



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH


IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 5, May 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512

 9940 572 462

 6381 907 438

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An Experimental Study on Plastic Paver Tiles

Dr. G. Balamurugan¹, I. Mohammed Rafi²

Professor, Department of Civil Engineering, P.A College of Engineering and Technology, Pollachi, Tamil Nadu, India¹

Assistant Professor, Department of Civil Engineering, P.A College of Engineering and Technology, Pollachi,
Tamil Nadu, India²

ABSTRACT: Plastic is one of the daily use as well as a hazardous material. Quarry fine dust also a waste material from the M-sand industry. To utilize these two waste materials and to save the environment this experimental study was carried out. PET bottle was heated and quarry dust was added at its molten stage with a little quantity of bitumen to make plastic paver tiles. Different mix proportions from 40% by weight of quarry fine dust to 65 % at the step of increment of 5%. Mainly flexural strength of paver tiles of size 150 x 150 x 25 mm was determined by conducting a flexure test with a central point load at normal temperature, elevated temperature and after Thermoshock. From test results, it is observed that PET bottles added 55% by weight of quarry dust gives higher compressive strength and less loss in weight due to Thermal and Thermoshock. It is concluded that plastic paver tiles manufactured using waste PET and Quarry fine dust reduces pollution results green environment.

KEYWORDS: Bitumen, Fine Quarry dust, PET bottle, Flexural Strength.

I. INTRODUCTION

Plastic is a non-biodegradable substance that 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 every 10 years. Plastic usage is large in consumption and one of the largest plastic wastes is polyethylene terephthalate (PET). To safeguard the environment, many efforts are being made for the recycling of different types of plastic wastes to utilize them in the production of various construction materials. PET bottles are everywhere in today's lifestyle. It is used for water, soft drinks, motor oil, cooking oil, medicine, shampoo, milk and all kinds of consumer goods. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material.

Plastic in a different form is found, which is toxic. It is commonly collected in both urban and rural areas. It creates stagnation of water and associated hygiene problems PET bottle hazard to the environment. PET bottles can be reused productively in construction materials. Though PET bottle is a very useful material that is flexible, robust and rigid they become waste after their use and they pollute the air and land. Recycling is processing used waste materials into new products to prevent waste of potentially useful materials. In India, approximately 40 million tons of municipal solid waste is generated annually, with evaluated increasing at a rate of 1.5 to 2 % every year. Therefore, the need for proper disposal, and if possible, use of these wastes in their recycled form arises. Fine quarry waste (below 75 microns) is the by-product from the manufacturing sand industry dumped outside the quarry which creates air pollution. Hence these wastes are effectively utilized.

II. LITERATURE SURVEY

G Mirthula et al. [1] carried out an investigation on plastic soil bricks using plastic and laterite soil. 60% PET bottle by weight of laterite soil was heated at 255° C and at the molten stage laterite soil is added. For binding, the material 2% of bitumen also added to the mixture. The molten liquid mix is poured into a mould of 23 x 10 x 8 cm and compacted. The compressive strength of Plastic soil brick is 11.10 MPa which is greater than the requirement of third class bricks 3.19 MPa. As the percentage of plastic increases, the compressive strength of the brick decreases. Ponraj Kumar P et al. [2] carried out an investigation on plastic waste as a replacement for fine aggregate and manufacturing of bricks with high-density polyethylene (HDPE) and polyethylene (PE) plastic bottles and bags. To predict the strongest specimen, 0 to 20 percent of replacement proportion was done by 5, 10, 15 and 20 percentages; plastic is partially replaced as fine aggregate in 14 days of curing. These results increase the strength of the structure and the weight reduction of bricks were tested for compressive strength and water absorption test. The test results show that the partial replacement of



natural sand by crushed waste plastics at the levels of 5 to 10 percentages has good effects on the compressive strength of the bricks.

N.Siva et al. [3] carried out an investigation on bricks in replacement of soil by waste plastics. Plastic bags are melt under 170°C to 180°C until the entire plastic content required for making bricks of one mix proportion is added into it. The size of the mould is 190 × 90 × 90 mm. The mould was assembled and placed on the base plate. Compressive strength, fire resistance test, water absorption test, ductility test, binding test, shape and size test, hardness test, crushing strength test, and soundness test is carried out as per Indian standard codal provisions. They concluded that increases the compressive strength when increasing the plastic content with decreasing the soil. Use of plastic soil bricks, the water absorption presence of alkalis was highly reduced. These bricks are highly ductility so they can be used in earthquake-resisting construction material. Aiswaria K et al. [4] carried out manufacturing and experimental investigation of bricks with plastic and M-sand. Mould 19 x 9 x 9 cm is used for manufacturing bricks. Various experiments are carried out to determine the properties such as compressive strength, durability, thermal resistance, water absorption, etc. Brick made with a 1:4 ratio of plastic to M-sand gives a compressive strength of 18.13 MPa, which is greater than the requirement for a first-class brick. It can be used as a permanent structure in the construction of walls. The water absorption for the brick is almost negligible. It is 98.2 % less compared to burnt clay bricks.

Dinesh S et al. [5] investigated the utilization of waste plastic in the manufacturing of bricks and paver blocks, ferric oxide and river sand. The mix proportion was in the ratio of 1:2, 1:3, 1:4, 1:5, 1:6 were used. Compressive test, Water absorption test, Efflorescence test, Hardness test, Fire resistance test are carried out as per Indian standard provisions. The compressive strength of the plastic paver block is higher when compared to the ordinary paver block. The cost of a paver block is reduced when compared to that of a concrete paver block. Though the compressive strength is low when compared to the concrete paver block. N.Thirugnanasambantham et al. [6] carried out manufacturing and testing of plastic sand bricks, size of specimen 230 x 100 x 75mm. The proportions of materials like fly ash 60%, cement 10%, fine aggregate 30% with a w/c ratio of 0.36. The proportions of plastic and sand are 1:2 to 1:6. From test results, they concluded that use of plastic sand bricks, the water absorption presence of alkalis was highly reduced. The Plastic sand bricks possess more advantages which include cost efficiency, Removal of waste products thus abolishing the land requirement problem for dumping plastic, reduction in the emission of greenhouse gases by the conversion of flue gases into synthetic oil, etc. Rajarapu Bhaushaiah et al. [7] carried out a study on plastic bricks made from waste plastic. The mould of size 19 x 9 x 9 cm is used. Water absorption of plastic sand brick is zero percent. The compressive strength of plastic sand brick is 5.6 MPa at the compressive load of plastic sand bricks is useful for the construction industry when we compare fly ash bricks and third-class clay bricks. Plastic bricks can help reduce environmental pollution, thereby making the environment clean and healthy.

From this literature review, it is clear that plastic tiles may be utilized. This experimental study illustrates fine quarry dust may an alternate or replacement material for sand that will keep the environment clean. This project helps us to study the performance of PET bottles, fine quarry dust, bitumen and mechanical properties of paver tiles in various proportions and findings out the strength. Due to the rapid usage of cement and aggregate for manufacturing paver tiles, there is depletion in resources. Hence an alternate should be found in the future for cement and aggregate. Nowadays river sand is scarce and so mostly replaced by m-sand. Hence m-sand manufacturing in the quarry is at its peak. Fine quarry dust is a residual by-product obtained while washing the m-sand. There is a huge amount of Fine quarry dust is available. To make use of this Fine quarry dust and considering economic, environmental and technical reasons, it is used as fine aggregates in tiles.

III. MATERIALS AND PROPERTIES

Pet Bottle

Polyethylene Terephthalate (PET) is a general-purpose thermoplastic polymer that belongs to the polyester family of polymers. Polyester resins are known for their excellent combination of properties such as mechanical, thermal, chemical resistance as well as dimensional stability. PET is one of the most recycled thermoplastic and has number one as its recycling symbol. PET is highly flexible, colourless and semi-crystalline resin in its natural state. Depending upon how it is processed, it can be semi-rigid to rigid. It shows good dimensional stability, resistance to impact, moisture. Commercially available PET grades include un-reinforced to glass-reinforced, flame retardant and high flow materials for various engineering applications that typically require higher strength and or higher heat resistance. The additions of fillers like glass fibers, CNTs, etc. helps improve impact strength, surface finish, reduce warpage and several other benefits.

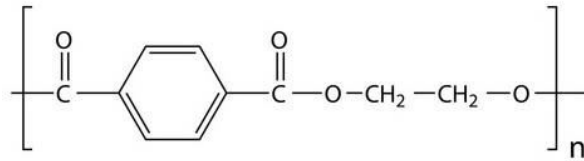


Fig. 1. Molecular Structure of Polyethylene Terephthalate PET Chemical Formula: (C₁₀H₈O₄)_n

Polyethylene Terephthalate is an excellent water and moisture barrier material. Plastic bottles made from PET are widely used for placing mineral water and carbonated soft drinks. Its high mechanical strength makes Polyethylene Terephthalate films ideal for use in tape applications. Non-oriented PET sheets can be thermoformed to make packaging trays and blisters. Its chemical inertness, together with other physical properties, has made it particularly suitable for food packaging applications.

Fine Quarry Dust

Quarry dust is the by-product of the stone-crushing process. In quarrying activities, the rock has been crushed into various sizes; during the process, the dust generated is called quarry dust and it is dumped as waste results creating air pollution. Fine quarry dust is the suspended particles washed out while washing quarry dust during the process of manufactured sand. There is a huge amount of Fine quarry dust is dumped at the m-sand production site. Therefore, quarry dust should be used in construction works, which will reduce the cost of construction and the construction material would be saved and the natural resources can be used properly. Most of the developing countries are under pressure to replace fine aggregate in concrete with an alternate material to some extent or totally without compromising the quality of concrete. Quarry dust has been used for different activities in the construction industry, such as building material, road development material, aggregates, bricks, and tiles manufacturing. The specific gravity of quarry dust is 2.62.

Bitumen

A black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation. It is used for road surfacing and roofing. For proper mixing of PET bottle and Fine quarry dust bitumen is added about 2 %. The various values of Bitumen obtained through the test are summarized, tabulated and presented in Table 1.

Table 1. Properties of bitumen

Properties	Value
Flash and Fire Point	65.66° C (Flash) 79.66° C (Fire)
Penetration value	20mm
Softening point	104°c
Ductility	6.3cm
viscosity	119sec

IV. EXPERIMENTAL INVESTIGATION

For the preparation of specimen weight batching was adopted. A total of six different ratios have arrived and the specimen was cast. The various mix proportions to make the mixture were worked out and presented in Table 2. The PET bottles were heated and at the melted state bitumen were added. Then fine quarry dust was added slowly and mixed thoroughly. At the instant the uniform mixture obtained, it is poured into the mould of size 150 x 150 x 25 mm to get the tile specimen. The entire specimen was then kept at room temperature for a day and then it was subjected to various tests. The test specimen was subjected to tests like the Hardness test, Moisture expansion test, Water absorption test, Modulus of Rupture test, thermal test and thermoshock test. The test results are tabulated and compared.

Table 2 Mix Proportions of plastic paver tiles

Specimen name	Plastic (Pet) % by weight of quarry dust	Pet quantity (gm)	Fine quarry dust (gm)	Bitumen (2%) (gm)
S1	40	320	800	16
S2	45	360	800	16
S3	50	400	800	16
S4	55	440	800	16
S5	60	480	800	16
S6	65	520	800	16

The surface of tiles is tested drawn upon by hand, using a sharp freshly-broken edge of the reference material applying a uniform effort such that at the end of the test, the edge of the tiles is intact. The procedure is repeated four times. After 4 times the scratch there is no impression on the tiles. The moisture expansion test is carried out eight hours since there is no expansion on the tiles. The water absorption for tile specimens is less than 1%.



Fig. 2. a) Materials and mould, b) PET bottle, c) Fine quarry dust, d) Bitumen, e) Mould, f) Tile Specimen

Modulus of Rupture

Flexural strength is a measure of the tensile strength of tiles. Flexural strength identifies the amount of stress and forces an unreinforced concrete slab, beam or other structure can withstand such that it resists any bending failures. Flexural strength is also known as bend strength or modulus of rupture or fracture strength. The single-point loading method is adopted. The load is evenly distributed on the tiles. The load-carrying capacity of the specimen is noted and tabulated in Table.3. For each test, three specimens (S1, S2 and S3) were tested.

Table 3. Ultimate Flexural load

% of PET	Ultimate Flexural Load (kN)								
	At normal temperature			After temperature effect			After thermoshock		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
40	1.44	1.52	1.60	1.52	1.44	1.52	1.52	1.44	1.44
45	1.60	1.68	1.68	1.60	1.60	1.68	1.60	1.52	1.68
50	1.76	1.68	1.76	1.60	1.68	1.68	1.60	1.60	1.68
55	1.76	1.84	1.84	1.76	1.76	1.84	1.76	1.76	1.76
60	1.68	1.68	1.68	1.60	1.60	1.76	1.60	1.52	1.76
65	1.68	1.60	1.68	1.68	1.52	1.68	1.68	1.44	1.60

Temperature Effect Test

The strength of tiles gets affected due to the increase in temperature. To find the change in strength, the tiles were kept at 100°C in an oven for 24 hours. Then it is immediately tested for flexure. The ultimate flexural load of the specimen was noted and tabulated in Table 3.

Thermoshock Test

Thermoshock testing exposes products to alternating low and high temperatures to accelerate failures caused by temperature cycles or thermal shocks during normal use. To find the change in strength, the tiles were kept at 100°C in an oven for 24 hours. Then it is taken out and immediately immersed in water and tested for an ultimate flexural load. The readings were noted and presented in Table 3.

V. RESULTS AND DISCUSSION

Hardness Test

It was observed that no impression was found out on the surface of tiles of all proportion of mixes indicates that the Plastic quarry dust Tiles are hard enough to bear the wear and tear.

Moisture Expansion Test

It was observed that no expansion in dimension was found out on the tiles of all proportion of mixes indicates that the Plastic quarry dust Tiles are not subjected to undergo deformation due to a hike in temperature of 100 C.

Water Absorption Test

It was observed that a very little percentage (less than 1) of water was observed if the specimen immersed in water. It was due to certain pores present in tiles and it is a negligible one. It indicates that the Plastic quarry dust Tiles are moisture absorption-free in nature.

Flexural Strength Test

The flexure test was carried out using the single-point loading method and from the ultimate load, the flexural strength was determined at normal temperature, elevated temperature of 100°C and due to Thermoshock. Flexure test was carried out and from ultimate load, flexural strength was determined and presented in Table 6.



Table 6. Flexural strength of plastic paver tiles

% of PET	Specimen	Flexural strength (MPa)					
		At normal temperature		After temperature effect		After Thermoshock	
		Flexural strength (MPa)	Mean Flexural strength (MPa)	Flexural strength (MPa)	Mean Flexural strength (MPa)	Flexural strength (MPa)	Mean Flexural strength (MPa)
40	S1	2.76	2.92	2.92	2.87	2.92	2.82
	S2	2.92		2.76		2.76	
	S3	3.07		2.92		2.76	
45	S1	3.07	3.17	3.07	3.12	3.07	3.07
	S2	3.23		3.07		2.92	
	S3	3.23		3.23		3.23	
50	S1	3.23	3.28	3.07	3.17	3.07	3.12
	S2	3.38		3.23		3.07	
	S3	3.23		3.23		3.23	
55	S1	3.38	3.48	3.38	3.43	3.38	3.38
	S2	3.53		3.38		3.38	
	S3	3.53		3.53		3.38	
60	S1	3.23	3.23	3.07	3.17	3.07	3.12
	S2	3.23		3.07		2.92	
	S3	3.23		3.38		3.38	
65	S1	3.23	3.17	3.23	3.12	3.23	3.02
	S2	3.07		2.92		2.76	
	S3	3.23		3.23		3.07	

Performance of Plastic Quarry Dust Tiles in Flexure due to Temperature effect

Flexure test was carried out on plastic quarry dust tiles at 100°C temperatures and from ultimate load flexural strength was calculated and presented in Table 6. From Table 6, it is observed that maximum flexural strength at elevated temperature say 100°C is obtained at 55% of PET added specimen. Loss in Flexural strength due to temperature effect was calculated and presented in Table 7. From Table 7, it is noted that the loss in flexural strength due to hike in temperature is less in 55% of PET added specimen and the value is only 1.44%. From this, it is noted that Plastic Quarry Dust Tiles withstand the temperature with a very little reduction in strength of negligible quantity.

Table 7. Loss in Flexural strength due to Temperature effect

% of PET	Flexural strength (MPa)		
	At normal temperature	After temperature effect	% of loss
40	2.92	2.87	1.71
45	3.17	3.12	1.58
50	3.28	3.17	3.35
55	3.48	3.43	1.44
60	3.23	3.17	1.86
65	3.17	3.12	1.58



Loss in Flexural strength due to Thermoshock effect was calculated and presented in Table 8. From Table 8, it is noted that the loss in flexural strength due to Thermoshock is less in 55% of PET added specimen and the value is 2.87%. From this, it is noted that plastic quarry dust tiles withstand the temperature with a very little reduction in strength of negligible quantity due to Thermoshock.

Table 8. Loss in Flexural strength after Thermoshock

% of PET	Flexural strength (MPa)		
	At normal temperature	After thermoshock effect	% of loss
40	2.92	2.82	3.42
45	3.17	3.07	3.15
50	3.28	3.12	4.88
55	3.48	3.38	2.87
60	3.23	3.12	3.41
65	3.17	3.02	4.73

A chart is prepared to compare the flexural strength of plastic paver tiles at normal temperature, Elevated temperature and after Thermoshock is presented as Figure 3.

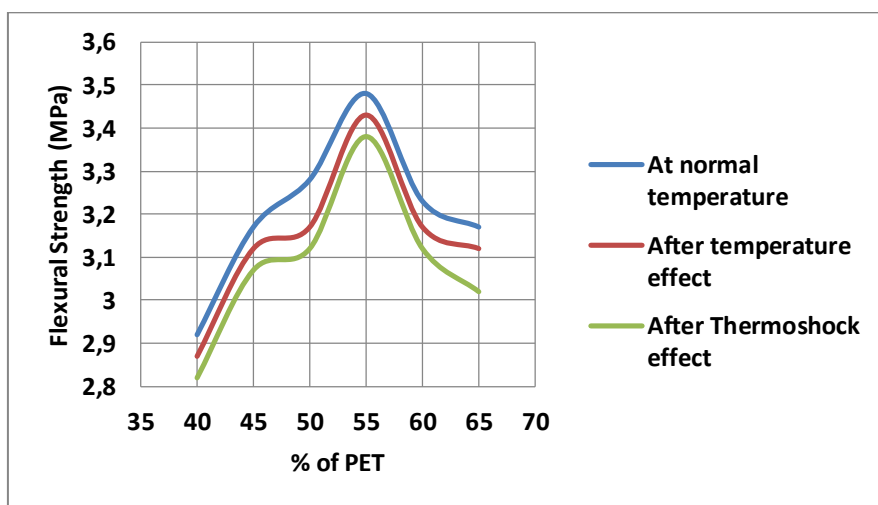


Fig. 3 Flexural strength of plastic paver tiles - comparison

From Figure 3, it is noted that the flexural strength due to Thermoshock for 55% of PET added specimen is higher than the flexural strength of other mix proportion of plastic tiles at normal temperature.

VI. CONCLUSION

The following conclusions were made from the experimental study:

- Plastic quarry dust Tiles are hard enough to bear the wear and tear.
- Plastic quarry dust Tiles are moisture absorption free in nature.
- Maximum flexural strength at high temperature say 100⁰ C is obtained at 55% of PET added specimen.
- Loss in flexural strength is only 1.44 % due to a hike in temperature in 55% of PET added specimen.
- Maximum flexural strength after Thermoshock is obtained at 55% of PET added specimen.
- Loss in flexural strength due to Thermoshock is less in 55% of PET added specimen and the value is 2.87.



These results give a clear conclusion that waste materials like fine quarry dust and PET bottles can be utilized in the production of Plastic quarry dust tiles with higher performance in the mix contain PET at 55 % by weight of quarry dust which leads to high reduction in land pollution.

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