CONSTRUCTIVE REUSE OF POLYMERS INTO PLASTIC PAVER BLOCKS

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Abstract

The need for the construction sector to be sustained by innovative technology targeted at conserving natural resources and protecting the environment cannot be overlooked. The use of plastic wastes in the production of paver blocks has both engineering and environmental implications. These manufactured paver blocks can be used in pavements, compounds, and other areas which require surfacing. The project is aimed at using plastic wastes as a replacement in place of cement, in the production of paver blocks. This will go a long way in solving part of our environmental and ecological problems resulting from the indiscriminate dumping of plastic wastes. An iron mesh is used as a reinforcement frame structure to give it additional strength. It is a unique method that has never been implemented before. Grades of Plastics such as LDPE, HDPE, and PET were mixed in fixed pre-thought proportions and melted at respective different melting temperatures in a closed system to produce plastic paver blocks by the open die molding method. By mixing these grades together with trial-and-error methods, it is observed that the manufactured plastic paver blocks are much more sustainable than concrete paver blocks. These plastic paver blocks have shown superior results in water absorption test, hardness test, oven test, furnace test over cement paver blocks. These plastic paver blocks have a very cheap mass production cost compared to concrete blocks. Hence, the project has shown more effective results than the traditional concrete paver blocks. This concept may provide a long-term sustainable solution to manage indiscriminate plastic wastes as well as produce durable plastic paver blocks at a relatively low cost.

***Keywords*:** Design, Manufacturing, Recycling plastic, Reinforced structure, Cheap mass production, Sustainable solution, Plastic waste.

1. Introduction

Paver block is one of the most flexible surface treatment options for outside walkway applications. These blocks are aesthetically pleasing, comfortable to walk on, extremely durable, and easy to maintain. The paver blocks are suitable for heavy work applications, able to support significant loads and resist shearing and braking forces. Paver blocks have interlocking characteristics which gives it great durability and strength. Plastic paver blocks are manufactured by using three types of plastic grades which are mixed in different combinations. The grades of plastics used are LDPE, HDPE, and PET. A reinforced iron framed structure is used. The reinforced structures are of two types, they are 2D reinforced iron framed structure and 3D reinforced iron framed structure.

Nomenclature

LDPE	Low-density polyethylene
HDPE	High-density polyethylene

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PET	Polyethylene terephthalate
ASTM	American society for testing and materials
UTM	Universal testing machine
W_1	Dry weight
W_2	Wet weight
F	Maximum load applied
A	Test specimen area
2D	Two dimensional
3D	Three dimensional

1.1 Problem Statement

- Plastic waste has been the problem for years and it is a major threat to the planet and oceans. One of the fastest growing environmental causes is plastic waste.
- Around 275 to 300 million tons of plastic waste is generated around the world each year, out of which 4.8 million to 12.7 million tons is dumped into water bodies.
- India alone generates around 26,000 tons of waste plastic per day, and around 9.46 million tons each year out of which 38 to 42% remains uncollected as per the environment ministry.
- As it cannot be disposed neither burnt completely it will impact the environment on a large scale. Plastic when disposed of on the ground reduces the ground water level as it does not degrade, causes landfills, human health issues and contributes to climate change.
- Accumulation of plastic in oceans such as non-biodegradable fishing nets, marine litter, fragments or microparticles of plastic causes a trap to aquatic life. Major form of marine litter comes from land.
- Plastic waste pollution can be the cause for natural disasters such as floods. It has to be recycled properly so that it can be at least reused and would cause less harm to the environment. Reduce the amount of waste plastic to get dumped in the environment which in turn will cause adverse effects on wildlife habitat and humans.

1.2 Objectives

- To reduce the impact of plastic waste on environment by reusing the waste plastic in innovative ways.
- Reusing the waste in plastic paver blocks can reduce the burden on the environment and determine the sustainability of waste plastic in the development of plastic paver blocks for construction and pavements.
- To assess the worth of the performance of plastic paver blocks to be used in pavements and other applicable areas like footpaths, roads, and other construction areas.
- To make an affordable plastic paver block in the view of a common person.
- To have the same or more strength and durability for plastic paver blocks compared to concrete.

2. Methodology

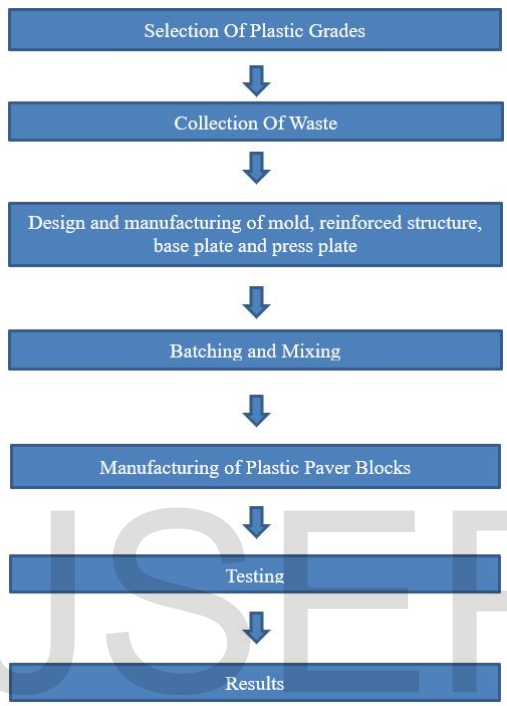

Fig. 1. Methodology flow chart

To begin with, we selected the type of grades of plastic depending on their physical and chemical properties like soft material, light weight material, high strength, resistance to heat, melting point etc. The waste plastic was collected from the plastic waste vendors and separated according to their grades. Then the process of mould designing and manufacturing was done mould design is done on CATIA V5 software with dimensions as 200*160*50 with the slant angle as 120°.The waste plastic is then dried and segregated and all the unwanted waste from the plastic is removed and then shredded into small pieces using a shredder machine. The two types of plastic grades are mixed in the ratio 1:1. The shredded plastic is put down into the plastic extrusion machine and within this process we place 3D reinforced iron mesh into the mould and then the melted plastic is poured into the mold. The melted plastic is pressed on the base plate using a press plate so that it hatches creating a frictional surface and also removes the air gaps. Brick is then kept in the normal water so that it does not shrink. Different types of tests are carried on the bricks and the results are obtained. The conclusion is derived based on results.

2.1 Procedure

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- Initially, preheat the plastic extrusion machine for at least 1 hour, by keeping the turning screw out of action.
- Meanwhile, get the plastic mixtures ready for the melting process, mix two grades of shredded plastic according to the combination in the ratio of 1:1. When the plastic extrusion machine is heated, transfer the mixture slowly and steadily into the barrel through the feed hopper keeping the turning screw in action.
- After transferring the mixture to the barrel, completely switch off the turning screw; and keep the mixture in the barrel for melting.
- For 2D Iron Framed Reinforcement: - Meanwhile, apply oil/grease to the mold and place the 2D reinforced Iron Framed structure in the mold accordingly and place it above the base plate; place this whole setup below the shaping die.
- For 3D Iron Framed Reinforcement: - Meanwhile, apply oil/grease to the mold and place the 3D reinforced Iron Framed structure in the mold accordingly and place it above the base plate; place this whole setup below the shaping die.
- Note- Feed enough Material through the Hooper that you will be able to mold 2D and 3D reinforced plastic paver blocks at the same time of same material
- As soon as you see some melted material extruded through the shaping die, turn on the turning screw so that melted material is extruded and transferred to the mold with the necessary reinforced Iron Framed structure (2D and 3D).
- When the mold is filled with melted material, turn off the turning screw after removing the excess material from the barrel.
- Meanwhile, place the press plate over the mold, and apply pressure vertically downwards and keep on stabbing it with pointed equipment (example. screwdriver), so that there are no air gaps in the block.
- Keep the Block in the same position for Cooling at atmospheric temperature after 10-15 mins
- Remove the block from the mold and immerse the block into the water tub till the Plastic Block cools down completely.
- After the paver is Completely cooled down clean the plastic paver block for excess oil on it so that it does not hamper any results for testing
- After cleaning the plastic paver block give numbering to the plastic paver block as mentioned above in the section manufacturing of plastic paver block, using spray paint or oil paint.
- Repeat the above procedure for all the other combinations of plastic blocks.

Fig. 2. Transferring molten plastic to mold and Stabbing to remove air gaps.

Fig. 3. Interlocking arrangement of plastic paver block.

2.2 Testing

2.1.1 Water absorption test

A water Absorption test is carried on the manufactured Plastic paver block to know the amount/Percentage of water absorbed by the particular plastic paver block. In this test, initially, a plastic paver block is cleaned to remove any extra material such as oil, water, dust and then weighed which is considered as a Dry Weight (W_1) of the particular Plastic paver block. Then these weighted plastic paver blocks are immersed in the freshwater for 24 hours. After 24 hours the plastic paver block is taken out and wiped with a cloth. These plastic paver blocks are then weighed in the wet condition called Wet Weight (W_2). Now the water absorbed by the brick is calculated by taking the difference between these two weights calculating the percentage of water absorbed. The Quality is then decided by the amount of water absorbed by the brick; a brick with great quality will absorb less amount of water.

FORMULA-

Percentage of water absorbed = $\{[(W_2-W_1)/W_1] *100\}$

Specimen	Dry weight	Wet weight	Weight difference (gm)	Percentage water	Volume (mm^3)	Percentage volume

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	(gm)	(gm)		absorbed		expansion
LDPE	1124	1127	3	0.0997	1110144	-0.8067
HDPE	1145	1151	6	0.0994	1180904	2.2392
PET (1)	1132	1137	5	0.0995	1170609	2.1729
PET (2)	1562	1586	24	0.0984	1264394	-2.92761
LDPE + HDPE (1)	1235	1238	3	0.0997	1159340	0.9670
LDPE + HDPE (2)	1184	1185	1	0.0999	1159340	1.3571
LDPE + PET (1)	1260	1290	30	0.0976	1212199	1.7374
LDPE + PET (2)	1399	1440	1	0.0971	1260990	-5.5571
HDPE + PET	1092	1098	6	0.0994	1147675	2.7006
LDPE	1080	1082	2	0.0998	1051519	-3.6812
HDPE	1057	1061	4	0.0996	1170668	0.7706
PET	1138	1154	16	0.0986	1157097	3.6321
LDPE + HDPE	1177	1178	1	0.0999	1198146	3.8013
LDPE + PET	1318	1324	6	0.0995	1217282	-0.7097
HDPE + PET	1153	1157	4	0.0996	1185095	7.5076

Table 1. Water absorption test readings

Fig. 4. Water absorption test

2.1.2 Hardness Test

The Rockwell Hardness Test, is carried out on the Plastic paver block/Test specimen with a hardened steel ball (Ball Diameter – ½ inch). Initially the depth of the Plastic paver block/Test specimen is recorded by forcing the indenter into the Plastic paver block/Test Specimen. This test is done with ASTM D 785-89 standard with an applied load of 60 Kg and Scale considered as R Scale .

Specimen	Rockwell Hardness (R Scale, 60Kg load, ½ Inch Dia. ball)	Rockwell Hardness (R Scale, 60Kg load, ½ Inch Dia. ball) (Mean)
LDPE	42 to 43	42.5
HDPE	44 to 45	44.5

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PET (1)	42 to 43	42.5
PET (2)	82 to 83	82.5
LDPE + HDPE (1)	38 to 39	38.5
LDPE + HDPE (2)	41 to 42	41.5
LDPE + PET (1)	35 to 36	35.5
LDPE + PET (2)	44 to 45	44.5
HDPE + PET	62 to 63	62.5
LDPE	40 to 41	40.5
HDPE	35 to 36	35.5
PET	37 to 38	37.38
LDPE + HDPE	24 to 25	24.5
LDPE + PET	33 to 34	33.5
HDPE + PET	36 to 37	36.5

Table 2. Hardness test readings

Fig. 5. Hardness test

2.1.3 Compression Test

The Plastic paver block/Test Specimen is placed in the Compression testing machine / universal testing machine (UTM). After placing the Plastic paver block/Test Specimen load is applied slowly and increased continuously without shock at a rate of 150 KN approximately. The load is applied continuously until the resistance of the Plastic paver block/Test Specimen to the increasing load breaks down and no greater load can be applied or up till maximum deflection of 10mm. This Maximum load on the Plastic paver block/Test Specimen is to be recorded and if there are any structural changes in this type of failure on the Plastic paver block/Test Specimen are to be noted.

Compressive Strength = Maximum load applied

Test Specimen Area

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Compressive Strength = F/A

Where,

F = Maximum Load Applied (KN)

A = Specimen Area (mm^2)

Specimen	Maximum load at peak (KN)	Maximum cross head travel at peak (mm)	Compressive strength(N/mm^2)
LDPE	147.76	8.5	6.037
HDPE	131.32	7.23	5.277
PET (1)	32.24	7.6	1.312
PET (2)	50.86	0.54	1.91
LDPE + HDPE (1)	146.46	8.03	5.958
LDPE + HDPE (2)	145.18	11.58	5.9
LDPE + PET (1)	143.44	6.28	5.694
LDPE + PET (2)	76.52	7.35	3.038
HDPE + PET	148.38	9.71	6.118
LDPE	129.24	10.42	5.389
HDPE	95.66	15.99	3.875
PET	131.92	8.7	1.15
LDPE + HDPE	145.62	8.78	5.97
LDPE + PET	137.24	4.75	5.341
HDPE + PET	133.18	8.84	5.506

Table 3. Compression test readings

Fig. 6. Compression test

2.1.4 Oven Test

Oven Test is carried out for determining physical changes of the Plastic paver block/Test Specimen up to 100°C, to observe changes in the Plastic paver block/Test Specimen.

Specimen	60ºC	100ºC
LDPE	No change	No change
HDPE	No change	No change
PET	No change	No change
LDPE + HDPE	No change	No change
LDPE + PET	No change	No change
HDPE + PET	No change	No change

Table 4. Oven test readings

2.1.5 Furnace Test

Furnace Test is carried out for determining physical changes of the Plastic paver block/Test Specimen above 100°C. Or increase the temperature to calculate the melting point of the samples or to observe changes in the Plastic paver block/Test Specimen.

Specimen	Time(min)	150ºC	200ºC	200ºC
LDPE	60	No change	Slightly soft	Clay type
HDPE	60	No change	Semi-liquid	Melted
PET	60	No change	Semi-liquid	Melted
LDPE + HDPE	60	No change	Slightly soft	Clay type
LDPE + PET	60	No change	Slightly soft	Clay type
HDPE + PET	60	No change	Semi-liquid	Melted

Table 5. Oven test readings

3. Experimental Validations

3.1 Water absorption test graphical representation

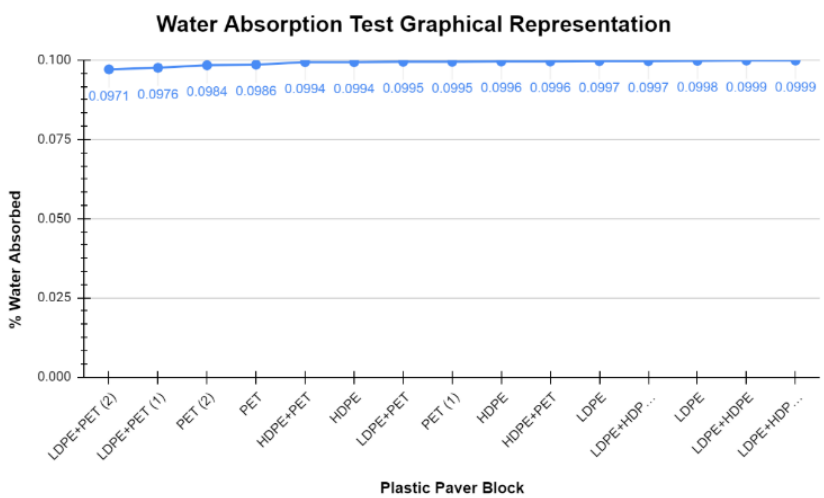

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Fig. 7. Water absorption test graphical representation.

In water absorption tests, as shown above in graphical representation, LDPE+PET (2), LDPE+PET (1), PET (2), PET, HDPE+PET respectively show best results in increasing order of their value. As very less percentage of water is absorbed. Hence, we can say that if less water absorption percentage is required PET shows the best results in combination.

3.2 Hardness test graphical representation

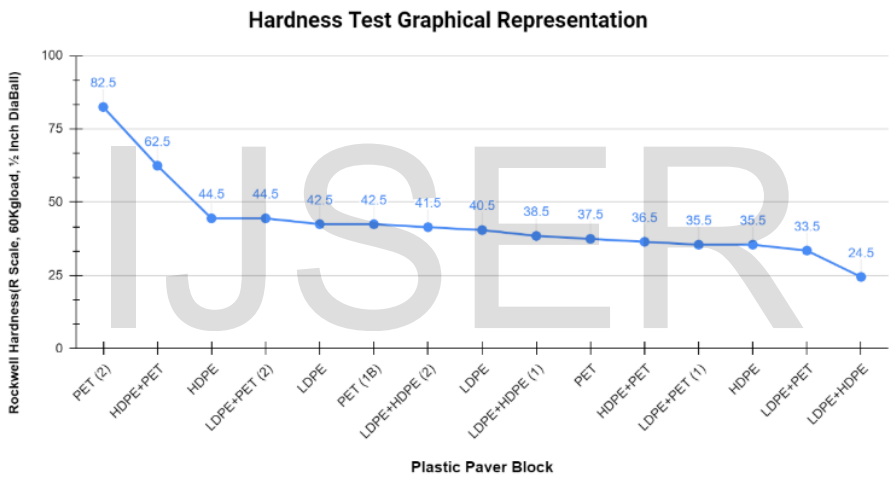

Fig. 8. Hardness test graphical representation

In hardness test, as shown above in graphical representation, PET (2), HDPE+PET, HDPE, LDPE+PET (2), LDPE, PET (1), LDPE+HDPE (2) respectively shows best results in decreasing order of their value. Hence, we can say that if hardness is required PET shows the best results in combination.

3.3 Compression test graphical representation

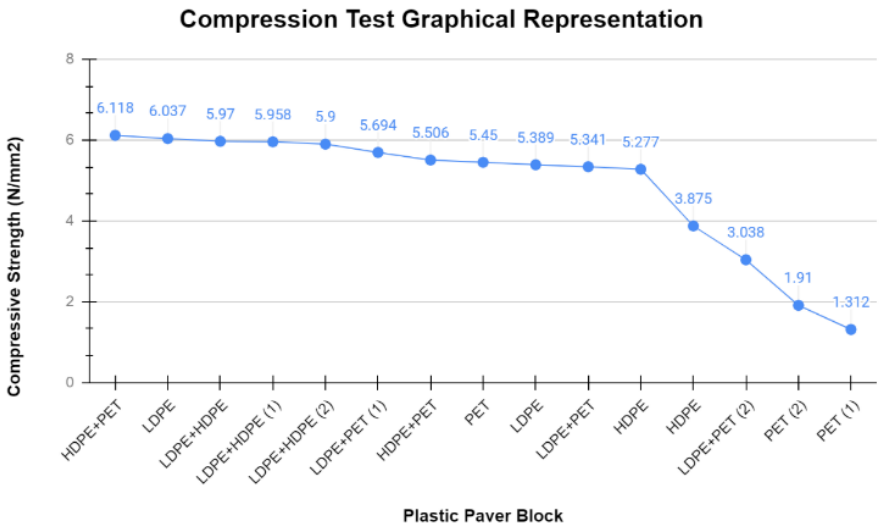

Fig. 9. Compression test graphical representation

In the compression test, as shown in above graphical representation, HDPE+PET, LDPE, LDPE+HDPE, LDPE+HDPE (1), LDPE+HDPE (2) respectively show best results in decreasing order of their values. Hence, we can say that if more compression is required LDPE shows best results in combination.

4. Conclusion

- In water absorption test LDPE+PET (2), LDPE+PET (1), PET (2), PET, HDPE+PET respectively shows best results in decreasing order of their value. Hence, we can conclude that if hardness is required PET shows the best results in combination.
- In hardness test, as shown above in graphical representation, PET (2), HDPE+PET, HDPE, LDPE+PET (2), LDPE, PET (1), LDPE+HDPE (2) respectively shows best results in decreasing order of their value.
- In compression test, HDPE+PET, LDPE, LDPE+HDPE, LDPE+HDPE (1), LDPE+HDPE (2) respectively shows best results in decreasing order of their values. Hence, we can conclude that if more compression is required LDPE shows best result in combination.
- According to the Oven and Furnace test it clearly concludes that it can sustain higher temperatures without any structural changes.
- We can also conclude that using reinforced iron framed structure leads to more strength than only plastic paver block.

5. Future Scope

- After the useful life, these plastic paver blocks can be demolished using different fragmenting techniques and can be used as recycle aggregates in making of roads, construction filling material, etc. which will lead to more reuse of plastic and less harm to the environment.

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- To improve the sustainability of the environment various plastic waste recycling is the viable option, as the plastic waste is increasing day by day and also plastic waste recycling will play an important role for global warming in a progressive manner.

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