Asian Journal of Water, Environment and Pollution, Vol. 21, No. 1 (2024), pp. 71-79.
DOI 10.3233/AJW240010

Analysing the Effectiveness of Municipal Wastewater Sludge, Bagasse Ash, Rice Husk Ash and Plastic Waste Powder for Manufacturing Bricks

M. Kalpana*, G.Venkatesan and S. Padma
Department of Civil Engineering, Saveetha Engineering College, Thandalam, Chennai – 602105, India
✉ kalpana@saveetha.ac.in

Received December 28, 2022; revised and accepted December 17, 2023

Abstract: Indian cities' rapid industrialisation and urbanisation have created a requirement for massive infrastructure growth. As a result, numerous homes have been built on a big scale. As one of the most important building materials, bricks must be produced in large quantities using resources including in-situ clay, energy, and water. The concern about the sustainability of expansion is raised by the rapid exploitation of such resources, which also leads to environmental imbalance. Numerous thousands of tonnes of waste are produced as a result of the rapid growth, which creates problems with not only disposing off the waste but also with the availability of landfill spaces in urban areas. This project aims to conduct an experimental analysis of the potential use of bagasse ash, rice husk ash, plastic waste powder, and municipal wastewater sludge as clay substitutes in brickmaking. Testing the efficacy of these materials revealed that the bagasse ash brick with plastic waste powder demonstrated a significant increase in compressive strength and less water absorption when compared to a conventional brick. According to the test results, the average compressive strength of the bagasse ash brick created using plastic waste powder is 9.81 N/mm^2 and 9.03 N/mm^2, respectively, which is higher than the standard necessary construction brick according to our Indian requirements. These bricks can be utilised as first- and second-class bricks. These bricks can be used in both load-bearing and non-load-bearing structures because the average water absorption, according to specifications, was not more than 20%. This process for producing building materials encourages the use of waste resources in construction.

Key words: Bagasse ash, plastic waste powder, rise husk ass, municipal wastewater sludge, waste reduction, brick.

Introduction

Urbanisation has led to a substantial surge in solid waste production, posing a significant disposal challenge. Methods like landfilling and dumping degrade the environment, causing soil pollution and groundwater contamination. Recent advances in solid waste utilisation focus on recycling valuable materials and reducing waste volume, pollutants, and disposal costs. Recycling offers various benefits, including decreased reliance on natural resources, conservation of non-renewable resources, enhanced population health and security, and lower waste disposal expenses. Sustainable construction materials can be developed by recycling and reusing waste, addressing the demands of rapid urbanisation. Bricks, as a fundamental component in construction, embody much of a wall's unit energy. While bricks are crucial due to their low cost, high strength, and durability, their production faces challenges such as high demand, resource scarcity, and environmental regulations, making it costly.

*Corresponding Author

Literature Review

Industries all around the world produce a variety of waste materials, including metals, chemical solvents, paints, agricultural wastes, paper products, industrial by-products, radioactive wastes, and agricultural wastes. Many of these wastes, including agro-industrial wastes, granulated blast furnace slag, waste paper pulp, waste steel slag, rice husk ash, and expanded polystyrene (Venkatesan et al., 2022b, 2023), etc., have been used to create sustainable products. Some of these are already preferred wastes for making bricks, while others are still the subject of investigation. The qualities and longevity of a newly designed product are impacted by all of these partial replacement materials. Natural and substitute materials must be optimised in the right proportions in order to uphold Indian standards. To determine whether a newly developed product may be reused and perform a cost-benefit analysis, a thorough investigation and systematic research are required (Dhanjode et al., 2022; Venkatesan et al., 2022a). In this experimental work, waste plastic powder, bagasse ash, rice husk ash, and municipal wastewater sludge are combined in optimum proportion to provide the desired strength.

In place of this, the treated wastewater can be used to make ready-mixed concrete, and the dried sludge and sludge ash that is obtained from the treatment plant can be utilised to make bricks. Incineration of municipal solid waste is a common method for lowering trash disposal. Due to the significant amount of silica found in cremated municipal solid waste ash, studies have demonstrated its enormous potential to be utilised for this purpose. Studies revealed that adding specific minerals to waste products produced significant outcomes (Amsayazhi et al., 2018; Federico et al., 2005; Venkatesan et al., 2022c). The economic analysis of developing a new product is influenced by the energy demand for the incineration process. Building materials and waste water sludge both have comparable chemical compositions. To determine whether dried sludge waste could be used in brick production, it is important to experiment with the potential. It is possible to manufacture bricks from water treatment plant sludge, and encouraging studies suggest that adding metal oxide nanoparticles generally improves mechanical characteristics and bulk density. Adding metal oxide nanoparticles generally improves the sintering and mechanical properties by improving the mechanical properties and bulk density while reducing the apparent porosity of the samples. It is reasonable to believe that this sludge could be a useful renewable resource of raw materials for making bricks (Kumar et al., 2013).

An abundant byproduct of the sugar and ethanol industries is sugar cane bagasse ash (BA). Due to the fact that it is typically either utilised as fertiliser or dumped in landfills, environmental problems have grown more serious. Recycling sugarcane bagasse ash waste into clay bricks has a significant positive impact on waste management, the environment, and the conservation of raw materials (Hwang et al., 2015). The compressive strength of the brick can be increased by replacing bagasse ash in the manufacturing of bricks (Sutas et al., 2012). The sugarcane bagasse ash's physicochemical characteristics are comparable to those of pozzolanic material. The use of agricultural solid waste for the creation of lighter, more energy-efficient and environmentally friendly masonry materials has a lot of potential (Aishwarya et al., 2023; Issa et al., 2020). The only workable solution to the issue of environmental concern and resource preservation for future generations is the recycling of solid wastes into energy-efficient, sustainable construction materials. The created bricks have a good chance of meeting the local demand for building, especially for non-load-bearing walls in low-cost housing developments where the climate temperature is the norm (Dar et al., 2014; Hamzah et al., 2022).

Materials and Methods

The alternative materials chosen and their quantities affect the different characteristics of brick. Figure 1 depicts the types of materials.

The following is a summary of some of the crucial characteristics to take into account while analysing the use of alternative materials:

Brick Quality

Common burnt clay building bricks must meet the specifications defined in IS 1077, 1992. The type of bricks must be as specified. Bricks must not be over- or under-burnt, and they must be devoid of fractures and similar flaws. Sub Class "A" bricks must be consistent in colour and have a smooth, rectangular face with sharp corners. Sub Class "B" bricks may have somewhat deformed and rounded edges as long as the laying of consistent courses is not made more difficult as a result. Bricks must be created from suitable soils and may be hand- or machine-molded.

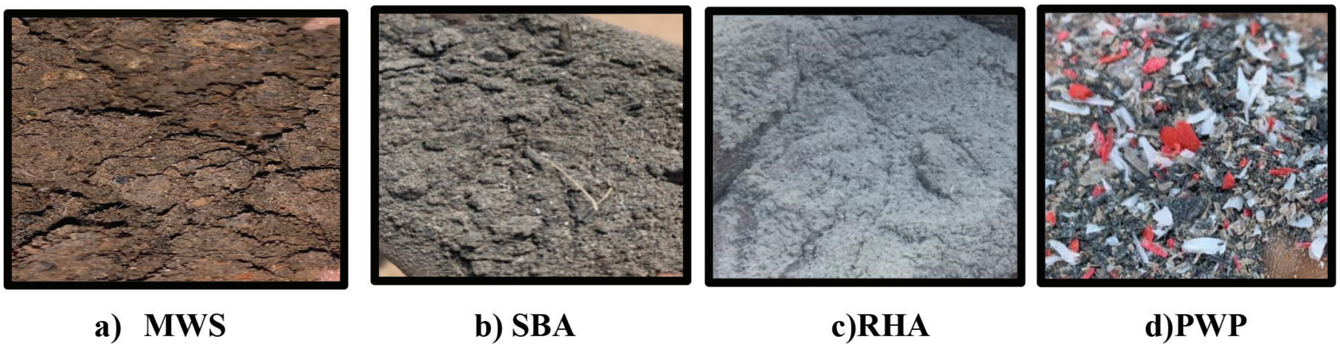

Figure 1: a) MWS, b) SBA, c) RHA and d) PWP.

Tolerance

Twenty entire bricks, randomly selected from the stack, must be positioned on a level surface in order to measure the length, width, and height, all while remaining in contact with one another and in a straight line.

Compressive Strength

Any individual brick's compressive strength may not be less than the minimum average compressive strength stated for the appropriate class of brick.

Water Absorption

For bricks up to class 12.5 and 15% for higher class bricks, the average water absorption after 24 hours of immersion in cold water shall not be greater than 20%.

Efflorescence

The efflorescence rating of the bricks must not be higher than moderate.

Handling and Storage

Brick handling and storage are strictly prohibited on construction sites. To reduce brick breakage and defacement, they must be unloaded in standard tyres arranged on level ground. Bricks chosen for facing and any specific usage must be piled individually.

Dimension

Actual brick dimensions are 19 × 9 × 9 cm, but nominal brick dimensions are 20 × 10 × 10 cm.

To choose the appropriate replacement percentage, the qualities of alternative materials were carefully analysed. Below is a discussion of the materials and their qualities.

Municipal Wastewater Sludge (MWS)

It is important to pay attention to the growing amount of residual sludge that is produced as contaminants crystallise during various stages of water treatment processes, as well as the procedures for disposing of it. Clay bricks have been used to construct buildings for thousands of years. The clay in bricks and the sludge from the water treatment plant (WTP) are practically identical. It is shown in Figure 2 and has a similar chemical makeup. As a result, this sludge can effectively be utilised in place of clay brick. The physical characteristics of MWS were examined and shown in Table 1. It is advised to use MWS as a clay substitute in the production of sustainable bricks based on the comparison analysis. It has been determined that replacing 40% of the clay with MWS will improve the characteristics of the brick by virtue of the replacement percentage.

Sugarcane Bagasse Ash (SBA)

Sugar cane, a primary global crop for sugar, thrives in tropical and subtropical regions across 31.3 million hectares. Sugar and ethanol are commonly derived from sugar cane, with bagasse, comprising 50% of sugar cane, utilised for cogeneration, producing steam and electricity. The residual waste, sugar cane bagasse ash (SBA), is explored for sustainable applications, particularly in building materials. Chemical and physical analyses, presented in Figure 2 and Table 2, reveal

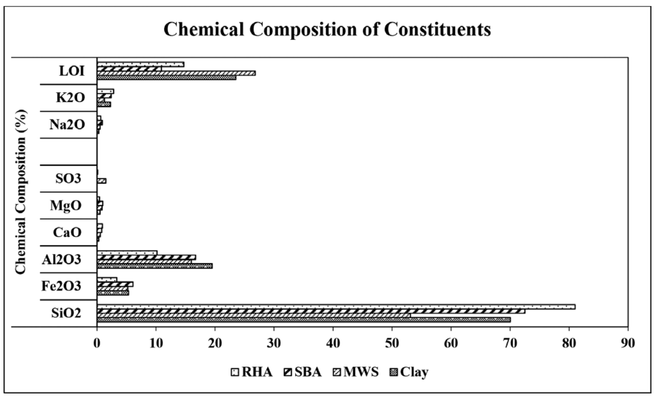

Figure 2: Comparison of chemical properties of clay with MWS, SBA and RHS.

Table 1: Physical properties of municipal wastewater sludge

Parameter	*Primary sludge*	*Secondary sludge*	*Dewatered sludge*
Dry solids	2-6%	0.5-2%	15-35%
Volatile solids	60-80%	50-70%	30-60%
Sludge specific gravity	1.02	1.05	1.1
Solids specific gravity	1.4	1.25	1.2-1.4
Shear strength (kN/m^2)	<5	<2	<20
Energy content (MJ/kg VS)	12-22	12-20	25-30
Particle size (90%)	<200 μm	<100 μm	<100 μm

Table 2: Physical properties of BA, RHA, PWP

Material	*Physical Properties*				
	Density *kg/m^3*	*Blaine surface area* *cm^2/g*	*Particle size* *mm*	*Specific gravity* -	*Colour* -
Clay	1300	3200	0.002	2.698	Grey
SBA	315	3250	0.0362	2.43	Dark Grey
RHA	375	4720	0.0605	2.14	Dark Grey
PWP	450	-	1.5 ϕ	-	-

SBA's resemblance to clay. Consequently, research supports substituting 40% of clay with SBA in brick production, ensuring an eco-friendly and economically viable approach (Hwang et al., 2015; Sutas et al., 2012).

Rice Husk Ash (RHA)

Burning rice husk yields rice husk ash (RHA), whose physical characteristics are significantly influenced by the burning conditions. RHA can replace clay in brick manufacturing, utilising waste rice husk ash. Samples, subjected to electric furnace temperatures from 800 to 1100°C, were analysed as shown in Figure 2 and Table 2, revealing RHA's chemical and physical traits compared to clay. The comparison shows comparable properties with clay (Hossain et al., 2011), suggesting RHA's effectiveness as a sustainable substitute in environmentally friendly and economically viable brick production. Results indicate a 40% substitution of clay with RHA (Chen et al., 2015).

Waste Plastic Powder (WPP)

Waste plastic profoundly impacts the environment, causing irreparable damage and escalating landfill waste. Environmentalists advocate for solutions, such as the 5 R's approach in waste management, to address the severe consequences on human life. Recycling waste plastic powder as a building material is a promising method. Comparative analysis with clay supports replacing 40% of clay with waste plastic powder for enhanced sustainability in brick production (Aneke et al., 2021).

Sample Making

The raw materials, listed in Table 3, are collected, proportioned and mixed as per calculations. Samples S1, S2, and S3 are cast (Figures 3 and 4), with three sets of six bricks each using a fixed combination. The 1999 brick mould, a standard size, is utilised. After mixing and placing the raw components in the mould, the bricks are sun-cured for 7 days, followed by 2-hour baking. The cast bricks' physical and chemical characteristics are observed and calculated for each set, and the proposed bricks are compared with typical clay bricks.

Table 3: Proportion and weight of S1, S2 and S3

Notation	*Constituent*	*Weight in kg*
S1	Sludge (40%)	3.6936
	Bagasse Ash (40%)	3.6936
	Clay (20%)	1.8468
S2	Sludge (40%)	3.6936
	Plastic Waste Powder (40%)	3.6936
	Clay (20%)	1.8468
S3	Sludge (40%)	3.6936
	Rice Husk Ash (40%)	3.6936
	Clay (20%)	1.8468

a) b) c)

Figure 3: a) Sludge 40%, bagasse ash 40%, clay 20%, b) sludge 40%, rice husk ash 40%, clay 20%, and c) sludge 40%, plastic waste powder 40%, clay 20%.

Figure 4: Moulding of brick samples S1, S2, and S3.

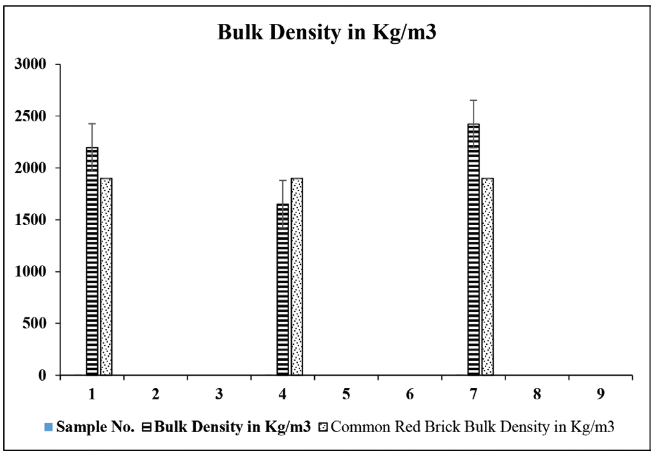

Figure 5: Bulk density of brick samples.

Experimental Results and Discussion

Bulk Density Test

The density of sample bricks, depicted in Figure 5, is influenced by brick strength. Common red brick has a bulk density ranging from 1500 kg/m^3 to 2000 kg/m^3 (Sutcu et al., 2015). The results in Figure 5 show increased bulk density values for the brick samples compared to the standard for common red brick. This enhancement is primarily attributed to the addition of finer particles like RHA and SBA. Notably, sample S2, with 40% PWP, exhibits a lower density than samples S1 and S3 (Algamal et al., 2018).

Compression Strength Test

A crushing testing device determines a brick's compressive strength, a critical engineering property. The brick, mounted on the apparatus, undergoes a crushing force (Figure 6). To be classified as First Class Bricks per IS norms, a minimum crushing strength of 105 kg/cm^2 is required. Test samples S1, S2, and S3's average compressive strength (Figure 7) are compared with IS standards. Brick samples' heating temperature ranges from 1000 to 1200°C. S1 and S3 meet Second Class Bricks criteria at 70 kg/cm^2, while S2 falls short.

Figure 6: Compressive strength test.

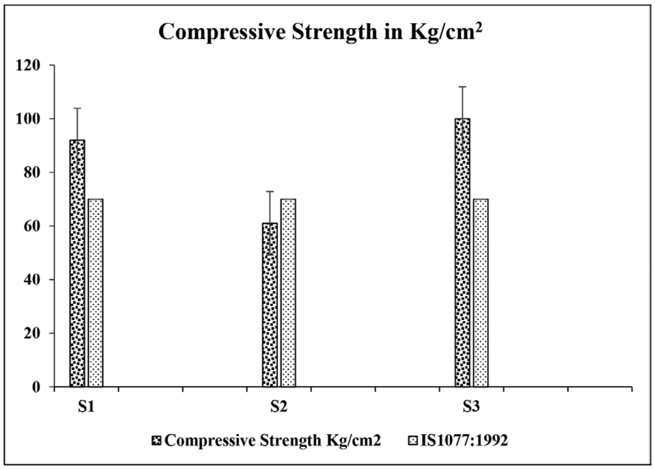

Figure 7: Comparison of compressive strength of samples with IS values.

Nevertheless, S2 exceeds common building bricks' strength of 35 kg/cm^2 in IS1077:1992. Open pores may lead to structural compaction loss and reduced compressive strength (Babu et al., 2018).

Water Absorption Test

Dry brick weights were measured, then submerged in water for 24 hours (Figure 8). Post-soaking, reweighed to determine water absorption; should not exceed 20% of dry weight for first-class as per IS. S1 and S3 show water absorption percentages aligning with first-class brick specifications. MWS bottom ash has high dust particle concentration, enhancing surface area (Alam et al., 2022) and angular particle shapes improve water covering area, boosting absorption (Chauhan et al., 2021). Experimental results in Figure 9 reveals S2's water absorption at 29%, rendering it unsuitable for construction. With a PWP percentage of 40%, high absorption occurs. Reducing PWP to 20–30% may make S2 suitable for construction.

Figure 8: Brick samples are submerged in water to measure water absorption.

Efflorescence Test

Bricks are submerged in water for 24 hours to detect soluble salts. Afterward, they are dried. If the white deposit covers approximately 10% of the surface, it's considered modest; if it covers about 50%, it's moderate. Efflorescence is deemed severe if deposits exceed 50%, leading to rejection. In the assessment of nine brick samples for efflorescence, no salt deposits were found. Therefore, all samples in Table 4 are of good quality (Figure 10).

Hardness Test

By attempting to scratch the brick surface with a fingernail, hardness is assessed. A lack of surface impression indicates ample hardness, signifying resistance to abrasion, as observed in samples S1 and S3. Conversely, impressions on S2 bricks reveal insufficient hardness, rendering them unsuitable for construction. Table 4 details these results. Reducing the replacement percentage can enhance S2 brick properties, making them viable for construction use.

Soundness Test

When two bricks are struck together, good-quality bricks should not crumble and should generate a loud ringing sound. When the samples S1, S2 and S3 were struck together, a clear ringing sound was produced and the bricks were not damaged. The results of the samples are presented in Table 4.

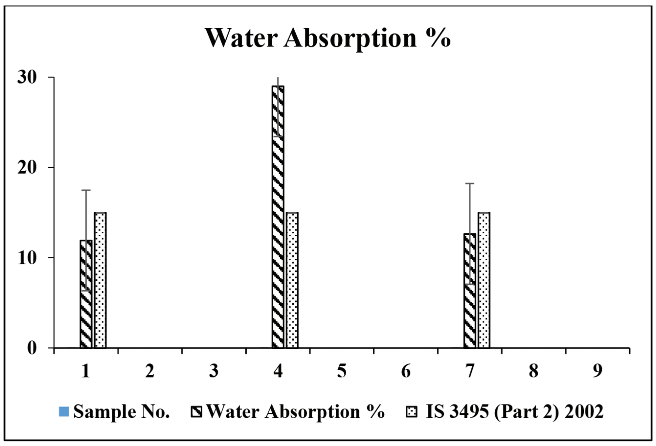

Figure 9: Comparison of water absorption % of brick samples with IS specification.

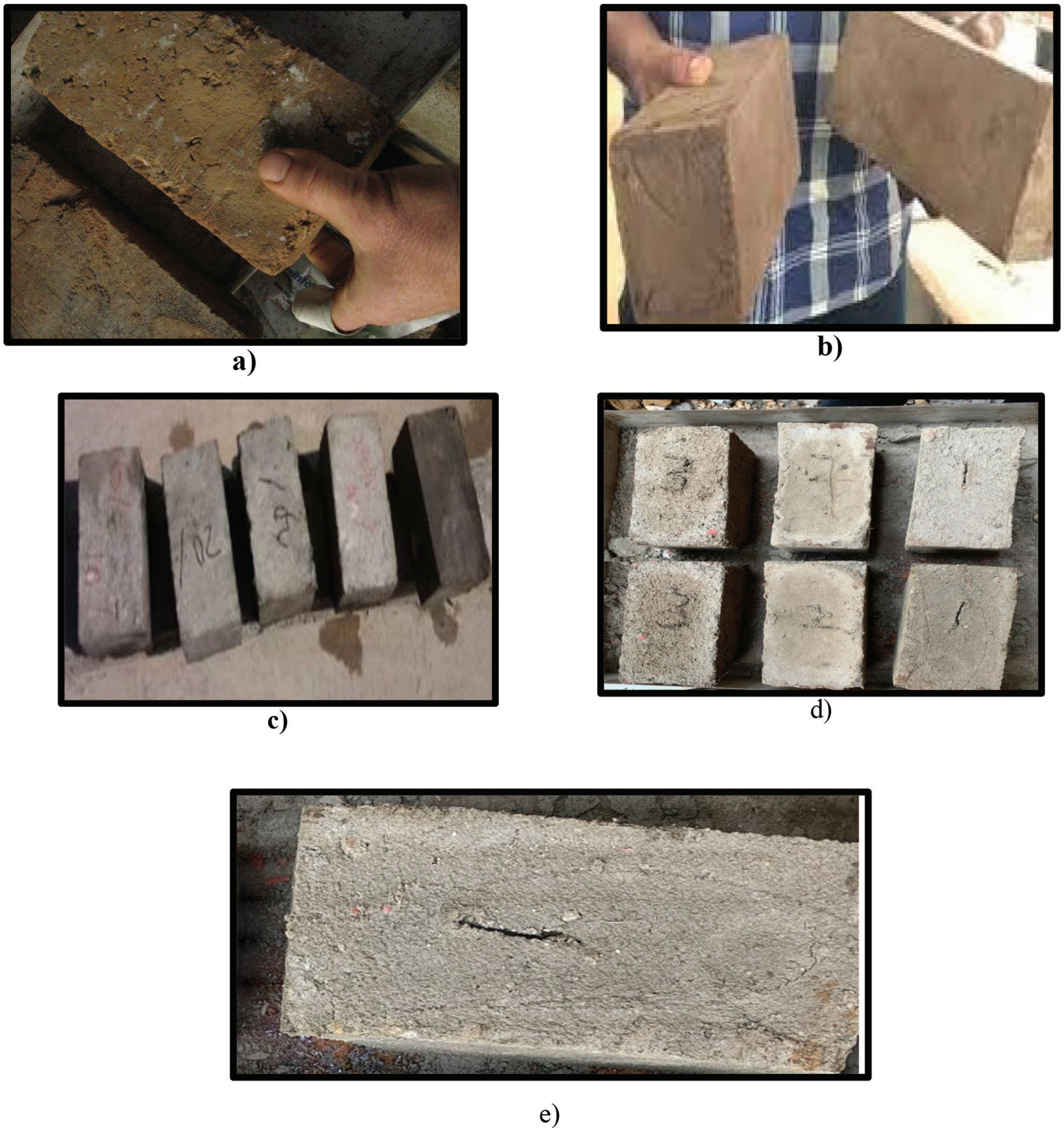

Figure 10: a) Hardness test on brick samples, b) impact test on brick samples, c) shape and size of brick, d) colour and structure of brick and e) efflorescence test on brick samples.

Impact Test

Take a brick and drop it in this test from a height of one meter. Bricks of good quality shouldn't crack at all. Bricks that are fractured indicate a low impact value and should be disregarded. When the samples S1, S2 and S3 are dropped from a one-meter height, none of them are broken and are presented in Table 4. The samples were able to maintain their shape even after the impact.

Shape, Size and Colour

A brick is scrutinised attentively in this test. It should be uniform in size and have a true rectangular shape with sharp corners and edges. To do this, a random sample of bricks of the typical size (190 mm × 90 mm × 90 mm) are chosen and stacked lengthwise, widthwise, and height wise. A brick is broken, and the inside is looked at. It should be uniform, tightly packed, and free of

Table 4: Tests conducted on brick samples

Tests Performed	*Normal Fried Clay Bricks*	*S1*	*S2*	*S3*
Hardness test	No Impression Found	No Impression Found	Impression Found on the Surface	No Impression Found
Sound test	A clear ringing sound occurs	A clear ringing sound occurs	A clear ringing sound occurs	A clear ringing sound occurs
Efflorescence test	No Salts are observed	No Salts are observed	No Salts are observed	No Salts are observed
Shape and size	Truly rectangular with Sharp edges and corners & 190 × 90 × 90mm	Truly rectangular with Sharp edges and corners & 180 × 90 × 90mm	Truly rectangular with Sharp edges and corners & 190 × 85 × 85mm	Truly rectangular with Sharp edges and corners & 190 × 90 × 85mm
Colour test	Deep Red, Cherry or Copper in Colour	Greyish colour	Greyish colour	Greyish colour
Structure test	Homogeneous, free from lumps and voids	Homogeneous, free from lumps and voids	Homogeneous, presence of lumps and voids	Homogeneous, free from lumps and voids
Impact test	Not break	Not break	Not break	Not break

flaws like holes, lumps, etc. The colour of samples S1, S2 and S3 are greyish, and a good fried clay brick with consistent deep red, cherry, or copper shade.

Conclusion

The study explores the feasibility of producing environmentally sustainable bricks by incorporating bagasse ash, plastic waste powder and rice husk ash, along with dewatered sludge. Various environmental parameters are analysed using established testing methodologies such as compression strength, water absorption, efflorescence, hardness, soundness, and impact tests. The research aims to understand the potential environmental impacts of these alternative materials. Results indicate that the bagasse ash brick with dewatered sludge exhibits significantly increased compressive strength and reduced water absorption compared to standard bricks. In contrast, the plastic waste powder brick demonstrates lower strength and higher water absorption. The bagasse ash and rice husk ash bricks surpass the required standards for construction bricks, making them suitable for both load-bearing and non-load-bearing structures. However, the plastic waste powder brick falls short of these standards, limiting its use to a third-class brick. The utilisation of waste products in construction reduces material wastage and pollution, showcasing a sustainable approach to building materials.

References

Aishwarya Lakshmi, A., Amalraj, S. and G. Venkatesan (2023). Granules as precursors in the working of upflow anaerobic sludge blanket reactor: A review on the impacts of granulation. *Asian Journal of Water, Environment and Pollution*, **20(4):** 41-45.

Algamal, Y., Khalil, N.M. and Q.M. Saleem (2018). Usage of the sludge from water treatment plant in brick-making industry. *Journal of Chemical Technology & Metallurgy*, **53(3):** 505-510.

Alam, P., Singh, D. and S. Kumar (2022). Incinerated municipal solid waste bottom ash bricks: A sustainable and cost-efficient building material. *Materials Today: Proceedings*, **49:** 1566-1572.

Amsayazhi, P. and K.R. Mohan (2018). Use of sludge waste as ingredient in making of brick. *International Journal of Engineering & Technology*, **7(3.12):** 419-422.

Aneke, F.I. and C. Shabangu (2021). Green-efficient masonry bricks produced from scrap plastic waste and foundry sand. *Case Studies in Construction Materials*, **14:** e00515.

Babu, S.G. and S. Krishnaiah (2018). Manufacturing of eco-friendly brick: A critical review. *International Journal of Computational Engineering Research*, **8(2):** 24-32.

Chauhan, S.S., Singh, J.K., Singh, H., Mavi, S., Singh, V. and M.I. Khan (2021). An overview on recycling plastic wastes in bricks. *Materials Today: Proceedings*, **47:** 4067-4073.

Chen, R.S., Salleh, M.N., Ab Ghani, M.H., Ahmad, S. and S. Gan (2015). Biocomposites based on rice husk flour and recycled polymer blend: Effects of interfacial modification and high fibre loading. *BioResources*, **10(4):** 6872-6885.

Dar, A.R., Verma, S.K., Ashish, D.K. and M.A. Dar (2014). Investigation on the properties of non-conventional bricks. *i-Manager's Journal on Structural Engineering*, **3(4):** 26.

Dhanjode, C. and A. Nag (2022). Utilization of landfill waste in brick manufacturing: A review. *Materials Today: Proceedings*, **62(12):** 6628-6633.

Federico, L.M., Chidiac, S.E. and R.G. Drysdale (2005, June). The use of waste material in the manufacturing of clay brick. *In:* Proceedings of the 10th Canadian Masonry Symposium, Banff, Alta (pp. 8-12).

Hamzah, A.F. and R.M. Alkhafaj (2022). An investigation of manufacturing technique and characterization of low-density polyethylene waste base bricks. *Materials Today: Proceedings*, **61:** 724-733.

Hossain, T., Sarker, S.K. and B.C. Basak (2011). Utilization potential of rice husk ash as a construction material in rural areas. *Journal of Civil Engineering (IEB)*, **39(2):** 175-188.

Hwang, C.L. and T.P. Huynh (2015). Investigation into the use of unground rice husk ash to produce eco-friendly construction bricks. *Construction and Building Materials*, **93:** 335-341.

Issa, E., Arul Murugan, C., Kannan, N. and G. Venkatesan (2020). Measurement of secure power meter with smart IOT application. *Journal of Green Engineering*, **10(12):** 12962-12972.

Kumar, S., Sangwan, P., Dhankhar, R.M.V. and S. Bidra (2013). Utilization of rice husk and their ash: A review. *Res. J. Chem. Env. Sci*, **1(5):** 126-129.

Sutas, J., Mana, A. and L.J.P.E. Pitak (2012). Effect of rice husk and rice husk ash to properties of bricks. *Procedia Engineering*, **32:** 1061-1067.

Sutcu, M., Alptekin, H., Erdogmus, E., Er, Y. and O. Gencel (2015). Characteristics of fired clay bricks with waste marble powder addition as building materials. *Construction and Building Materials*, **82:** 1-8.

Venkatesan, G., Subramani, T., Joyal Isac, S. and G. Sindhu (2022a). Groundwater potential mapping and natural remediation through artificial recharge structures in Vellore District, Tamil Nadu, India using geospatial techniques. *Desalination and Water Treatment*, **254(1):** 229-237.

Venkatesan, G., Arul Murugan, C., Joyal Isac, S. and G. Jerome Nithin Gladson (2022b). Experimental investigation on a load-carrying capacity of hollow and composite pile materials in layered soil. *Materials Today*, **65(9):** 3951-3958.

Venkatesan, G., Joyal Isac, S., Jerome Nithin Gladson, G. and S. Amala (2022c). Demarcation of non-carcinogenic risk zones based on the intake of contaminated groundwater in an industrial area of southern India using geospatial techniques. *Desalination and Water Treatment*, **274(1):** 140-149.

Venkatesan, G., Kalpana, M., Sakthivel, S., Guruchandran, K. and W. Mathew (2023) A combined approach for the treatment of textile dye bath effluent using CO_2 gas. *Asian Journal of Water, Environment and Pollution*, **20(2):** 59-65.

Asian Journal of Water, Environment and Pollution

Volume 20 Number 6 **November, 2023**

Contents