

“Mechanical Properties of Pavement Tiles Manufactured from Waste Plastic and River Sand”

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Abstract- One of the main environmental issues that need quick and ongoing solutions is plastic trash. Either recycling or product conversion is required for these wastes. A side from this, the construction sector is expanding at a rapid pace due to the strong demand for building supplies. The goal of this thesis project is to investigate the mechanical characteristics of pavement tiles used in construction that are made from leftover plastic and river sand. This study is important because it will reduce plastic waste, and if it is successfully translated into industrial production, it will benefit producers and the local community in many ways. It can also reduce environmental pollution and its effects on the environment and treatment costs. Preparing (collecting) raw materials, melting plastic waste, combining molten plastic with sieved river sand, and molding are all processes in the production process. Three process variables' individual and combined effects on tiles' compressive strength and water absorption were examined and addressed. In order to get the best compressive strength—13.12 Mpa in this thesis work, a new ratio of river sand to waste plastic was utilized. This is significantly higher than the traditional one, which is concrete tile. The water absorption of plastic tiles is 0.17% and the maximum water absorption of conventional concrete tile is 0.5% so the plastic tile is 194% less water absorbent than the concrete tiles which makes it recommendable for out-door services like pedestrian roads, parking areas etc. In the presence of reinforcing river sand, high density polyethylene (HDPE), and polyethylene terephthalate (PETE or PET), plastic wastes may be utilized to produce tiles because the necessary qualities are within the often encountered range. In this instance, plastic waste is utilized for binding purposes and may eventually replace cement in the manufacturing of composite pavement tiles. The ideal ratio is 1:2, which implies that one part waste plastic and two parts river sand are used to make pavement tiles.

Key words: -

Waste Plastic, High density polyethylene (HDPE), Manufactured Pavement tile, Mechanical Properties.

INTRODUCTION

Plastic wastes from used plastic products are one of recent environmental concerns that require vital solution. Plastic products are used almost everywhere on the earth. There are different types of plastics, the common one are thermoplastics and thermo set plastics. Thermo set plastics cannot be re-molded after ones made. But thermo plastics can be re-shaped and reprocessed many times into different shapes upon the application of heat. Polyethylene is one of thermoplastics. Based on density, polyethylene is categorized into low density polyethylene (LDPE) and high density polyethylene (HDPE). This thesis work is considered high density polyethylene. HDPE is tougher and stiffer than LDPE and is always milky white in color, even when very thin. High density polyethylene is used in many applications such as bags and industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, cans, crates, dust bins, and other household articles. The waste plastics alone or blended with other materials can be used in production of various profiles such as pavement blocks, roof tiles, floor tiles, wall tiles, draining canal, boutique shopping toys, park benches, fences, poles and the like based on the proportion of raw materials and the required properties of the final products. This study focuses mechanical properties of pavement tile manufactured from wastes plastic and river sand in construction applications of Production of tiles from such materials may have various advantages.

Objectives of the Study

The objective of this study is to investigate the mechanical properties of pavement tiles manufactured from waste plastic and river sand.

LITERATURE REVIEW

Younis M. Alshkane, et.al (2017) Today waste plastic bottles are spread widely throughout our world especially in Kurdistan, an autonomous region in Iraq. These waste products cause many environmental problems and at the same time some soils are weak and need reinforcement using cheap materials such as Polyethylene terephthalate (PET) waste plastic bottle. Use of waste plastic bottles as a reinforcement of soil is highly recommended to reduce the amounts of plastic waste, which creates a disposal problem. In this study an attempt was made to use plastic fibres produced from waste bottles to reinforce sandy soil.

Hejazi, S.M., Sheikhzadeh, M., Abtahi, S.M. and Zadhoush, A., 2012. A simple review of soil reinforcement by using natural

and synthetic fibers. *Construction and building materials*, 30, pp.100-116

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Abdelhamed Ganaw et al. (2018) It is well known to all of us that water plastic bottles waste has become a major problem to the environment. At the same time, incorporating the fibres in concrete like polypropylene is advantageous as they improve its properties. Nowadays self-compacting concrete (SCC) has become very common in casting concrete due to its high flow properties and attained the required strength.

Bhatia et al. (2019) highlighted the significant role of material composition in paving block performance. Their research showed that increasing plastic content reduced water absorption and improved both compressive and tensile strengths but at the expense of workability and long-term durability.

Research by Saïfoullah et al. (2020) in Cameroon examined varying sand-to-plastic ratios, revealing that optimal ratios minimized water absorption while maximizing compressive strength. These findings emphasized the need for precise control over material composition to achieve desired mechanical properties.

Ndepete et al. (2022) investigated the valorization of plastic waste in paving block production, highlighting a reduction in water absorption and an initial increase in compressive strength with higher plastic content. However, beyond a certain threshold, mechanical performance declined. A similar trend was observed in tensile strength, underlining the complex interplay between plastic content and overall material properties.

Guy Oyéniran Adeoti et.al (2025) This study investigates the enhancement of mechanical and physical properties of paving stones manufactured from plastic waste, targeting potential applications as road surface materials. Initially, paving stones were produced using an artisanal method with varying plastic content ranging from 20% to 40% to identify the optimal plastic-to-sand ratio. The results indicated that a plastic content of 25% provided the best performance, achieving compressive and tensile strengths of 4.85 MPa and 1.38 MPa, respectively. In the subsequent phase, polyethylene terephthalate (PET) fibers derived from recycled plastic bottles were introduced in proportions of 0.5%,

1%, 1.5%, and 2% (relative to sand weight).

MATERIALS AND METHODS

River Sand- Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand is typically made up of Quartz (SiO_2). It can in fact be composed of almost any mineral or combination of minerals or even sand sized fragments of rocks. The source rock and weathering and transportation history of sand usually results in a particle size distribution that can be characteristic of a sample. Sands from these different sources are washed and taken by the rain water and deposited alongside of rivers.

Fig. no. River Sand

Plastic Wastes

Plastic wastes used were mainly from packaging and other elements with a basis of High Density Polyethylene (HDPE). These plastic wastes were collected from waste disposal areas of Addis Ababa city. HDPE plastic waste was isolated



from other plastic wastes by their codes on the plastic products.



Fig. no. Plastic Collection

Preparation of Materials

In this research, the component manufactured was made from the waste plastic. Following are the steps involved in its manufacturing:

- (i) Plastic Collection (ii) Manual Sorting (iii) Washing (iv) Shredding

Making of the Mold

To give the molten plastic their final shape of the tiles, molds were made. This was manufactured by welding MS plates together. Along with it, a hammer was manufactured to apply vertical forces and compress the molten plastic and sand to make it compact.



Fig. no. Proposed Shape of Molds:

Melting:

Next the collected waste plastic is cleaned with water and dried to remove the water present in it after this the plastics are burned out by using stones and firewood. The stones are arranged to hold the drum and the firewood is placed in the gap between the stones and it is ignited. The drum is placed over the above setup and it is heated to remove the moisture present in it. Then the plastic is added to the drum one by one and the river sand is added to the plastic when it turns into hot liquid. The sand is added is mixed thoroughly using rod and trowel before it hardens. The mixture has a very short setting hence mixing process must not consume more time on the other hand the process should be complete. In case of sample or pavement tiles, coloring ingredients added (less than 10% of the total weight). These mixtures are then poured in to the mold and they are compacted using steel rod and surface is finished using trowel. Before placing the mixture into the mold, the sides of the mold are oiled to easy removal of sample or tiles.



Fig. no.6.9: Melting Process.

Methods

For checking the properties of HDPE and river sand made pavement tiles the following tests were done on the component:

Tests on Fine Aggregate

Aggregate passing through a No. 4 (4.75 μm) sieve and predominantly retain on a No. 200 (75 μm) sieve are classified as fine aggregate. Rivers sand is the most commonly used fine aggregate. In order to investigate its properties for the required application different test can be carried out but for this research purpose we conduct only two of Then this is sieve analysis and silt content of the fine aggregate. Tests conducted are discussed below.

(i)Sieve analysis (ii) Silt content of fine aggregate

Mix Design

Before proportioning can begin, it is important to understand the design restrictions. Often, production will be limited by the material availability (sand and chopped plastic.), environmental exposure conditions, as well as the strength requirements. The mixture designer needs to understand all these parameters in order to correctly create a mixture. To get the compressive strength of 13.12 MPA ratio of 1:2 the following mix design has been followed.

Table no. 6.1 Amount for Mix Design

Description	Amount (in kg)
Chopped waste plastic(HDPE)	0.749kg/0.0012m ³
Fine aggregate	1.498kg/0.0012m ³
Melting temperature	150°C - 180°C(This value is assumed based on other literature reviews or The plastic when it turns into hot liquid)

Compression Test:

In order to determine the loading capacity of polyethylene and sand composite and also to evaluate the effects of sand on the compressive strength of HDPE compressive test was carried out using hydraulic press machine tester and three samples per each percentage were tested and the average strength determined by averaging the three results.

Fig. no. Sample Cube

Fig. no. Compressive Strength Test

Compression test conducted as per ASTM C109/C109M-2016 Standard. For this, the standard specimen size is 50mm x 50mm x 50mm. The specimen is placed between compressive plates parallel to the surface. The specimen is then compressed on 40KN/min uniform rate. The maximum load is recorded along with stress-strain data. They are calculated using the following equations.

$$\text{Compressive strength} = \frac{\text{Maximum load}}{\text{Area of the specimen}}$$

$$= P/A \dots [1]$$

Where,

P –Maximum load (KN)

A- Area of specimen (mm²)

➤ Calculation (one sample)

1KN=1000 Newton

Load by machine =29.2KN

Load in Newton =29.2*1000 =29200N

Compressive strength= 29200N/50*50mm² = 29200N/2500mm²

N/mm² (11.68 Mpa)

Compressive strength for 7day

Compressive strength of 7 days is conducted on 1:0, 1:1, 1:2 and 1:3ratios of plastic tile and to done test for each 12 samples and to use the average.

1:0 (7 days)	1:1(7days)	1.:2(7days)	1:3(7days)
Sample (1)	Sample (1)	Sample (1)	Sample (1)
16.25mpa	11.28mpa	11.53mpa	12.19mpa
16.46 mpa	12.27 mpa	12.29 mpa	11.72 mpa
17.45 mpa	9.82 mpa	11.97 mpa	12.30 mpa
Sample 1 Average: -16.73mpa	Sample 1 Average:11.26	Sample 1 Average:11.93	Sample 1 Average: 12.70
Sample 2	Sample 2	Sample 2	Sample 2
15.32mpa	13.44mpa	12.60mpa	11.69 mpa
16.16mpa	12.31mpa	11.97mpa	11.43mpa
16.10mpa	11.63mpa	11.97mpa	11.43mpa
Sample 2 15.86mpa	Sample -2 12.46mpa	Sample -2 12.00mpa	Sample -2 11.83mpa
Sample 3	Sample 3	Sample 3	Sample 3
18.72 mpa	13.42 mpa	15.36 mpa	11.26 mpa
15.69 mpa	12.23 mpa	14.13 mpa	10.43 mpa
15.39 mpa	13.23	12.93 mpa	11.06
Sample 3 15.74 mpa	Sample 3 12.96 mpa	Sample 3 14.08 mpa	Sample 3 11.00 mpa
Total Average	Total Average	Total Average	Total Average

16.11 mpa	12.22 mpa	12.67 mpa	11.60 mpa
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Water Absorption Test

The strength of any building material will be drastically reduced if allowed to absorb excessive moisture. This is the major reason for restricting the application of the material without a protective measure such as DPC and DPM covering which are more resistant materials to weather the water absorption value will have a direct bearing on other performance characteristics such as mechanical resistance, the resistance to sudden temperature changes and frost resistance. It also gives us an idea of the degree of internal cohesion and compaction of the fired product.

The testing procedure involved the following:

- Cubes from each mix ratio were randomly selected.
- The cubes were dried in an oven for 24 hours at 60° C according to ASTM standard D2216 to ensure that all the water was removed.
- The dried cubes were weighed and recorded as M1.



Fig. no. Weighing the Dried Cube

- Then the cubes were immersed in water for 24 hours.



Fig. no. Immersing the Dried Cube in to Water for 24hrs

- Their weights were measured accurately and noted as M2.

Then the formula below was used to obtain the results

$$\frac{(M2-M1)}{M1} \times 100$$

Where: **M1**= the mass of the dry sample, **M2** = the mass of the wet sample.

The average absorption of water of the sample was determined by the arithmetic average of the individual results, and results must be rounded off to a single decimal place.

Shape of the tile and its production process

There are different parameters for the selection of tile shape this are: -

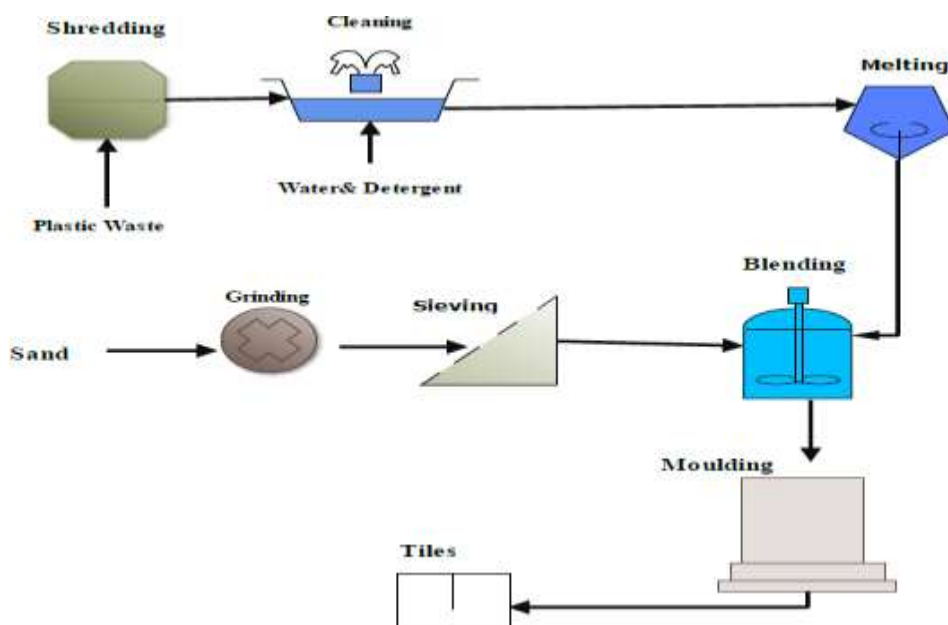
- ✓ Workability
- ✓ Aesthetic value
- ✓ Compatibility and functionality
- ✓ Strength
- ✓ Etc...

Based on the above criteria's the following sample is suitable for this research purpose, the size of the tile is 20cmx20cmx3cm.



Fig.no. Proposed Shape of the Tiles

➤ The Main Process of Pavement Tiles Production



RESULTS AND DISCUSSIONS

Test Procedure of Fineness Modulus of Sand

Take the sieves and arranged them in descending order with the largest sieve on top.

If mechanical shaker is using, then put the ordered sieves in position and pours the sample in the top sieve and then closes it with sieve plate. Then switch on the machine and shaking of sieved should be done at least 5 minutes.

If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outward, vertically and horizontally. After some time shake the 3rd and 4th sieves and finally last sieves. After sieving, record the sample weights retained on each sieve.

Let us say the dry weight of sample 1000gm after sieve analysis the values appeared are tabulated below.

Table 4.1: Calculation of Fineness Modulus of Sand

Sieve size	Weight retained(g)	Cumulative weight retained(g)	Cumulative percentage weight retained	Percentage passing Weight
10mm	0	0	0	100
4.75mm	21	21	2.16	97.84
2.36mm	88	109	11.3	88.7
1.18mm	123	232	23.48	76.52
600µm	158	390	39.47	60.53
300µm	436	826	83.6	16.4
150µm	140	966	97.87	2.13
Pan	22	988	100	0
Total cumulative			257.88	

Fineness Modulus = cumulative % weight retained / 100

= 257.88/100

= **2.5788**

Values of Fineness Modulus of Sand

Fineness modulus of fine aggregate varies from 2 to 3.5mm. Fine aggregate having fineness modulus more than 3.2 should not considered as fine aggregate. Various values of fineness modulus for different sands are listed below

Table : Fineness Modulus Range

Type of sand	Fineness modulus range
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Conclusion: -Note the fineness modules (FM) of the fine aggregate shall not be less than 2.0, and the test result is 2.58 so it is achieving the specific requirement.

A. Silt Content

Sand used for construction should be clean, free from dust, loam, clay & vegetable matter. If there is too much silt the aggregate will have less adhesive property with cement resulting in weaker bond strength with a probability and it is

assumed that this works for plastic tiles. Moreover, it decreases workability by absorbing water.

The test result of silt Content is to done in laboratory is to use 1.5m cylinder cube and to add water 75% of the cylinder and finally 3 % add in to the cylinder.

Silt content: - $\% \text{ SLIT CONTENT} = (M2-M1)/M1 \times 100\%$

Table : Silt Content Test Result

Sample	M1	M2	%Silt content
1	300	284	5.3
2	300	283.1	5.63
Average			5.46%

Investigation on Properties of Manufactured Pavement Tile

In order to decide the best ratio several aspects to be considered because plastic tiles have different results from different perspectives the followings are points to be considered for selecting the best ratio: -

Strength of the Material

Compressive strength of the tile is conducted as per ASTM C109/C109M-2016 to different trials. For comparison purpose and quality check, four types of plastic and sand mixing ratio is tested the ratio used to conduct the test are listed as follows i.e. 1:0, 1:1, 1:2 and 1:3 (See Chart 1 & 2). Based on strength achievement the sampling process is classified in to two phases this are 7 days' test result and 28 days' test result. The 7 days and 28 days' compressive test result purpose is to compare the standard and to check the difference between the results 7 days up to 28 days.

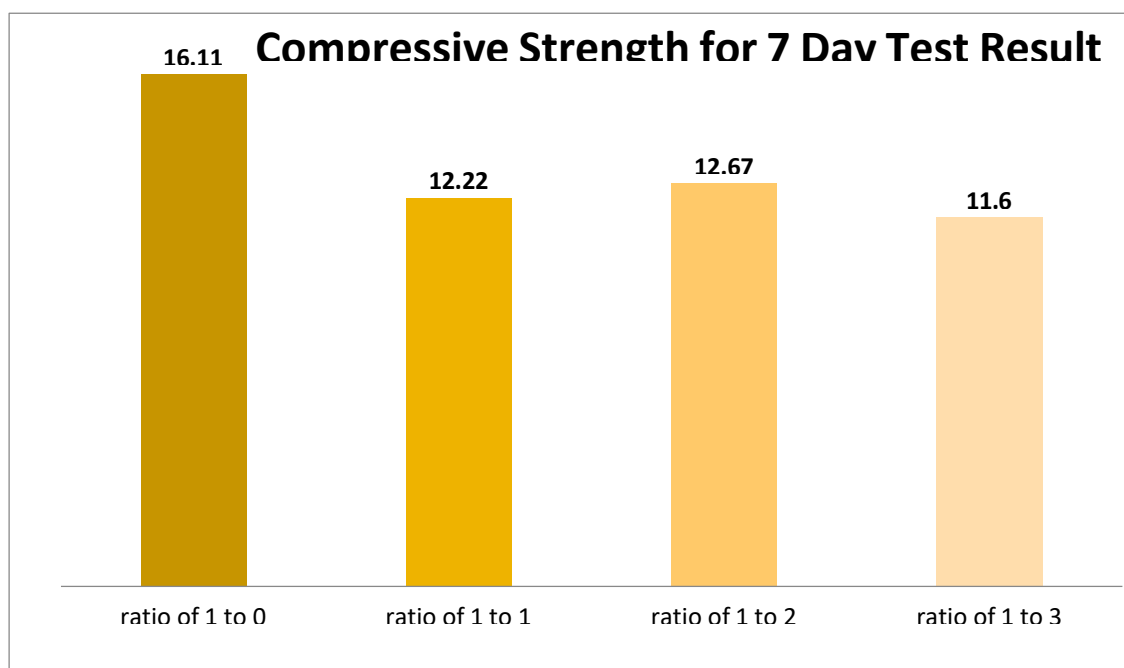
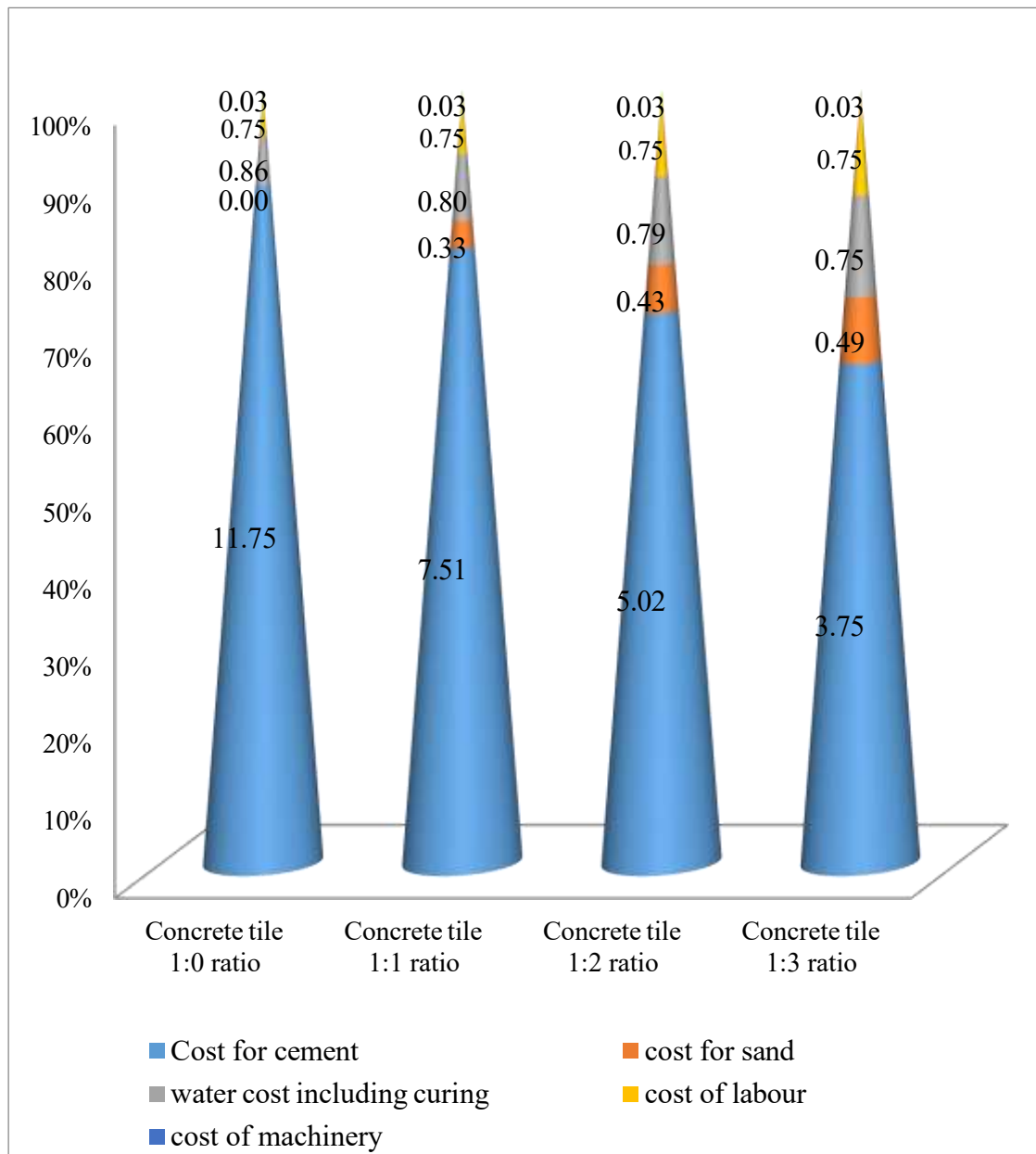


Fig Compressive Strength of Plastic and Sand Samples for 7 days Test Result

Cost Comparison Analysis

The direct material cost needed for the production of this specific type of tile from plastic and concrete is illustrated in



the following charts.

Fig. : Direct Material Cost for Concrete Tiles

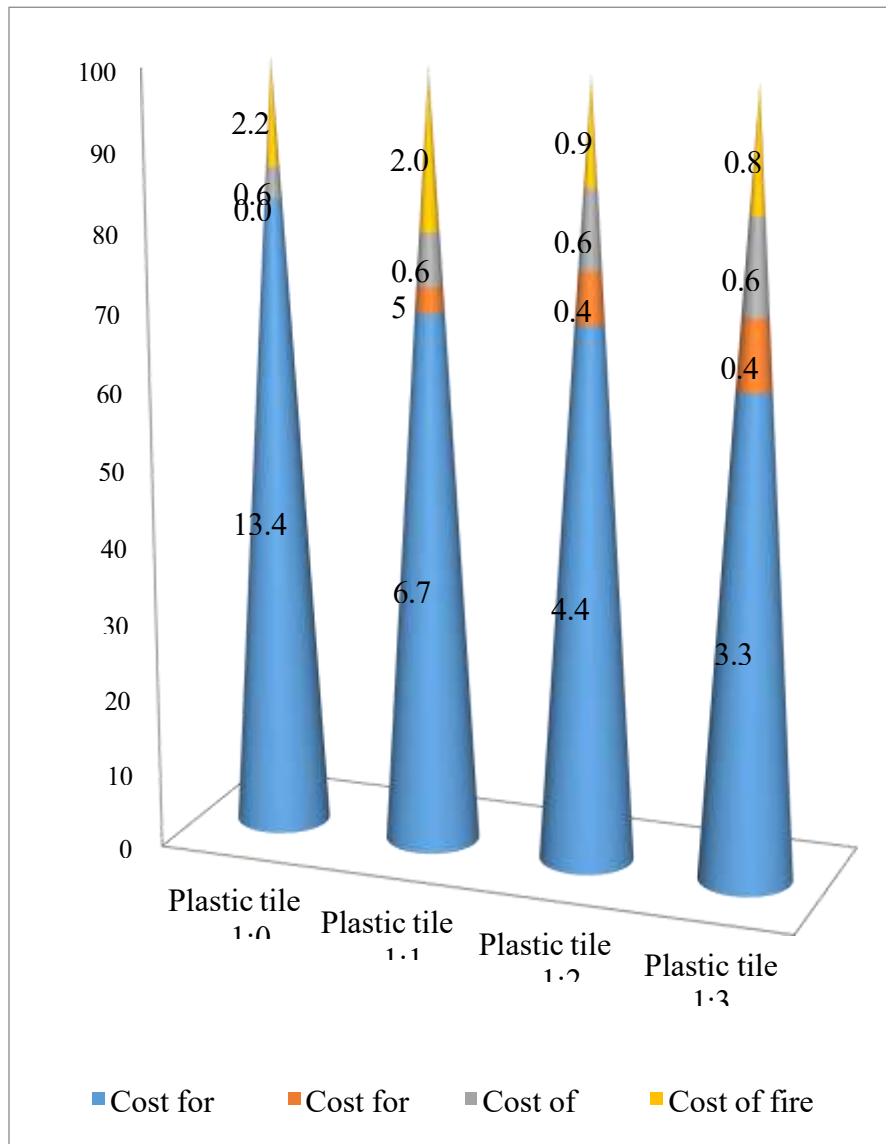


Fig. Direct Material Cost for Plastic and Sand Tiles

From the above chart it is concluded that the total direct cost for the production of 1:2 ratio mix ratio tile is 3.90 Rs approximately it costs 3.9 Rs for the production, on the other hand the direct cost of concrete tile with the same ratio is 4.25 Rs approximately 4.30 Rs.

Note: this price is not including coloring ingredients.

Water Absorption

A standard water absorption test was performed according to British standards. It involved immersing three samples (that offers the highest compressive strength) in water for a period of 24 hours after weighing them with a weighing balance for dry weight determination. Therefore, since these tiles have 0.17% water absorption rate, they can convincingly be used as floor finish materials, because from the result of water absorption test, we conclude that the ability of the tile to resist water absorption is in agreement with British standards which is 0.5% maximum for floor tiles.

Table : Time Consumption for Production

TIME CONSUMPTION FOR PRODUCTION		
	PLASTIC TILE	CONCRETE TILE
Chopping the plastic(1kg)	2min	0.00min
Weighing the ingredients	30sec	30sec
Melting the plastic(1kg)	5min	0.00min
Mixing and molding	5-7min	5min
Compacting	1.00min	1.5min
Curing	0.00min	7days
Total time consumption	14.5min	7 days and 7min

Conclusions

The general objective of this study is to analyze the property of pavement tile by fully replacing cement with recycled waste plastic for production of plastic tile.

The results of the replacements were compared with the results of the control mix and the following conclusions are drawn and recommendations are forwarded:

Conclusion

a) The replacement of cement with recycled HDPE decreased the compressive strength test result of the concrete mix when compared with the control mix. As the percentage replacement of HDPE increased the compressive strength test result is correspondingly decreased so that for this research purpose the optimum ratio of the mix design is 1:2 because it has maximum compressive strength numerically it is 13.12mpa.

Therefore, pavement tiles produced from river sand and HDPE plastic waste as binding Agent has better compressive strength which fulfills the expected standard.

b) Tiles produced by fully replacing cement with recycled HDPE have more pleasant aesthetics than the one produced without replacement. The test result of total water absorption and surface water absorption of fully replaced specimen are better than that of the control mix. The result revealed that tile produced by full replacement of cement with recycled HDPE satisfied the requirements as per the standard accordingly; it can be used for different purposes such as floors, counter tops, etc.

c) Economically, the tiles made using waste plastics are affordable (3.9 $\approx$ 3.95 RS per pieces) compared to (4.25 Rs per pieces) for Concrete tiles available commercially and the production process is cheap since it does not involve more expensive industrial equipment. Wastes plastics and sand are the major materials that are used to manufacture of these tiles.

- d)** What makes tiles made from plastic waste special is that, it is less breakable, requires few time for aging (1-2 days) after production, it has higher compressive strength and expected to have better water resistance. Generally, with its minimum thickness to weight ratio, it gives comparable physical and mechanical properties to conventional tiles.
- e)** Tiles made from waste plastic are light weight and easy to handle because of its plastic nature this tiles cannot be break if falls from hand. When compared to the conventional methods that uses cement, utilization of HDPE waste also helps to produce 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.
- f)** The fines modulus of the sand (FM) is 2.58 and the silt content of sand after washing it is 5.46% so it is recommendable characteristics fine aggregate for the production of quality plastic tile.
- g)** This study can minimize the risk of plastic wastes to the environment so it is preferable to use plastic tiles than concrete tiles.
- h)** Plastic tiles are likely less water absorbent than concrete tile due to this nature it is recommended to use this tiles for outdoor pavement as well as to floor pavements inside the building.
- i)** The current waste management system of the municipal is not bad but they have to work with entrepreneurs to recycle waste in effective and efficient way.

Generally based on the above observation it is possible to use plastic in the production of pavement tile, and it is having the bonding property. Considering the specific use plastic is used in manufacturing of tiles and construction of; pedestrians walk way, parking areas, balcony and terrace floor covering purpose, etc. It is the effective and efficient way to disposal plastic wastes and it is a best solution to the environmental and ecological challenges associated with the use of plastics.

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