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Usage of Plastic in Manufacturing of Solid Bricks along with M-sand and Bitumen

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ABSTRACT

Plastic, one of the greatest materials invented by mankind. Since the development of plastic earlier this century, it has become a popular material used in different ways. They are cheap, durable and easy to make. In today's world, plastic is used to make or wrap many items, we buy or use. But the main problem arises when we no longer want those items and we have to discard them. As the production cost of plastic is very less, it is readily available in the market. The cheapness means plastic gets discarded easily, its long life means it doesn't decompose easily and requires high ultraviolet ray to break down. In the 21st century, one of the major environmental issues is arising due to the plastic waste. Plastic is non-biodegradable hence the discarded plastics are affecting our environment gravely. Due to the huge popularity of plastic as a production material, decrease in plastic usage policies isn't encouraged by manufacturing companies, rather it is estimated that the plastic usage rate going to be double for the next 10 years. As we are still looking for viable solutions to this plastic waste management problem, this study is solely focused on the recycling of discarded plastic bottles in building materials. The main purpose of this particular study is to introduce plastic waste in brick production and explore the performance of plastic bricks, made out of polyethylene terephthalate (PET) bottles and M-Sand. The bricks were casted with plastic to M-sand in different proportion and bitumen was used as a binder material. The experimental outcomes were compared with locally available clay bricks.

Keywords : Plastic Bricks, PET bottles, Bitumen, M-Sand, Compressive Strength, Water absorption.

I. INTRODUCTION

During the nineteenth century, the dawn of industrial revolution saw the development of many innovative materials and synthetic plastic is one of them. After World War I, typically in the time period 1950 to 1960, global plastic production had increased drastically from 2 billion tonnes to approximately 380 million tonnes in 2015. In the past 70 years, the world has seen a production of 8.3 billion plastic in which 6.3 billion tonnes have been discarded. Each year from those remaining wastes, a large number of plastic wastes are found in oceans. Due to their high durability, plastic does not decompose easily and takes up almost 450 to 1000 years in that process. India, a country whose plastic industry is growing rapidly, only 30% of the total disposed plastic is collected. The sources from The Energy and Resources Institute (TERI) suggested that the country produces approximately 26,000 tonnes of plastic waste daily. Furthermore, the source also anticipates that by 2020, the annual plastic consumption is going to increase from 12 million tonnes to 20 million tonnes.

Given this predicted growth in plastic production, The Energy and Resources Institute (TERI) also encouraged that there should be subsequent recycling for the plastic waste. This recycling policy of plastic will be a critical step towards the reduction in the generation of new plastic waste. But repeated recycling of plastic poses a grave threat of transforming plastic into a carcinogenic material. Also, the poor waste management system of Indian cities made the matter worse. In today's world, it is very much impractical to ban the plastic use completely. Rather than completely banning the plastic use, it is much more essential to manage the plastic waste systematically.

1.1 Recycling of Plastic Waste (PET) in Construction:

Plastic waste is increasing exponentially every year throughout the world. Both manufacturing and destruction of plastic pollute the air, water, and land. Currently, 10 to 15% of the plastic waste is recycled into road construction. Polyethylene terephthalate (PET) is a type of plastic resin, used in the production of plastic bottles and plastic containers for packaging food and beverages and other products. Although PET bottles can be recycled and reused, they hold a significant amount of bacterial contamination threat. The molecular composition of polyethylene terephthalate consists of ethylene molecules (-CH2-CH2-), ester molecule (-COO) and terephthalate ring. Basically, it is made out of hydrogen, carbon and oxygen atom. Hence the burning of PET only generates carbon dioxide (CO2) and water (H2O), which are not carcinogenic emissions.

1. Objectives

- ✓ To develop considerably light weighted bricks for the construction works.
- ✓ To develop and study the salient properties of bricks made from polyethylene terephthalate (PET) bottles.
- ✓ To reduce and reuse the plastic waste in a way that will improve the plastic waste management system.

2. Materials and It's Properties

Plastic Bottles (PET bottles):

For this experimental study, plastic bottles are collected from three main sources. Those are given below,

- ✓ Municipal- This source includes residential buildings, commercial establishments such as hotels, hospitals etc.
- ✓ Distribution and Industrial Sectors- This source comprises of food and chemical industries etc.
- ✓ Others- This source predominantly comprises of automotive waste, agricultural waste, and constructional debris

Table 1. Properties of Polyethylene Plastics

Properties of Polyethylene plastics (Results are collected from Central Institute of Plastic Engineering and Technology, Chennai, India)	
Density at 23oC	0.958
Elasticity modulus	9
Tensile creep strength	8
Bending creep modulus	1
Tensile strength at 23oC	2
Elongation at break (%)	>600
Thermal conductivity	0
Ignition temperature	3

Fig 1. Collection of PET bottles

Bitumen

Bitumen is a binder material, usually present in either viscous liquid form or solid form. It consists of hydrocarbons and their derivatives, possess waterproofing and adhesive properties. The following results are obtained from bitumen testing.

Table 2. Properties of Bitumen

Properties of Used Bitumen		
Tests on Bitumen	Results	Values
Ductility Test	Ductility Value of Bitumen	72
Flash & Fire Point Test	Flash Point of Bitumen Fire Point of Bitumen	315OC 340OC
Softening Point Test	Softening Point of Bitumen	45OC
Penetration Test	Solid Cone Penetration Value Hollow Cone Penetration Value Solid Needle Penetration Value	87.34 mm 83.34 mm 228.34 mm

M-Sand:

Manufactured sand also known by the name of M-Sand is an alternative to river sand in the construction field. It is produced from the granite rocks by crushing them. M-Sand usually consists of silica, aluminium dioxide, ferric oxide and magnesium oxide. So for this particular experiment, M-Sand is selected as fine aggregate and has a specific gravity of 2.72. The coefficient of curvature (CC) and uniformity (D60/D10) of the M-Sand is 1.125 and 4.5 respectively, which indicates that the used M-Sand is well graded in nature.

1. Proportioning of Materials and Mixing Process

Proportioning of Materials

Initially, with the help of trial and error method, the total amount of required material for a brick is selected as 3.5 kg. Later, the material proportioning is done to the weight of the brick material. The material proportion table is given below.

Table 3. Material Proportioning (Quantity of Materials)

Designation of Mix	**Plastic**		**Bitumen**		**M-Sand**	
	In percentage	*In grams*	*In percentage*	*In grams*	*In percentage*	*In grams*
Mix1	50	1750	2	70	48	1680
Mix2	60	2100	2	70	38	1330
Mix3	70	2450	2	70	28	980
Mix4	80	2800	2	70	18	630

ii. Mixing of Materials

In the beginning, a specific amount of plastic bottles were melted in a vessel at high temperature. Due to this high temperature, the plastic changed its phase from solid to liquid. As the temperature rises, the viscosity of plastic reduces drastically. At the melting point, when all of the plastic inside the vessel melted into liquid form, the required amount of bitumen and M-Sand were added to the liquid solution of plastic. Following the addition of bitumen and M-Sand, the solution is mixed throughout to prepare the absolute mix.

Fig 2. Melting of PET bottles

Fig 3. Mixing of M-Sand and Bitumen

2. Preparation of Mould, Casting and Drying

Rectangular moulds of dimension 20 cm X 10 cm X 10 cm were prepared. After obtaining the absolute molten mix, the molten mix then poured into the hollow moulds and left to dry for 24 hours. The de-moulding of bricks was done after 24 hours. The removed bricks then kept for further drying periods of 7 and 28 days. After attaining the drying period, the compressive strength test and water absorption test were carried out on the samples.

Fig 5. Mould of dimension (20 X 20 X 20) cm

Fig 6. Dried Plastic Brick

Tests and Results

Compressive Strength Test

Compressive strength is the resistance of any material to break under a compressive load and tested with the help of compression testing machine. For this test, the used compression testing machine had a capacity of 2000 kN and loaded at a constant rate of loading at 200kg/cm²/min as per Indian standard procedure. Total five number bricks from each of the different mix proportions are tested. The maximum compressive loads and any unusual failure of test samples are recorded. From the compressive loads, the compressive strength value is calculated with help of the following formula

Compressive Strength = (Maximum Load / Cross Sectional Area)

Table 4. 7 Days Compressive Strength of Bricks

Designation of Mix	Days	Amount of Plastic Used (%)	Amount of M-Sand Used (%)	Compressive Loads (kN)	Compressive Strength (N/mm²)
Mix_1	7	50	48	155	7.75
Mix_2	7	60	38	98	4.9
Mix_3	7	70	28	85.1	4.25
Mix_4	7	80	18	51	2.25

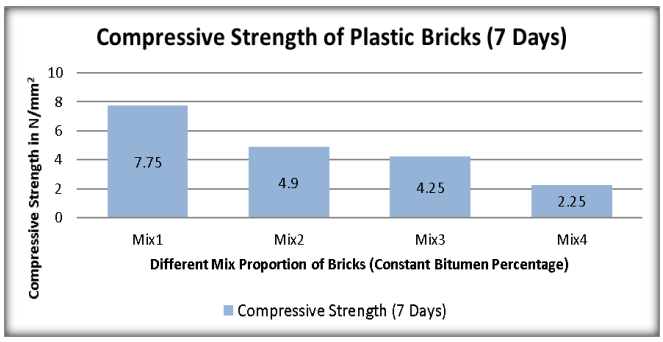
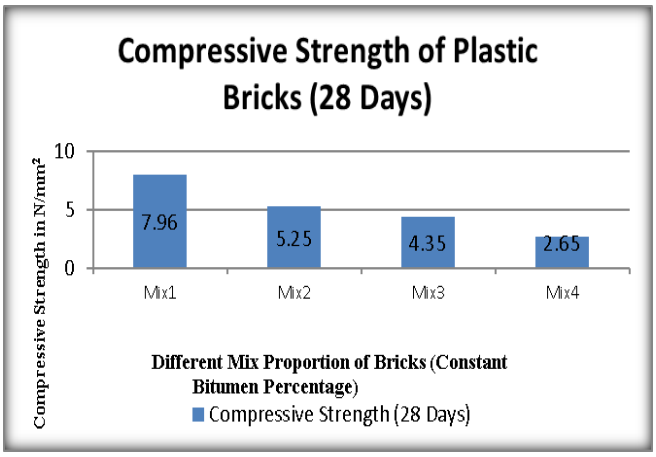


Table 5. 24 Days Compressive Strength of Bricks

Designation of Mix	Days	Amount of Plastic Used (%)	Amount of M-Sand Used (%)	Compressive Loads (kN)	Compressive Strength (N/mm^2)
Mix$_1$	28	50	48	159	7.96
Mix$_2$	28	60	38	105	5.25
Mix$_3$	28	70	28	87	4.35
Mix$_4$	28	80	18	53	2.65

Chart 2. 28 Days Compressive Strength of Bricks



Water Absorption

Water absorption test is conducted to check the durability property (such as degree of burning, quality and behaviour under weathering action etc.) of the bricks (IS: 3495, Part-II). The dried bricks with different mix proportion were subjected to the water absorption test. Initially, the weight of the dry brick samples was recorded as W1. Then the samples were immersed in the clean water at a temperature (27+2)OC for 24 hours. Finally the samples were taken out of the water, subsequently wiped clean with damp cloths to remove the surface water. The final weight of brick samples was then recorded as W2. The percentage of water absorption (by mass) of the brick samples was calculated with the following formula.

Water Absorption= [(W2- W1) / W1] X 100

Mix Designations	Plastic Bricks			Conventional Clay Bricks		
	Dry Weight of Bricks (W1) kg	*Weight of Bricks after 24 hours in the water (W2) kg*	*Water Absorption in %*	*Dry Weight of Bricks (W_1) kg*	*Weight of Bricks after 24 hours in the water (W_2) kg*	*Water Absorption in %*
Mix1	2.95	2.95	Nil	3.14	3.65	16.24 %
Mix2	2.72	2.72	Nil			
Mix3	2.325	2.325	Nil			
Mix4	2.17	2.17	Nil			

Conclusions

Even before obtaining any of the experimental outcomes, we can easily pronounce that the overall idea of producing plastic bricks is an environment-friendly decision. Not only will it be an eco-friendly material but it will also be an economical building material and will offer a great plastic waste management solution.

Though plastic brick has some great benefits but to be used as a building material it has to qualify some important structural properties. Now, based on the experimental investigations carried out on bricks made out of plastic, M-Sand, and bitumen, the following inferences are drawn.

- ✓ As the plastic percentage in a brick increases, the weight of the brick significantly reduces. This eventually will have a positive impact on

transportation cost. The average weight of conventional clay brick is 3.5 kg, whereas bricks made out of plastic percentages 50, 60, 70, 80 have average weights as 2.95 kg, 2.72 kg, 2.325 kg and 2.17 kg respectively.

- ✓ In case of both 7 and 28 days, the highest compressive strength is noticed in the bricks with 50% of plastic and 48% of M-Sand. As the plastic percentage increases, the bricks lose its compressive strength drastically.
- ✓ From the water absorption test, it is observed that the water absorption is nil for all of the different mix proportions. This indicates that these bricks are more susceptible and durable in nature.

Henceforth, it can be concluded that bricks made out of PET bottles, M-Sand and bitumen is eco-friendly and lightweight in nature. Furthermore, with enhanced compressive strength and reduced weight and water absorption, these bricks already have some superior results when compared to the conventional clay bricks

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