

Embracing Sustainability - A Journey with Municipal Solid Waste Ash in Brick Production

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Abstract: This research investigates the potential of incorporating municipal solid waste (MSW) ash into brick production to mitigate challenges arising from urbanization and waste disposal. MSW ash was substituted for fly ash at varying proportions (5%, 10%, 15%, 20%) in this experimental study. Analytical techniques such as SEM analysis, XRD, and EDAX were employed to assess the characteristics of MSW ash. Various experimental tests, including compressive strength, water absorption, soundness, leaching, and efflorescence tests, were conducted to evaluate the suitability of MSW ash as a raw material in brick manufacturing. The compressive strength test revealed a value of 12.2 MPa after 15 days of curing, without compromising the strength of conventional bricks, while water absorption remained below 20%, indicating an acceptable level. Although leaching tests detected trace amounts of heavy metals in MSW bricks, overall, the incorporation of MSW ash in brick production presents a promising solution to MSW waste disposal challenges, offering a sustainable approach to urban waste management.

Keywords: Brick, MSW, Compressive strength, Water absorption, Soundness, Leaching, and Efflorescence tests, Waste management.

1 Introduction

In recent days, there has been an increase in urbanization, leading to a rise in the population in particular areas. Consequently, there is a problem with the disposal of Municipal Solid Waste (MSW). Landfilling consumes large areas of land resources, causing several cities in China [1], United States [2], Kurukshetra [3], Bangalore [4] to be surrounded by MSW. Alternate arrangements are required to select another site for waste disposal through various model analyses and studies [1-4]. However, even if we find an alternate site, direct disposal of waste is not possible, as it contains hazardous and non-hazardous materials. Therefore, MSW can be incinerated, thereby utilizing the incinerated fly ash as an additional or replacement material in the construction industry [5].

Similar to MSW fly ash, various other ashes such as Bagasse ash [6-8], rice husk ash [9-11], Sludge ash [12-16] and Groundnut shell ash [17-18], have been used as replacement materials in concrete and brick manufacturing based on various experimental studies. These

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ashes find applications in the construction industry, thereby forming environmentally friendly materials [6]. Bagasse ash, a waste material from sugarcane, acts as a supplementary cementitious material and filler material due to its finer silica particles, making it suitable for use in brick production [6-8]. When Rice Husk Ash (RHA), obtained by burning rice husk, is added with bagasse ash (BH), they are utilized in manufacturing lightweight bricks [9-10] with good thermal and acoustic performance [11]. Additionally, the addition of sewage sludge, paint sludge, textile sludge and tannery sludge in the replacement of soil in brick manufacturing enhances compressive strength and porosity [12-16]. A mixture of groundnut shell ash and silica shows improvements in the compressive strength, flexural strength, and split tensile strength of concrete [17-18]. Through the effective utilization of natural ashes as industrial byproducts along with geopolymer concrete, there is an increase in compressive strength and durability [19].

MSW fly ash can be used as a raw material in the construction industry, but it cannot be used directly due to the presence of certain soluble salts, which may have a negative impact on physical and mechanical properties. These salts can be removed by washing or Electroanalytic treatment to obtain high-performance bricks with low porosity and water absorption [20-23]. From various experimental studies, MSW fly ash can be used in the production of cement clinker, alternative binders (e.g., alkali-activated material), cement substitutes, aggregates, and construction sectors. It also finds application in asphalt and concrete [24-27]. Incinerated municipal solid waste generates both bottom ash and fly ash. While fly ash finds many uses, bottom ash is often directly sent to landfills due to its unsuitability for brick production because of its high porosity and low weight compared to clay. By stabilizing inorganic compounds with cement, bottom ash can be utilized in brick manufacturing. Tests show bricks meeting standards for water absorption, compressive strength, and efflorescence, suggesting cost-effective construction applications and reducing environmental impact from landfill disposal of MSW ash. [28-30]

This study focuses on the effective utilization of municipal solid waste ash (MSW) in brick production, thereby addressing the large volume of municipal solid waste generated. There are lots of municipal solids that have been generated, causing a huge disposal problem, and so they have been incinerated into ash. But these ashes cause environmental issues during land filling and underground disposal. This study suggests finding an alternative solution for the utilization of treated MSW ash in brick production in limited proportions. This research aims to evaluate the environmental, socio-economic, and structural benefits of brick made with MSW ash, thereby contributing to sustainable construction practices and effective waste management solutions.

2 Materials and Methods

In this study, the core materials used for the manufacturing of brick are MSW ash, Fly ash, M-Sand, Cement. The MSW ash (Figure 1) was collected from Keeranur waste dump yard disposal site, Pudukkottai district, India (10.574564 latitude and 78.784416 longitude). Various tests were conducted to find its suitability for brick manufacturing. From the test conducted as per IS 2720 (Part-3)-1980, it was found that MSW ash has Specific gravity of 2.3.

In this study fly ash (Figure 2) was collected from Thoothukudi district, TamilNadu, India and M-Sand has been obtained from locally available quarry in Trichy. The specific gravity of fly ash was found to be 2.275 as per the code IS 2386-3 (1963). Fly ash was used in brick manufacturing since it has cementitious properties. Hydrated calcium sulphate called Gypsum was added to control the setting time of brick.



Fig. 1 Municipal Solid Waste Ash



Fig. 2. Fly ash

2.1 Test on MSW Ash

2.1.1 SEM analysis for MSW Ash

A scanning electron microscope (SEM) projects and scans a focused stream of electrons over a surface to create an image. The electrons in the beam interact with the sample, thereby producing various signals that can be used to obtain information about the surface's topography (Figure 3)

2.1.2 EDAX

EDAX is used to analyze the concentration of elements present in the sample. The test result of EDAX was shown in Figure 4 and the elements are listed in table 2. XRD test was conducted to know the crystalline structure of materials arranged and the peak value represents that the material is crystalline and this can be verified from Figure 4.

Spectrum processing:

Peak possibly omitted: 8.029 keV

Processing option: All elements analyzed (Normalized)
 Number of iterations = 6

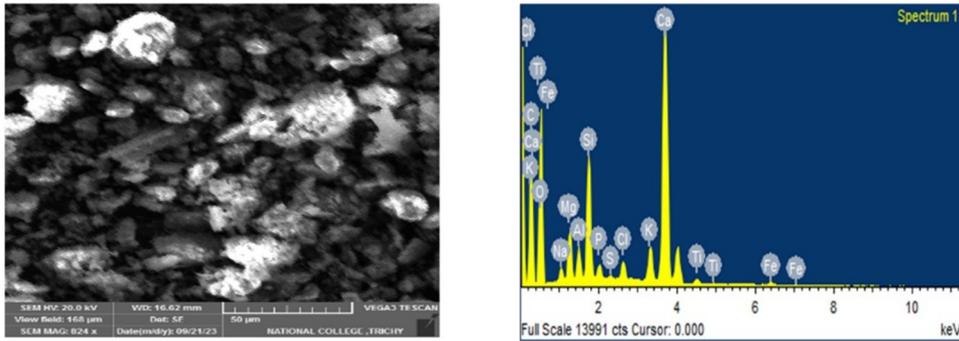


Fig. 3. SEM and EDAX results of MSW ash

Table 1 displays the elemental composition of Municipal solid waste (MSW) ash. EDAX Analysis, it is observed that there is a predominance of oxygen and carbon, indicating the oxidized organic matter, calcium, signifying the content of construction waste and food waste. The detection of silicon and aluminum reflects the removal of glass and packaging materials, while small amounts of elements such as chlorine and sulfur indicate the potentially dangerous nature of the waste. Figure 5 shows the XRD Test Image of MSW ash Brick.

Table 1. List of compound elements present in MSW ash from the EDAX test result

Element	Weight%	Atomic%
C K	27.59	38.67
O K	46.09	48.50
Na K	0.73	0.53
Mg K	1.96	1.36
Al K	1.08	0.68
Si K	4.03	2.41
P K	0.57	0.31
S K	0.12	0.06
Cl K	0.75	0.36
K K	1.64	0.70
Ca K	14.68	6.17
Ti K	0.40	0.14
Fe K	0.36	0.11
Totals	100.00	

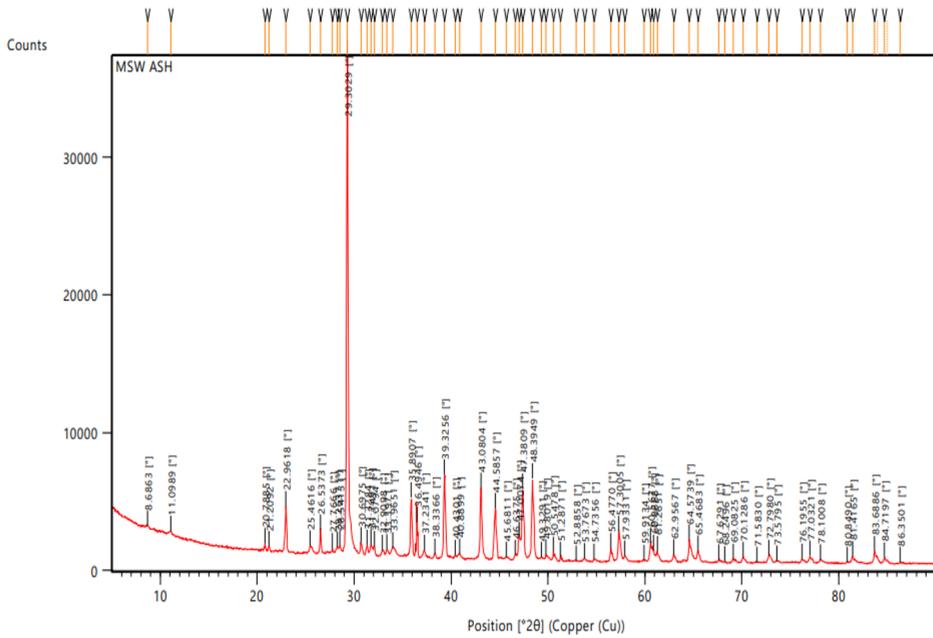


Fig. 4 EXRD Test Image of MSW ash Brick

3 Experimental Investigation

3.1 Manufacturing of brick

A combination of Fly Ash, MSW Ash, Cement, Gypsum and M-sand (as shown in table 2) are manually feed into a pan mixer where water is added to the required proportion for homogeneous mixing. Hydrated calcium sulphates gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Gypsum was added as 5% for binding.

After the combination of materials, the mixture is mixed, pressed into an automatic brick making machine, and then placed on wooden pallets for two days. The bricks are then water-cured for 7 days, sorted, and tested before dispatch. The quality of the bricks was maintained according to IS: 12894:2002. Figure 6 shows the manufacturing plant of brick and MSW Ash Bricks



Fig. 5 Manufacturing plant of brick and MSW Ash Bricks

The M sand, fly ash, MSW fly ash, cement and Gypsum are mixed together. The Fly ash is replaced by 5%, 10%, 15%, 20% ratio of MSW Ash.

3.2 Design Mix for MSW brick

Table 2 Mix Proportion of MSW brick

S.No.	Trial	Fly Ash (%)	MSW Ash (%)	Cement (%)	M Sand (%)	Gypsum (%)	Total
1	Conventional	40	0	15	40	5	100
2	Trial-1	35	5	15	40	5	100
3	Trial-2	40	10	15	40	5	100
4	Trial-3	45	15	15	40	5	100
5	Trial-4	50	20	15	40	5	100

3.3 Test conducted on Bricks

In this paper, a series of tests were conducted on bricks, compression test (figure 6), water absorption test and efflorescence test (figure 7). The compressive strength test was conducted as per IS: 516 – 1959 and shows variation with different percentages of MSW fly ash (5%, 10%, 15% and 20%) incorporated at different curing time periods (7 and 15 days). The water absorption test was conducted as per IS 1124:1974 (figure 8). The weight of dry brick was measured initially, followed by soaking the specimens in water for 24 hours. The increase in weight after soaking indicates the amount of water absorbed.



Fig. 6. Water Absorption test

As per IS: 3495 (Part III), efflorescence test was conducted (figure 8). The bricks were immersed in distilled water at a temperature range of 18°C to 30°C with adequate ventilation. After drying, efflorescence observed was noted down.



Fig. 7 Compressive strength test on MSW brick



Fig. 8 Efflorescence test on brick

3.3.1 Leaching Test on Brick

A leaching test was conducted on MSW (Municipal Solid Waste) brick to assess the presence of heavy metals leached from MSW Ash. The Static Leaching Test (SLT) methodology was employed, wherein the release of elements is predominantly influenced by the exposed surface area rather than the mass of the material. In this procedure, regular particle geometry with a precisely determined surface area is submerged in a fixed volume of leaching solution. To ensure consistency, the leaching solution remains unchanged throughout the test duration, preventing any disruption in the leachate concentration due to solution renewal processes. To achieve this goal, 4 solid MSW Ash Brick samples were meticulously prepared, each incorporating varying proportions of MSW Ash (5%, 10%, 15%, 20%) as a replacement for Fly Ash. Subsequently, these Brick samples were suspended within a sealed container for a duration lasting up to 30 days. Throughout this period, the leaching behavior and the amount of heavy metals released were closely monitored and analyzed.

3.3.2. Soundness Test for MSW Bricks

The soundness test for MSW bricks involves subjecting the bricks to cycles of wetting and drying. The bricks are initially soaked in water and then exposed to air or other drying conditions. This process is repeated several times to simulate the effects of moisture and environmental changes over time. The soundness of MSW bricks is determined by assessing any changes in volume or structural integrity during and after the test. This test helps ensure that MSW bricks maintain their strength and durability under varying moisture conditions, making them suitable for long-term use in construction. Similarly, conventional bricks undergo the soundness test to assess their resistance to volume changes. The bricks are subjected to cycles of soaking in water and subsequent drying. The goal is to identify any expansion or contraction that may occur due to the absorption and release of moisture. Conventional bricks with good soundness will exhibit minimal changes in volume, ensuring their stability and reliability in different environmental conditions.

Both MSW bricks and conventional bricks must meet specific soundness criteria to ensure their suitability for construction. The results of the soundness test provide valuable insights into the materials' ability to withstand the impact of moisture and environmental factors over time, contributing to the overall quality and longevity of the constructed structures.

4 Results & Discussions

The compressive strength values for bricks incorporating different levels of fly ash (0%, 5%, 10%, 15%, and 20%) under room temperature conditions (20 to 25°C) for curing period of 15 days are illustrated in Figure 9. Based on the experimental investigation, it is recommended that the inclusion of MSW ash in fly ash brick production alters the mineral composition, resulting in comparable compressive strength compared to conventional fly ash bricks, with no significant reduction observed till 15% of replacement. Whereas beyond 15%, there is a significant decrease in the compressive strength.

Furthermore, water absorption tests were conducted on bricks with varying proportions of fly ash replaced by MSW ash. As depicted in Figure 10, the findings demonstrate that higher percentages of MSW ash lead to increased water absorption capacity in the bricks. However, bricks with 15% and 20% replacement of fly ash with MSW ash exhibited water absorption rates of 15.4% and 16%, respectively, compared to traditional bricks.

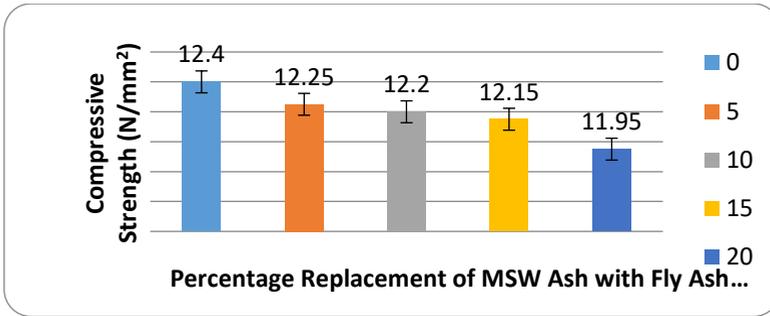


Fig. 9 Compressive Strength of MSW bricks and conventional fly ash brick

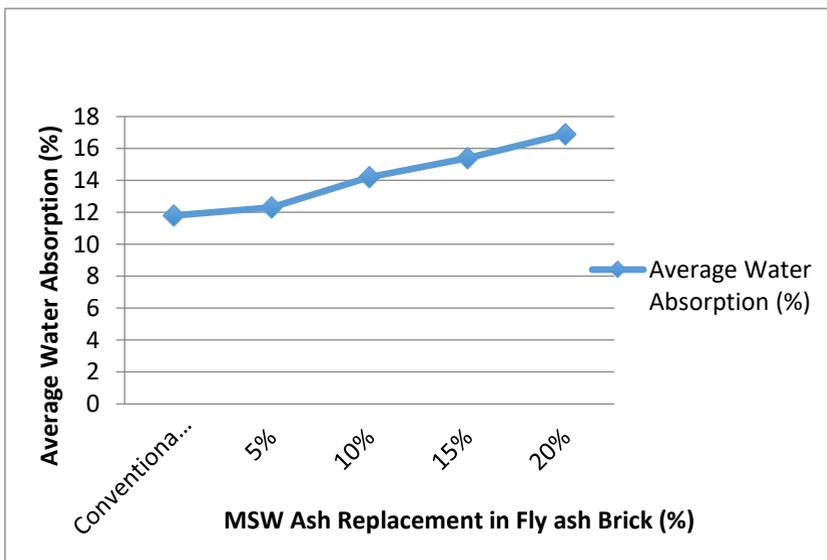


Fig. 10 Graph showing percentage of water absorption of MSW brick

From figure 11 it is observed that a leaching test on MSW (Municipal Solid Waste) ash bricks indicates the presence of cadmium, chromium, copper, lead, zinc and mercury in trace amount which is less than that of standard leaching toxicity value recommended. This finding is important for assessing the potential environmental impact and safety of using MSW ash bricks, as it indicates that there may be some risk of heavy metal contamination under specific circumstances.

Also, the MSW brick has successfully passed the soundness test, demonstrated minimal volume change and maintained its structural integrity after exposure to specified conditions of wetting and drying. Leaching test also conducted showing the presence of cadmium, chloride, copper, lead, zinc and mercury in trace amount which is less than that of standard leaching toxicity value recommended.

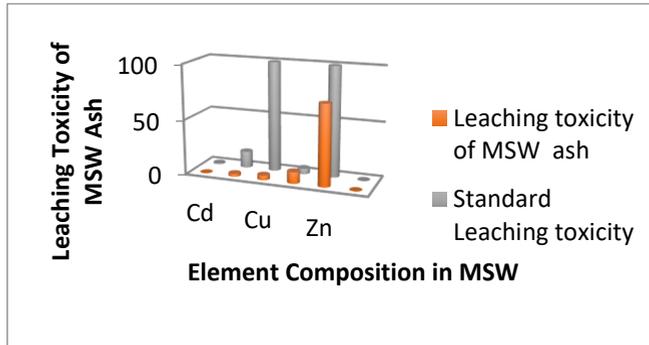


Fig. 11 Leaching Test Result on MSW Ash Brick

4 Conclusion

- Based on the experimental investigation, it is recommended that the inclusion of MSW ash in fly ash brick production alters the mineral composition, resulting in comparable compressive strength compared to conventional fly ash bricks, with no significant reduction observed till 15% of replacement.
- SEM Analysis, XRD, EDAX Test has been conducted to ensure the possibility of utilizing MSW Ash as a replacement material for Fly Ash for manufacturing of MSW Ash Brick
- Leaching Test on MSW Ash Brick indicates the presence of trace number of heavy metals in MSW Ash Brick during leaching.
- Water absorption in MSW bricks increases with higher proportions of municipal solid waste in the mix, but it remains below 20% when replacing fly ash, indicating an acceptable level as per code IS 1077 -2016.
- In conclusion, employing municipal solid waste for MSW brick production proves to be an effective approach in mitigating the challenges associated with municipal solid waste disposal.

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