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Brick Manufacture using Waste Rocket Propellant: Characterization and Utility

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Abstract

Waste Rocket Propellant is used in manufacture of Fire-clay Brick to neutralize twin-problems of waste propellant disposal and scarcity of raw materials for Brick manufacture. Waste rocket propellants, containing Ammonium Perchlorate (AP), Aluminium powder (Al) and hydrocarbons, as major ingredients, is processed as granular powder of 300 micron and mixed up to 2.5% by weight in the green mix of brick, containing clay, silica and soil. Impregnated Brick is characterized by XRD and SEM. Water absorption, compressive strength and thermal conductivity are determined following suitable standards and equipments. XRD revealed presence of alumina in the propellant impregnated brick without formation of any secondary phase. SEM indicated higher porosity with hardened surface around pores. Compressive strength is comparable and water absorption is favorably improved on an average, from 29% to 20%. The thermal conductivity is found to reduce from 0.72 W/m.K to 0.68 W/m.K. Overall, the effect of pollution reduction, waste utilization and property enhancement can pave way for a sustainable and eco-friendly solution in construction domain.

Keywords: Bricks; Waste propellants; Microstructure; Water absorption; Compressive strength; Additives; Rocket; Composite propellant

Introduction

Asian countries contribute to 87% of the total global demand of the bricks, out of annual global consumption of around 1500 billion bricks. To meet this exorbitant demand, the used raw materials are getting consumed very fast and attempts are regularly made to explore possibility of incorporating alternate available waste materials, leading to their utilization and disposal, simultaneously. Different types of raw materials including organic combustible waste materials like cigarette butts [1], Charcoal [2], sugarcane bagasse [3-7], husk [2,3,7], Paper [4,5], ground nutshell [6], orange peel [7], Plastics [8], dung [9], etc are used as additives. Combustible materials are consumed during baking of bricks and this result in increase in porosity of brick. Density reduction, high water absorption, and reduced compressive strength are contemplated for such additions. One more concern due to high porosity of combustible material impregnated fire clay brick is loss of structural integrity. So, the amount of combustible materials addition in bricks is mostly restricted to around 10-15%. Similarly incombustible waste like granite [10], glass [11,12], sludge [13,14], radioactive waste, television tubes, computer waste, etc are also utilized as additives for their faster disposal, exposure mitigation and impregnated status. Many a time, incombustible materials lead to enhanced density, high strength due to fusion of additive with clay and ceramic nature of bricks. The major concern becomes low emission for such altered fire clay bricks. In light of these recent developments, it was conceived to incorporate waste high energy materials, to be more precise, waste rocket propellants as combustible additive for exploration of effect on behaviour of brick. The waste composite propellants are obtained from a propellant production center used to be disposed of by open burning. This was polluting atmosphere and at the same time, generating infertile burning grounds, due to contamination. The idea was converted into a patent and filed in 2019 [15]. The patented idea was implemented in actual fire clay brick manufacture and properties are evaluated to understand the efficacy of such exercise. The waste propellant used for the study has around 68% ammonium perchlorate, 18% aluminum powder and rest hydrocarbon binder and other additives.

Propellant Impregnated Bricks

The soil used for the manufacture of bricks is taken from Brick Kiln, Nasik India. The Brick kiln is operational for last 20 years and has been regularly producing fire clay brick for construction in peripheral area [16]. Production of composite propellants for rocket has around 15-20% waste generation. Such process waste, which is otherwise generally burnt in open for disposal are granulated to 300 + 20-micron size. The waste propellant in powder form is added to the extent 2.5% by weight. A homogenous mix is obtained, and dough plasticity is maintained by addition of distilled water (20-25% by weight). No change in normal manufacture of brick is made, except for an additional step for the incorporation of propellants. Efficient mixing for proper homogeneity is ensured to avoid localization of propellant dust powder. The bricks are then molded in test brick molds (Figure 1). The brick samples are oven dried for 48 h at 100˚C to remove excess moisture and avoid cracks during firing. The propellant composition decomposes around 350 to 400 ˚C. The dried samples are then slow heated in electric furnace at 1100 ˚C at a heating rate of 5˚C/min and dwelled for 6 hours before cooling them down to room temperature. The obtained Bricks are shown as (Figure 2). Crystalline phases present in the fired clay bricks are investigated using X-ray diffractometer (Model, Bruker D8 Advance) with a copper kα, radiation. Water absorption test is carried out to determine the durability of bricks during weathering conditions. Brick is weighed after oven drying and again after immersion in water for 24 hours. Percentage weight gain is taken as water absorption capacity indictor. The compressive strength of the brick samples is measured by universal testing machine. Both water absorption and compressive strength are carried out as per IS 3495. The densification, microstructure and porosity of the samples are investigated by scanning electron microscope (Model, Zeiss, Merlin). Thermal Properties are ascertained by laser flash method. The equipment used in the study is Antemark Flashline 3000, which has provision to hold sample on a trolley. The trolley moves inside a furnace and requires thermal flash is applied on one side of standard and test sample, simultaneously and measurements are made (Figure 3).

Figure 1: Mold used for Making Brick.

Figure 2: Waste Propellant Impregnated Fire Clay Brick.

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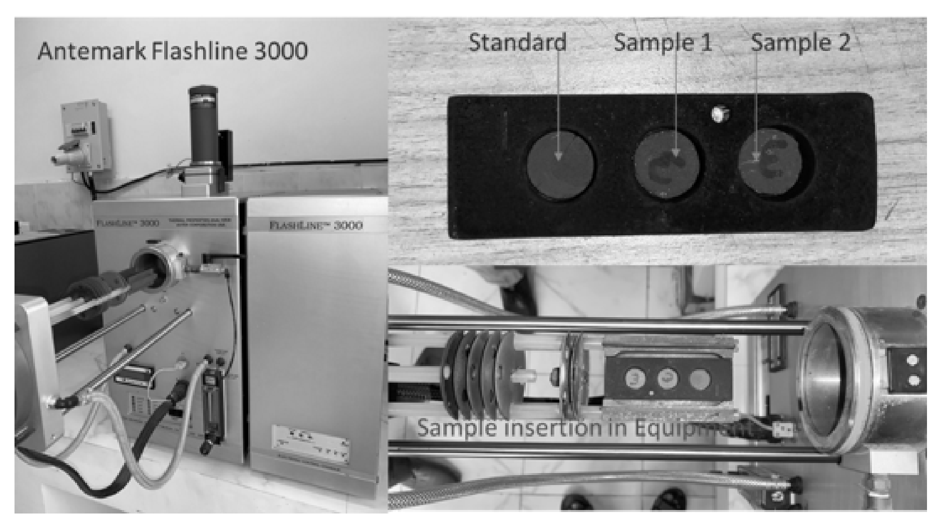

Figure 3: Set-up for Thermal Conductivity Measurement by Laser Flash Method.

Result and Discussion

Quartz, hematite, feldspar and mullite minerals are present in the fired bricks and their corresponding patterns are identified in XRD plots. The presence of other minerals confirms occurrence of vitrification process during firing which is responsible for densification of the bricks. As waste rocket propellant contains aluminium powder, incorporation of waste propellant results in a peak of alumina in XRD pattern. The XRD pattern for reference and 2.5% waste propellant impregnated brick has almost similar peaks, except for alumina. Due to impregnation, formation of any secondary phase is not observed in XRD. The XRD pattern is repeated 5 times to confirm the observations. Microstructure of brick samples are studied using Scanning Electron Microscope (SEM). Actually, waste propellant is combustible, and it is a pores forming substance. So, addition of propellant in brick leads to formation of more pores and voids (Figure 4). The homogenous dispersion of porosity indicates a very good uniform mixing of waste propellant in green mix of brick. The reference sample without any waste propellant impregnation has lower porosity and at 2.5% impregnation, the microstructure has more porosity. Other than porous area, the microstructure is found to be dense for given propellant percentage. The observed pores size may be between 1 and 50 micron. Reference sample gave a weight gain of 29+3 %, while the 2.5% waste rocket propellant impregnated sample gave around 20+2 % weight gain. This clearly indicated that although samples might have become porous by propellant addition, but the pores are not assessable to water. This may be attributed to local hardening around pores, which makes water ingress difficult and makes the pores impervious to water. Propellant is an energy producing substance with calorific value of 5000 kJ/kg, and auto-ignition temperature of 240°C. During kilning/baking of bricks, combustion of propellant takes place, releasing energy locally and providing alumina deposits in the vicinity. The local heating makes the materials of brick hard enough for any penetration by water. In fact, less water absorption is an advantage for the bricks. Compressive strength of the reference brick is found to be 4.25+0.5MPa, while that for impregnated brick is 4.0+0.5 MPa. Compressive strength is not adversely affected by propellant addition. The thermal conductivity reduced from 0.72 W/m.K at ambient condition to around 0.68 W/m.K for the 2.5% by weight impregnated brick sample. This indicates that propellant addition has multiple advantages, and it affects the properties of bricks favorably. Lowering of thermal conductivity can make the brick more insulating and reduction in heat load can be implemented for the buildings constructed with such bricks. The air-conditioning load and heating load for both hot and cold countries can be tackled by such improvements. The disposal of waste propellant has been an area of concern and currently open burning is resorted to. This leads to severe environmental pollution in light of the chlorinated combustion gases. Incorporation of propellant in small quantity is also some form of confirmed burning of propellant in small quantity during baking of bricks, but the release of chlorine is restricted within bricks. In addition to pollutant control, porous brick formation is also an advantageous perspective. The low water absorption due to localized hardening around pores is another advantageous effect. The marginal reduction in compressive strength may be absorbed considering various other advantages. The most important is inculcating thermal insulation properties. The work is being extended for higher percentage of waste propellant impregnation for further enhancement in results. The effects of adding waste rocket propellant to bricks is summarized in a Table 1.

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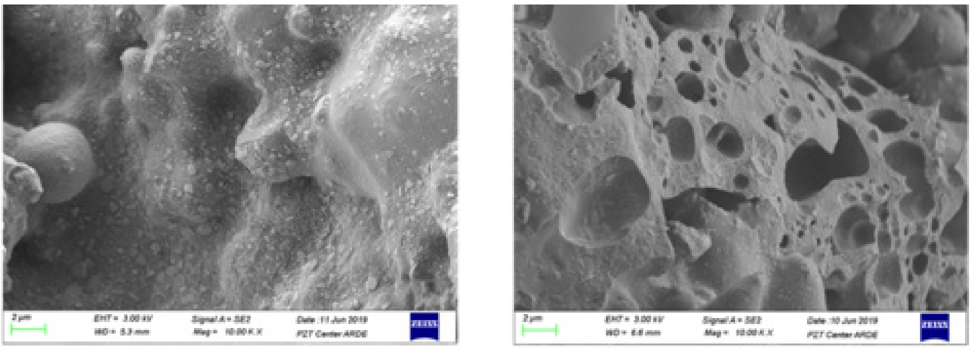

a. Reference Sample without propellant Impregnation

b. 2.5% by weight Propellant Impregnated Sample

Figure 4: Microstructure of Brick with and without Waste propellant.

Table 1: Comparison of Characterizing Bare and Impregnated Bricks.

Characterization Tools/Methods	Reference	2.5% Propellant
X-Ray Diffraction (XRD)	Quartz, Hematite, Feldspar, Mullite	Additional Alumina Peak
Scanning electron Microscope (SEM)	Less pores Homogenous	More pores Hardening
Water absorption (weight Gain)	29±3 %	20±2 %
Compressive Strength (MPa)	4.25±0.5MPa	4.0±0.5 MPa
Thermal Conductivity (W/m.K)	0.72	0.68

Conclusion

The current innovative approach of utilizing waste rocket propellant in manufacture of brick is an effective example of "Best out of the Waste". The waste rocket propellant is utilized, the harmful emissions of open burning are controlled, and properties of parent brick materials are improved. The environmental concerns and sustainable development are addressed through this research work, where brick with high porosity, low water absorption capacity, comparable mechanical strength and improved thermal insulation properties are realized. The effort is being extended further to find the extent in which waste propellant can be utilized in brick manufacture with advantageous results.

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