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Development of Composite Floor Tiles of Sand and Recycled Thermoplastics Mixture: A Sustainable Approach for Building Material Production

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Abstract:
Environmental degradation, depletion of natural resources and increase in demand of construction material for the settlement of rapid growth in population has driven the scientific study to find the best alternatives for construction materials. This study aims to provide the idea of sustainability and economy via utilization of non-degradable plastic waste product. The research explores the potential of plastic waste and sand to produce floor tiles as composite construction material. The fabricated floor tiles were tested for water absorption, compression strength, load bearing and drop test to characterize its durability and suitability for paving on non-traffic pavement of public places. The maximum load bearing capacity was found 660KN and compressive strength of 25.4MPA with minimum water absorption of 0.04 and hence found very suitable as paving material in public places for all weather condition. The study recommends the recycled plastic waste as green building material for sustainable development.

Keywords: Environment, Solid waste, Sustainability, Floor tile, Green building material

1.Introduction

Plastic is non-degradable material which requires centuries to degrade. The use of plastic is increased for packaging goods in households, business market, health institutions, and education centers extremely and traditional packaging systems has been replaced. Despite its numerous implications its use cannot be avoided because of its wide application and beneficial properties[1]. The productions of plastic bags are significantly increasing globally as a commercial purpose and have become emerging industrial product having adequate earning capacity. After use plastic becomes a huge amount of waste product from municipality. The wastage from urban area comprise of 12% plastic material as non-degradable waste. The amount of plastic is around 190 million approximately generated annually in the world. Australia only produces 16% plastic as waste material and even in India it is around 8.5 million annually from households[2] .Thus plastic waste has become a major factor for environmental pollution due to its hazardous properties and problems for

disposal. For underdeveloped countries the waste management has become a serious problem as it requires high cost technology for safe disposal and traditional method needs large landfill area for environmental friendly disposal[3].To control the increase in plastic production has become challenging job. Reuse of plastic by recycling is one of the best ways to manage the plastic waste which are under research[4]. The research demonstrates the thermoplastic composite of plastic and sand as floor tiles is eco –friendly product. The successful recycling production of plastic and sand for the development of new civil construction material would significantly contribute to control the plastic production and eventually helps to control the environmental pollution by reducing demand of virgin material. It also saves and sustains natural resources of energy and raw material by decreasing

the environmental pollution[5].Plastic waste product management is still big challenge in underdeveloped countries like Nepal. There is not a fixed plan, policy and technology adopted for its management by the government. The study aims to provide a direction of future research work for polymer composite material with sand as civil construction material production which helps to manage the plastic waste and it eventually helps to improve the environmental conditions of the municipalities in a sustainable way.

1.1 Solid waste management scenario in Nepal

This section includes the sources of waste generation in Nepal. The wastage from households, educational institute, industrial area, health institution, business center is the sources of waste. The survey was carried out on 58 municipalities to estimate the waste product. When all major sources of waste are combined, the average composition of MSW is as organic waste 56%, plastics 16%, paper and paper products 16%, glass 3%, metals2%, textiles 2%, rubber and leather 1%, and others 4% as shown in Figure.1[6].The waste on regional basis the mountainous municipality has higher than in hill and Terai municipality of Nepal. However there is plenty of technology developed for waste management which is eco-environmental friendly but disposal of municipal waste are dumped in undefined and inadequate landfill in undesirable way[7]. The capital city Katmandu is always in conflicts with the local people near of landfill site. Because of conflicts the waste dumps in city area for a long time causing the environment of the city unhygienic and causes different fatal diseases like cholera, fever, and diarrhea in dry season. The solid waste management of all municipal city of Nepal is insufficient, ineffective, unplanned and challenging. Many studies have been carried out at different times especially by ADB and WHO and they have suggested managing the waste by making an effective policy from central and local government level. The study says there are no formal recycling plants system in Nepal and forecasts the future problems to be faced providing the useful suggestions for the recycle of both degradable and non-degradable waste for sustainable environmental friendly solid waste management using information and communication technology (ICT).

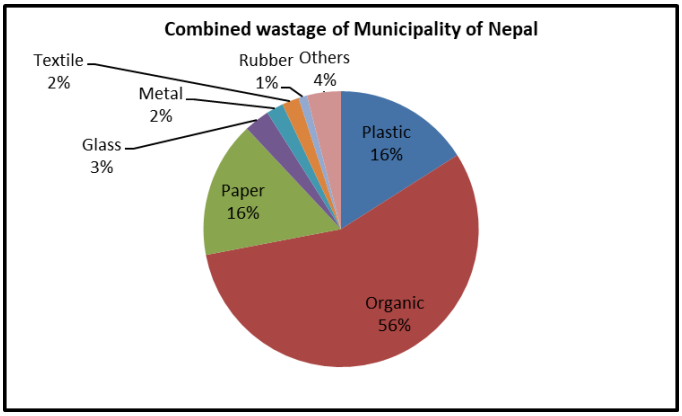


Figure 1: Combined average Waste generation from Municipality of Nepal (Source: ADB report)

1.2 Challenges and issues for solid waste management

The main challenges for solid waste management are related with the waste generation, insufficient and improper waste collection, and transport of the waste, treatment and disposal processes. The rapid increase in waste production with poor practice of waste collection is big challenge for solid waste management[8]. Disposal and damping in undefined and inadequate landfill area as shown in figure 2 and figure 3 is causing water pollution, soil pollution due to leachate formed from the waste[6] .The ecosystem of the landfill area is affected adversely. People are suffering from fatal diseases related to skin and even cancer[3]. The main problem is to change the mode of waste treatment from mechanical to biological. The availability of trained and certified personnel to manage the waste treatment protocol is mandatory. The management is also a cost–intensive process such as handling, logistic and environmental safety consideration[9].

Figure 2: Waste piled in Kathmandu valley, Teku (Source: ADB Report)

Figure 3: Unsanitary waste disposal at final landfill site of Nepal (Sources: ADB report)

1.3 Statement of Problem

Rapid grow in population, industrialization, and increase in consumption level of people are the cause for exponential rate of increase in waste production.[10] With the increase of world's population there is increase in waste production [11]. The study report has stated the production is increasing at rate of 8% globally from the year 2007 to 2011 and from 2015 it increased to 13% annually[12]. Furthermore it is expected 19 billion tons solid waste will be generated annually by the year 2025. The solid waste will have 8-10% non-biodegradable that need around 500 years to decompose thus requires vast land for disposal and remarkable factor for socio economic development and environmental health. To construct the shelter for the population increased needs huge construction material. The recycle of degradable and non-degradable waste helps to full fill the requirement of increased population. Hence recycle of plastic waste for construction material is considered as a reliable solution.

2. Literature Survey

The plastic recycling process is the sorting and shredding of photochemical materials to create useful and functional products[1]. Various methods are developed for solid waste recycling process. But still there is restriction to use them. The main parts of recycling are economy, compatibility and material properties. During recycling the waste produces very harmful product that pollute to the environment extremely[13] .Carbon and chemical production damage both atmosphere and soil in nature. A critical stage in *recycling plastic* is shredding or grinding *plastic* into smaller flakes[14]. The most common way of recycle is mechanical method for plastics like polythene terephthalate (PET) and high density plastic (HDPE).A new research from MIT appears much better way. A chemical process using a catalyst based on cobalt has been found to be very effective at breaking down a variety of plastic like PET and PP[15] .After recycling the plastics are used for the development of construction materials like roof tiles, bricks composed with sand clay and concrete. The damping property of concrete tile with plastic fiber showed better than conventional concrete tiles and reduction in size having better mechanical properties. Experiments for the development eco- friendly tiles by utilizing waste plastics and sand showed that the addition of sand enhances its strength that makes it more durable to withstand the temperature and explores its suitability for use in a terrace. Ilkeret et al. 2007; investigated for the production ceramic tiles by mixing blast furnaces slag and clay. Raimondo et al. 2019; described the production of sheet molded compound roof tiles. Setyanto, 2014; had discussed the preparation of roof tiles by using rice husk, M- sand, and soil. The test results suggest that the particles of rice husk in an appropriate proposition can successfully replace M-sand. Novais et al.2015;

compared the properties roof tiles prepared by using waste plastic and rubber with ceramic roof. Siddiqui et al., 2008; elaborates on the waste management techniques for recycling of plastic in concrete. William, 2006; proposed the use of plastics waste for the sustainable development. Turku et al, 2017; conduct an experiment intended to use plastic bottles with concrete to ensure it in the masonry unit[16]. On the basis of previous research works this study aims to fabricate floor tiles by composite of recycled plastic and sand achieving acceptable strength properties experimentally.

3. Methodical Approach

The presents research study initiates with the solid waste management scenario, issues and challenges, scope of the study and literature survey that suggests the possible ways of solid waste management which are economically feasible, environmental friendly and contribute to sustainable development of the country. The study work demonstrate the manufacturing process of floor tiles composite of recycled plastic with natural sand as binding material in replacement of cement material. The plastics available in various forms are found to have binding quality with various other remarkable properties like lightweight, non-corrosive, toughness, durability, etc. thus making it suitable to use as a raw material for construction. The test results suggest for application of composite plastic and sand floor tiles in non- vehicle public place that reduces the demand of traditional cement concrete tile which are costlier and it helps to manage the solid waste by mitigating the problems related to waste management and improve the environmental condition. Also the study examines the need for further scope of investigation work in future.

3.1 Development of Samples

First of all plastic are collected (most of which are LDPE) and cleaned against organic waste. The so prepared plastic is then shredded and converted to pieces. In a closed oven, the shredded plastic is then heated to melt such that no oxidation takes place (health safety purposes). Semi-liquid plastic is then mixed with sand and shaped into mould (with pressure application). The material so obtained is allowed to release heat and a finishing touch is given. This way we successfully obtained recycled paving tiles. Specimens were prepared on the following process as shown in figure 4.

Figure 4: Process of flow chart for development of specimens

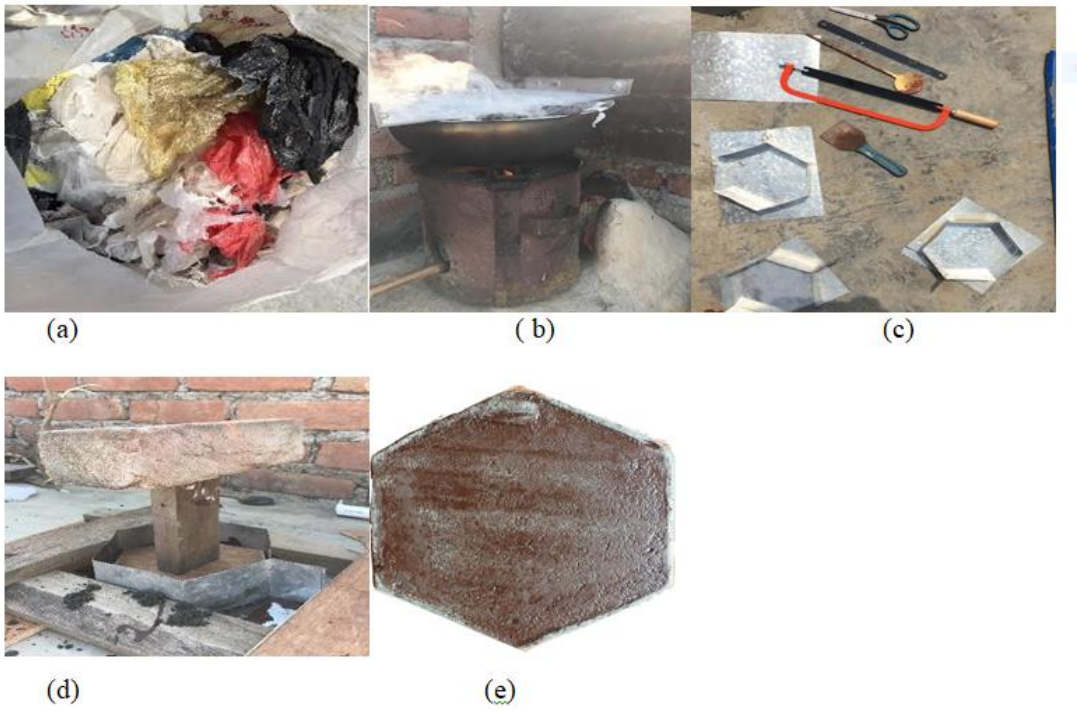
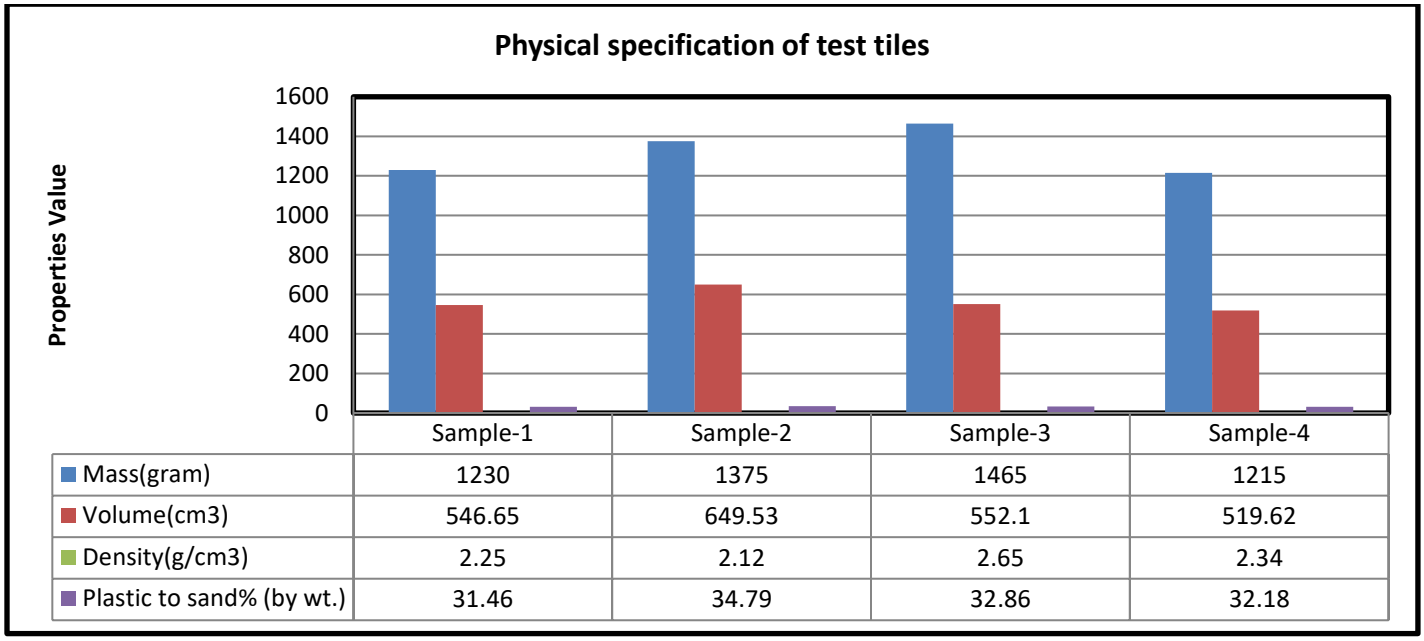


Figure 5: Images of Fabrication processes (a) Plastic waste collected (b) Melting of plastic waste (c) Mold set preparation (d) Casting on mold set (e) Final product.

For physical test we created four plastic-sand composite paving tiles as shown in figure 6 in ratio varied from 31% to 34% of plastic. In previous studies the percentage of plastic waste were found 30 to 50%. For this study the proportion was chosen 31 to 34% for low density plastic waste to reduce the weight of plastic waste and its corresponding mass, volume and density were calculated. Figure 7 shows the physical properties of the samples made.

Figure 6: Images of the four samples Developed in Laboratory



	Sample-1	Sample-2	Sample-3	Sample-4
Mass(gram)	1230	1375	1465	1215
Volume(cm3)	546.65	649.53	552.1	519.62
Density(g/cm3)	2.25	2.12	2.65	2.34
Plastic to sand% (by wt.)	31.46	34.79	32.86	32.18

Figure 7: Physical specifications of test

3.1.1 Main Variables

The main parameters Mass, Volume, Density and plastic to sand ratio by weight in percentage were considered as main variables for sample preparation. The mechanical strength properties depend on mainly on these parameters of the product. The water properties depends on the proportion of the plastic waste to sand so that the water absorption was to be tested at different plastic to sand weight (%) and hence the corresponding mechanical strength were to be tested for each sample to make comparative study.

3.2 Experimental Evaluation

The properties evaluation is important for identifying the performance of the prepared specimens and to observe the workability of the developed composites. The developed paving tiles samples are tested for physical, mechanical and tribological properties in term of water absorption, compressive strength, drop and load bearing strength.

3.2.1 Physical Properties (Water absorption)

This is carried out to determine the moisture content of the paving tiles. It is percentage of dry weight. It was evaluated by 24 hour immersion procedure to the sample made[14]. The test identifies the suitability of the floor tiles in different weather conditions. It defines the internal porosity, water holding capacity and quality of the material used. The water content is evaluated by the following equation.

$$Water\ absorption(\%) = \frac{(Wet\ weight - Dry\ weight)}{Dry\ Wet} X100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The water absorption indicates the moisture content which equivalent to the difference between the wet and dry weight of the specimen divided by the weight of the dry specimen and multiplied by 100 to express it as a percentage. The equation (1) gives the formula to find the water absorption of specimens.

3.2.2 Mechanical Properties (Compressive Strength)

The compressive strength indicates the stability of a material against the external forces[11]. The evaluation for compressive strength of the prepared specimens was carried out using a universal testing machine Model No. HL 590 20 having a capacity of 800 KN at laboratory of campus itself. The

specimens were prepared as per the test requirement. The compressive strength of the specimen was evaluated by placing the samples parallel to the surface between the compressive plates to provide the compressive load with a uniform rate. The maximum load was recorded along with the stress-strain data. The Figure 8 is the testing machine and sample tested during evaluation.

Figure 8: Compression Strength Test Setup (Laboratory hall)

4. Result ad Discussion Approach

4.1 Water- absorption Test

Following data were collected during water absorption test of floor tiles samples during 24 hour test observation as in figure 9. The water absorption ration was found 96% for sample third that is the water content in specimen was below 0.05 which indicates very low porosity and good water repellent behavior of the material at a ratio of plastic with sand 32.86 by weight %.

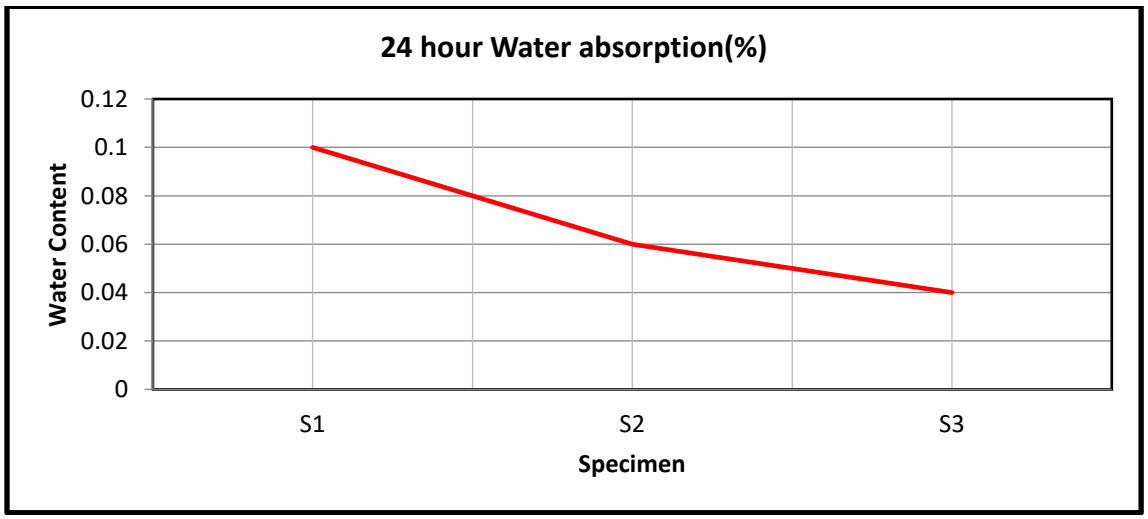


Figure 9: Water absorption (%) of the specimen

4.2 Compressibility Test

Sample-1 & Sample-2 were subjected to compressive load test. From the test result the specimen made at a density of 2.25gm/cm^3 has maximum compressive strength of 25.4Mpa and load bearing capacity of 660KN. The plastic sand ratio by % weight is 31.46. For maximum compressive strength the density of paving tiles is 2.25gm/cm^{3-} .Figure 10 shows the test results.

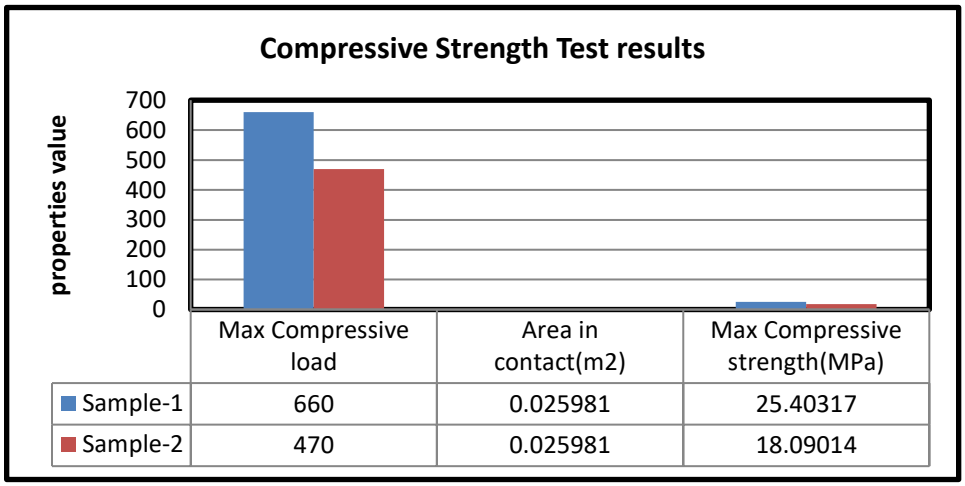


Figure 10: Compressive Strength Test results

4.3 Load Bearing Test

The evaluation of the strength of a hexagonal tile (Sample-4) made from recycled plastic waste and sand was carried out. The tile had a dimension of 10 centimeters and was aligned parallel to two brick supports with an offset of 3 centimeters. A load was applied parallel to the supports and the load-bearing capacity of the tile was determined. The results of the study showed that the maximum load that the hexagonal tile (Sample-4) could bear was 7.5 kilo Newton (kN). This value represents the maximum stress that the tile can withstand before undergoing permanent deformation or failure. It is important to note that this result provides a snapshot of the strength of the hexagonal tile under specific testing conditions and does not necessarily reflect its performance in real-world applications. Further research and testing may be needed to determine the durability and longevity of the material, as well as its suitability for different environmental conditions and loading scenarios. The research findings demonstrate the potential for recycled plastic waste and sand to be used as a construction material. The development of sustainable and environmentally friendly building materials is becoming increasingly important as the construction industry looks to reduce its impact on the environment. By using waste plastic as a resource, it can help to reduce the demand for virgin materials, lower greenhouse gas emissions, and provide economic benefits.

4.4 Drop Test

Sample-3 was evaluated in a drop test. The tile was dropped from a height of 1 meter onto a normal ground and no major failure was observed. The drop test was designed to assess the resistance of the tile to impact loading, which is a common type of loading encountered in real-world applications such as foot traffic and outdoor weather conditions. By demonstrating that the tile was able to withstand the impact of being dropped from a height of 1 meter without major failure, the results suggest that it may have good durability and resistance to impact loads.

Overall, the results of the drop test contribute to our understanding of the potential of using recycled plastic waste and sand as a construction material. By demonstrating the durability and resistance to impact loads, this study provides valuable information for further development and application of this type of material.

5. Conclusions

The study examines the opportunities for effective utilization of generated solid wastes. The experimental work successfully demonstrates the manufacturing of floor tiles by using non-degradable plastics waste and silica sand at proportions. The effective management of plastic waste by turning it into construction material helps in reducing its negative impact on the environment. This not only tackles the issue of plastic waste, but also creates a sustainable and environmentally responsible solution for managing municipal waste.

From the experimental observation some short of conclusions are made on the product fabricated as follows:

1. The uniform silica sand can be used as binding material in composite product with plastic for floor tiles. The water repellent property of plastic makes the tile more durable against water effects.
2. The percentage of water absorption for the developed floor tiles specimens is quite low (below 5%). It is suitable to use under different ambient conditions i.e., dry, wet or moisture.
3. The maximum compressive strength was obtained 25.04MPA for the specimen having 31.46 wt. % at density of 2.25gm/cm^3.This strength value was found at recommended value for paving in public places.
4. Load bearing and drop test results showed specimens were found of sufficient strength to use as paving material in non-traffics areas of public places.

Conflict of interest

There is no conflict of interest regarding the publication of the article.

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