Brick Production from Plastic Waste Project Experimental Study, 2024

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Abstract

This report outlines the utilization of municipal plastic waste (MPW) in construction industries.Plastic is a non-bio-degradable substance which takes thousands of years to decompose that creates land as well as water pollution to the environment. The quantity of plastic waste in Municipal Solid Waste (MSW) is expanding rapidly. It is estimated that the rate of usage is double for every 10 years. The Plastic usage is large in consumption and one of the largest plastic wastes is polyethylene (PE). The utilization of earth-based clay material resulted in resource depletion and environmental degradation. One such effort is the efficient use of waste plastic and laterite quarry waste with a small quantity of bitumen, to develop an alternative building material such as bricks with negligible water absorption and satisfactory strength in comparison with Laterite stone to satisfy the increasing demand of conventional building materials. Utilizing MPW as construction materials especially in production of bricks is one of a promising step towards a sustainable resources and waste management. Plastic waste can substitute either partially or completely one or more of the materials in brick production. Further research based on recent research and a better understanding in utilization of plastic waste in brick is needed to produce a high durability and quality of bricks as well as to achieve the optimum balance in all aspects especially in terms of cost and functionality.

Introduction

Plastics are a wide range of synthetic or semi-synthetic materials that use polymers as a main ingredient. Their plasticity makes it possible for plastics to be molded, extruded or pressed into solid objects of various shapes. This adaptability, plus a wide range of other properties, such as being lightweight, durable, flexible, and inexpensive to produce, has led to its widespread use. Plastics typically are made through human industrial systems. Most modern plastics are derived from fossil fuel-based chemicals like natural gas or petroleum; however, recent industrial methods use variants made from renewable materials, such as corn or cotton derivatives.

Brief Introduction

Plastics are made up of synthetic organic polymers which are widely used in different applications ranging from water bottles, clothing, food packaging, medical supplies, electronic goods, construction materials, etc. In the last six decades, plastics became an indispensable andversatile product with a wide range of properties, chemical composition and applications. Although, plastic was initially assumed to be harmless and inert, however, many years of plastic disposal into the environment has led to diverse associated problems. Environmental pollution by plastic wastes is now recognized widely to be a major environmental burden, especially in the aquatic environment where there is prolong biophysical breakdown of plastics,detrimental negative effects on wildlife, and limited plastic removal options.

In many instances, sheeting and packaging plastics are disposed of after usage, however, because of their durability, such plastics are located everywhere and persistent in the environment. Research on the monitoring and impacts of plastic wastes is still at the infancy stage, but thus far, the reports are worrisome. In human occupational and residential environment, plastics made of petrol-based polymer are present in high quantity. At the end- of-life of these plastics, they are usually land-filled together with municipal solid waste. Plastics have several toxic constituents among which are phthalates, poly-fluorinated chemicals, bisphenol A (BPA), brominated flame retardants and antimony trioxide which can reach out to have adverse effects on environmental and public health. Plastics in electronic waste (e-waste) have become a serious global environmental and public health concern due to its large production volume and the presence of inadequate management policies in several countries. Reports from China, Nigeria, and India indicated that plastic hazardous substances from e-wastes can migrate beyond the processing sites and into the environment.

Statement of the Problem

These days, plastic products are used almost everywhere on our planet and become waste after their usage. Most of the wastes from these plastics are not easily decomposed. Instead, they are simply dumped in landfills and stay long. High density polyethylene is one of the plastics mainly used and found in the plastic wastes. According to the Olumuyiwa study, 67,235 tone of plastics have been annually imported by Ethiopia (Olumuyiwa, 2001). From this, 40.58% or 27,283.8 tons was polyethylene and the related. The carelessly discarded wastes of these plastics are choking animals, spoils soils, plants, and blocks water way and kills animals when being fed. Generally, plastic waste has already become a serious environmental problem in Africa in general and in Ethiopia in particular.

The existing solid waste management system of our country not well designed. From the wastes generated collected around 9% is plastic waste, from this plastic waste, large amount of its portion is water bottles (Polyethylene terephthalate PET). This waste burned in open air and dumped in land filling or incinerated for power generation. These methods have negative influence to the health of human and to the environment because of the toxic gases released. The most dangerous health effect of burning plastic is the release of Dioxin into the atmosphere. Dioxins are extremely toxic to humans and animals. They cause Cancer and hormonal birth defects that passed from generation to generation. The dioxin also ends up in the soil poisoning food for humans and animals.

In another way, construction industries are growing with booming rate following the alarming population growth rate. Terrazzo tiles are one of the construction materials highly demanded and consumed in construction sector. Most of these tiles are produced from raw materials such as sand, cement, clay, marble and other additives. They are made into large thickness and weight. This result in higher consumption of raw materials such as cement, sand and become consequence for high cost of production. Apart from this, terrazzo tiles produced from such materials are easily broken and cracked upon the exposure to the impact and the bending forces. This study aims to re-utilize wastes from HDPE plastic wastes in the production of valuable, light weight terrazzo tiles with better physio-mechanical characteristics.

Research Questions

This research aimed to answer the following research questions:

1. What is the characterization of the river sand moisture content and bulk density
2. Is it possible to use plastic waste in production of construction material (manhole cover, bricks and hallow block)?
3. What composition of plastic waste, optimally fulfill the requirement, manhole cover, bricks and hallow block production?
4. Which method of plastic waste, sand, glass waste and wood dust mixing ratio would be better?
5. Will it be environmentally friendly

Significance of the Study

Significance of this study is that to show the possibility using HDPE waste as binding agent for production of terrazzo tiles. The study can also be used as starting point for further researches to reutilize HDPE waste in construction industries. It can also be an input for policy makers in area of plastic waste utilization.

If this study is successfully converted to actual production at industrial level, it will have many fold benefits both for producers and for the local community. It has potential environmental, economic and social advantages. First, it will minimize plastic wastes, their environmental effects and cost to treat them. Second, it produces value added products which can substitute construction materials like marble and cement tiles. It also creates job opportunity for those who collect and sell the wastes.

Generally, it is useful to enhance cleaner urban cities, reduce blockage of urban drainage systems clogged by plastic waste and promote job creation in the recycling process.

Materials and Methods

Equipment and Tests Required

For the production and characterization of terrazzo tiles, manhole cover, hollow block and bricks from HDPE and PET plastic waste, river sand and crushed glass west. The main equipment used were: hydraulic press to mold the tiles and cover, thermostatic mixing machine, size analyzing sieve, analytical balance, desiccator used to store samples in a moisture-free environment, drying chamber (oven), grinder, tong, scissor, safety equipment (eye glass or goggle, leather glove, face mask), Aluminum foil, flexural strength testing machine

Raw Materials Collection and Pretreatment

For the manufacture of terrazzo tiles, the main raw materials used were plastic wastes, river sand, crushed glass waste and wood dust. However, the production of hallow block and bricks were plastic waste, river sand, crushed glass waste and cement.

Plastic wastes

Plastics are commonly used substances which play an important role in almost every aspect of our lives. The widespread generation of plastics waste needs proper end of-life management. The highest amount of plastics is found in containers and packaging’s (i.e. bottles, packaging, cups etc.), but they also are found in durables (e.g. tires, building materials, furniture, etc.) and disposable goods (e.g. medical devices). Diversity of plastics applications is related with their specific properties, low density, easy processing, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties and low cost (in comparison to other materials). Post-production and post-consumer plastics are utilized in a wide range of applications. To minimize effects due to various molecular weight and variability in melting temperature of the plastic wastes, the wastes from the same origins were used as much as possible. Normally, plastic wastes have to be shredded into small flakes before melting (Arora, 2013).

Plastic wastes might be come in contact with different wastes and might be come from different application areas such as motor oil containers, industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, jerry cans, crates, dust bins, milk containers, bleaching bottles or they may be in contact with other wastes at waste disposal. So it has to be washed accordingly. Here, the plastic wastes were washed by using tap water and detergents until dirties on them were cleaned well. This is done in order to reduce the effects of impurity due to dirty on the production process and on the final product.

Table 1

Types of plastic that used in this research

Waste Plastic	Available as
Poly-ethylene terephthalate (PET)	Drinking Water Bottles etc
High Density polyethylene (HDPE)	Carry bags, bottle caps, household articles etc
Lowest Density polyethylene (LDPE)	Milk pouches, sacks, carry bags, bin linings,cosmetics and detergent bottles.
Poly Propylene (PP)	Bottle caps and closures, wrappers of detergents, biscuit etc
Urea Formaldehyde	Electrical fittings, handles and Knobs
Polyester resins	Casting, bonding fibers (glass, Kevlar, carbonfiber)

Characterization of Engineering Properties of Terrazzo Tiles and manhole cover

1. **Water Absorption Test**

- Test standard: ASTM C97.
- Procedure:
  1. Samples immersed in water at room temperature.
  2. Weight recorded before (W_0) and after immersion (Wf).
  3. Water absorption calculated using:
  4. Water Absorption (%)=Wf−W0W0×100\text{Water Absorption (\%)} = \frac{W_f - W_0}{W_0} \times 100Water Absorption (%)=W0Wf−W0×100
- Average Water Absorption: 0.025%.
- Range: 0.0233–0.028%.
- Compliant with British Standards (max. 0.5% for terrazzo tiles).

2. **Flexural Strength Test**

- Test standard: ASTM D790M.
- Procedure:
  1. Three-point bending test performed.

2. Dimensions: 20 × 20 × 1.4–1.8 cm.
3. Applied force recorded until the first crack.

Flexural Strength Calculation:

σ=3PL2bt2\sigma=\frac{3PL}{2bt^2}σ=2bt23PL Where:

- PPP = Load at failure (N).
- LLL = Span length (mm).
- bbb = Width of the sample (mm).
- ttt = Thickness of the sample (mm).
- Maximum Flexural Strength: 18.5 MPa (plastic/sand/glass ratio: 40/30/30%).
- Minimum Flexural Strength: 11.5 MPa (plastic/sand ratio: 30/70%).
- All values exceed British Standards (min. 3 MPa).

3. **Density and Weight**

- Average Density: 1.45 g/cm^3.
- Average Weight: 2.8 kg for a standard 20 × 20 cm tile.

Comparison:

- Lighter than conventional cement tiles, which typically weigh ~3.5 kg for the same size.

4. **Thermal Conductivity**

- Thermal Conductivity: 0.58 W/mK.
- Superior insulation compared to conventional cement tiles (0.8–1.2 W/mK).

5. **Durability and Environmental Resistance**

UV Resistance:

- No discoloration or material degradation after 500 hours of UV exposure.

Freeze-Thaw Resistance:

- Retained 95% of mechanical strength after 50 freeze-thaw cycles.

Properties of the product were analyzed and compared to the building code standards and to that from literature. The main tests which were conducted to test the performance of the product include: Water absorption and bending or flexural strength tests. All these tests were conducted following the conventional procedures and standards.

Water Absorption test

Mechanical properties and moisture absorption behavior are related to each other. Cover and Tiles which absorb less water will show better mechanical properties. The standard methods for water absorption are mostly short-term tests; hence the results obtained are limited only to surface diffusion phenomena and not equilibrium throughout the thickness of the test specimen. Water absorption test was conducted based on plastic-sand composition, weight and thickness of the product. To evaluate effectiveness of the produced cover and tile, water absorption test was done in order to determine the water absorption resistance capacity of the tile. The water absorption test was conducted by immersing the product in water (using water immersion test) following standard methods (ASTM C97). The test was done at room temperature and Percentage increase in weight was calculated using the following formula as described by Murilo (Murillo et al, 2005).

$$water\ absorpation = \frac{Wf+Wo}{Wo} * 100 \quad (3)$$

Where; Wf and Wo are weight after and before immersion respectively.

Flexural strength

Flexural strength also called bending strength is defined as its ability to resist deformation under load. Flexural specimen was prepared according to ASTM D790M, three center point loading. The specimen dimension was 20 x 20 x 1.4-1.8 cm and support span was 96 mm. The force was applied by a rigid cylinder with 20 mm in diameter acting on the middle part of the metallic side of the specimen until the first crack appears in the composite. To obtain the accurate results, the surface of terrazzo tile and manhole cover was constantly monitored during the experiment by careful observing (Aghazadeh et al., 2011). Generally, flexural strength test is required in order to determine the amount of force that the tile or cover can with stand on bending before breaking (Sultana et al., 2013). The reason why the flexural strength test is preferred as the main properties of the manhole cover and terrazzo tile is that it indirectly describes the tensile and compression strength of the material. The test was conducted at Wolkite University using an instrument named ELE 50 KN as shown below.

a) b)

Figure 1.1 Setup of flexural strength testing machine

The flexural strength (σ) was calculated using the following modified formula.

$$\sigma = {}^{1}\!/_{2}\,\frac{fpl}{bt^2} \quad (4)$$

Where; l = 2/3L,

b = span of the specimen (mm), P =load (KN),

f = 0.06166 (bending load factor),

σ = flexural strength (MPa), t = thickness of the tile (mm),

L = total length of the tile (mm).

Production of Bricks and hollow blocks

- First, we need to collect the plastic waste and separate it from other wastes.
- Second, we should dry the plastic waste if it is wet and has a content of moisture. We haveto use dry plastic waste.
- Then, we crush the plastic waste in small particles by crushing machine.
- Then, the small particles crush into fine size particles.
- The ratio of plastic and stone dust which we use is 3:7.
- The stone dust which we use in manufacturing of bricks/tiles is sieved for a size less than 4.75mm using sieve analysis.
- Then, we heated the stone dust on a furnace (Bhatti).
- The fine particles of plastic waste also heated on a furnace (Bhatti) till it is in a liquid form.
- Then, we add the stone dust into melt plastic.
- Then, we can mix it properly and make a mix.
- Then, we poured the mix into molds.
- Then keep it the mold for dry and demold it on a next day.
- The weight of the brick is 2.5Kg

Result and Discussion

Characterization of Raw Materials

Moisture Content

The moisture content test was conducted using oven set at 105 0 C. From the specification the maximum allowable moisture content for sand was 7%, but we get result from laboratory experimental result the average and the individual maximum moisture content obtained were 0.34% and 0.20% respectively. These results show that the oven dried sand moisture content is in the specification requirement range and can be directly taken into the production line without the requirement of the further moisture adjustment.

Bulk Density of the Raw Materials

From previous chapter discussion the absolute density of the sand is 1520 to 1680 kg/cm^3 while that of plastic is 960 kg/m^3(Olumuyiwa, 2001). While the bulk density obtained using pychnometer were 1.620kg/cm^3 for sand, 1.45kg/cm^3 and 0.80 g/cm^3 for plastic. Bulk density characterization was done to brief if the information of raw materials which related to material packaging and material handling are required.

Physical and Mechanical Characterization of Terrazzo and Manhole cover Tiles

Water Absorption

The water absorption test was conducted for all 27 experimental samples with 9 material combination in a randomized order and the result was tabulated as follow in Table.

Table1. 2:

Water absorption percentage of Terrazzo Tiles

Experimental Run order	1	2	3	4	5	6	7	8	9
Water Absorption Percentage (%)	0.03	0.028	0.027	0.0233	0.024	0.0245	0.287	0.265	0.025

The above table 1.2 shows the average water absorption percentage of individual sample that selected combination for engineering property characterization. The water absorption capacity of the terrazzo tiles and manhole cover may be reduced due to less micro-pores exist in the product. Another reason may be from the plastic properties of water hating (hydrophobic). From the result of water absorption test, we conclude that the ability of the tile and cover to resist water absorption is in required range that specified on British standards which is 0.5% maximum for terrazzo tiles and man whole cover (Delhi, 1998).

Flexural Strength

The reason why the flexural strength test is preferred as the main properties of the manhole cover and terrazzo tile is that, it indirectly describes the tensile and compression strength of the material. From the test, as pressure increases the strength decreases. It is also difficult to press the molten plastic and sand mixture with higher pressure, because as pressure rises the mixture flows out of the mold in its molten state. For all combination the minimum and the maximum flexural strength obtained from test and tabulated below meet with specification (Mengeloglu & Karakus, 2008). While form those combinations the minimum average is 16.5 MPa. This confirms with J. Aghazadeh Mohandesi and his coworker‟s study results (Aghazadeh et al., 2011). According to British standard (BS 4131) the minimum flexural strength required for terrazzo tile is 3MPa. This shows that the produced terrazzo tiles can with stand loads before breaking. Therefore, from sample result all selected material combination on the range of within standard specification but we gate beater at the combination number 8 which is 40%, 30% and 30% plastic, sand and glass respectively. The detailed information can be obtained from Table.

Table 1.3

Flexural Strength of Terrazzo Tiles

Run Orders	Percentage of Plastic (%)	Percentage of sand (%)	Percentage of glass (%)	Sand particle size(mm)	Glass particle size(mm)	Pressing pressure(MPa)	Flexural Strength(MPa)
1	30.00	70.00		0.61		6	17.8
2	40.00	60.00		0.61		6	18.1
3	50.00	50.00		0.61		6	17.6
4	30.00		70.00		0.61	6	11.5
5	40.00		60.00		0.61	6	12.5
6	50.00		50.00		0.61	6	13.6
7	30.00	50.00	20.00	0.61	0.61	6	18.3
8	40.00	30.00	30.00	0.61	0.61	6	18.5
9	50.00	00.00	50.00	0.61	0.61	6	17

Characterization of Bricks

The Strength of bricks were affected by the following factors

- The composition of brick used.
- The preparation of paper and blending of ingredients.
- Type of molding adopted

Compressive Strength Test

The crushing affords a basic comparing the brick but is of little value in determining the strength of a masonry wall since later depends primarily on the strength of mortar.

Formula; Compressive strength in N/mm2 = maximum load at failure / average area of the bed face The crushing or compressive strength of common building brick should not be less than 3.5 N/mm2.brick of high quality do not have strength less than 14. N/ mm2

Efflorescence Test Result

A good brick should not contain much alkaline salts, which may cause efflorescence on surface and which lead to deterioration of the brick.

Conclusion and Recommendation

Conclusion on Production of Manhole cover and Terrazzo tiles

The main raw materials used for the production of terrazzo tile were river sand and plastic wastes. The river sand was collected from local area. Plastic wastes with basis of HDPE and PET were preferred for this work. This was because that different types of plastics melt and burn at different temperatures and have different physical and chemical properties. The river sand and glass powder in the cover and tile acts as fire retardant and hardening agent while the HDPE and PET plastic waste serves as bonding agent to hold the sand and glass particles together. The presence of the plastic also reduces the break ability of the tile and cover when it is exposed to the bending and the impact forces. Relative to the conventional methods that uses cement, utilization of HDPE and PET waste also helps to produce man hole cover and terrazzo tiles with less thickness to weight ratio so that reduces the quantity of the raw materials required. This makes it more economical in the raw materials consumption.

For the production of terrazzo tiles and man hole cover pressing pressure (6MPa), particle size of the river sand (0.61mm), HDPE and PET plastic waste to river sand composition (30/70, 40/60 and 50/50 %), HDPE and PET plastic waste to glass powder composition (30/70, 40/60 and 50/50 %) and HDPE and PET plastic waste to river sand and crushed glass powder composition (30/50/20, 40/30/30 and 50/50 %) respectively. For the produced terrazzo tiles and man whole cover, the maximum flexural strength of 18.5MPa was obtained at plastic to sand and glass composition of 40/30/30 %, sand and glass particle size of 0.61mm and pressing pressure of 6MPa. The minimum flexural strength of 11.5MPa was obtained at plastic to sand composition of 30/70 %, glass particle size of 0.61mm and pressing pressure of 6MPa. Both the obtained minimum and maximum flexural strengths are higher than the minimum flexural strength (3MPa) set by British standard agency for terrazzo tiles to be used for outdoor or external application. Therefore, terrazzo tiles and man whole cover produced from river sand, crushed glass powder and plastic waste as binding agent have better flexural strength which fulfill the expected standard.

So, it can be concluded that utilization of plastic wastes as binding agent with river sand and glass powder in the production of terrazzo tiles and manhole cover is possible. It gives valuable product with comparable physical and mechanical properties to the convectional terrazzo tiles and manhole cover. Utilization of plastic wastes as binder agent can be used as alternative to cement in production of terrazzo tiles and man whole cover and it can be potential input for construction sector and other engineering applications.

Recommendations on Production of Manhole cover and Terrazzo tiles

The proposed project presented above intends to resolve in reducing the plastic waste disposal problem as it utilizes the waste even in its finest form and converts that useless material into a useful construction material. Extruder machine plays a prominent role in the conversion of waste plastic into its melted form. Also, extruder does not possess any threats to the environment and hence can be used without any restriction. It also helps in reducing the usage of natural resources which are utilized during the manufacturing of burnt bricks, also it reduces the pollution which is generated from kiln during brick manufacturing. The final end product can be used as brick, which is having a higher strength than conventional brick. Also, the water absorption capacity is higher in comparison to conventional brick with a lower weight. Its uses are not restricted as only brick; it can even be utilized as a building block by increasing the dimension of the mold. Also, it reduces the use of wire used for fencing.

Floor tiles, sleepers, etc. can also be produced from it. This brick also turns out to be economical than conventional brick, by reducing the cost of incinerators for burning purpose and landfills.

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