustainable construction materials: a review, Constr. Build. Mater. 38(2013)872–878,https://doi.org/10.1016/j.conbuildmat.2012.09.011.

[55]Z. Zhang, Y.C. Wong, A. Arulrajah, S. Horpibulsuk, A researchof studies onbricks using alternative materials and approaches, Constr. Build. Mater. 188 (2018)1101–1118, https://doi.org/10.1016/j.conbuildmat.2018.08.152.

[56]A.L. Murmu, A. Patel, Towards sustainable bricks production: an overview, Constr. Build. Mater. 165(2018)112–125, https://doi.org/10.1016/j.conbuildmat.2018.01.038.

[57]Y. Singh, H.S. Sidhu, Management of cereal crop residues for sustainable rice-wheat production system in the Indo-Gangetic Plains of India, Proc. Indian Natl. Sci. Acad. USA80(2014)95–114,https://doi.org/10.16943/ptinsa/2014/v80i1/55089.

[58]P. Rautray, A. Roy, D.J. Mathew, B. Eisenbart, Bio-brick - Development ofsustainable and cost-effective building material Proc. Int. Conf. Eng. Des. Iced.2019-Augus20193171 3180doi:10.1017/dsi.2019.324.

[59]B.Rajwade,N.Netam,Investigation of effects of corncob ash in fly ashbricks, Mater. Today Proc. 28(2020)2431–2434, https://doi.org/10.1016/j.matpr.2020.04.721.

[60]M.V.Madurwar,S.A.Mandavgane,R.V.Ralegaonkar,DevelopmentandFeasibility Analysis of Bagasse Ash Bricks, J. Energy Eng. 141 (2015) 04014022,https://doi.org/10.1061/(asce)ey.1943-7897.0000200.

[61]O. Kizinieviˇc, V. Kizinieviˇc, I. Pundiene, D. Molotokas, Eco-friendly firedclay brick manufactured with agricultural solid waste, Arch. Civ. Mech. Eng. 18(2018)1156–1165,https://doi.org/10.1016/j.acme.2018.03.003.

[62]L.M.Luna-Ca˜nas,C.A.Ríos-Reyes, L.A. Quintero-Ortíz,Recyclingofagroindustrial solid wastes as additives in brick manufacturing for development of sustainable construction materials, DYNA81 (2014)34–41, https://doi.org/10.15446/dyna.v81n188.39717.

[63]I.Demir,Aninvestigationontheproductionofconstructionbrickwithprocessedwastetea,Build. Environ.41(2006)1274–1278,https://doi.org/10.1016/j.buildenv.2005.05.004.

[64]S.M.S. Kazmi, S. Abbas, M.J. Munir, A. Khitab, Exploratory study on theeffect of waste rice husk and sugarcane bagasse ashes in burnt clay bricks, J. Build.Eng.7 (2016)372–378, https://doi.org/10.1016/j.jobe.2016.08.001.

[65]K.C.P. Faria, R.F. Gurgel, J.N.F. Holanda, Recycling of sugarcane bagasse ashwasteintheproductionof claybricks,J.Environ.Manag.101(2012)7–12,https://doi.org/10.1016/j.jenvman.2012.01.032.

[66]S.M.S. Kazmi, S. Abbas, M.A. Saleem, M.J. Munir, A. Khitab, Manufacturingof sustainable clay bricks: Utilization of waste sugarcane bagasse and rice huskashes, Constr. Build.Mater.120(2016)29–41, https://doi.org/10.1016/j.conbuildmat.2016.05.084.

[67]C.Bories,L.Aouba,E.Vedrenne,G.Vilarem,Firedclaybricksusingagricultural biomass wastes: Study and characterization, Constr. Build. Mater. 91(2015)158–163,https://doi.org/10.1016/j.conbuildmat.2015.05.006.

[68]L.Barbieri,F.Andreola,I.Lancellotti,R.Taurino,Managementofagricultural biomass wastes: preliminary study on characterization and valorizationinclaymatrixbricks,WasteManag. 33(2013)2307–2315,https://doi.org/10.1016/j.wasman.2013.03.014.

[69]N.S.M.Saman,R.Deraman,M.H.Hamzah,Developmentof lowthermalconductivitybrickusingricehusk,corncobandwasteteainclaybrickmanufacturing, AIPConf.Proc.1901(2017)3–9,https://doi.org/10.1063/1.5010567.

[70] M.H. Hamzah, R. Deraman, N.S.M. Saman, Investigating the effectiveness ofusing agricultural wastes from empty fruit bunch (EFB), coconut fibre (CF) andsugarcane bagasse (SB) to produce low thermal conductivity clay bricks,AIPConf.Proc.1901 (2017),https://doi.org/10.1063/1.5010470.