



An experimental study of utilization of plastic waste for manufacturing of composite construction material

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Abstract

Plastic is common material widely used all over the world. Plastic manufacturing crosses 150 million tonnes per year. Plastic is involved in all activities of human life. So, waste of plastics is also increasing gradually. This paper focuses on recycling waste plastic and making plastic composite construction material (PCCM) that include fine and coarse aggregate along with three types of waste plastic, i.e. high density polyethylene (HDPE), low density polyethylene, and polyethylene terephthalate. In this research, 27 mixes of plastic composite construction materials (PCCM) have been made, in which plastic is softened or melted up to a semi-liquid state with the help of used engine oil and mixed with aggregate. This material has been evaluated for various properties such as compressive strength, flexural strength, split tensile strength, density, and water absorption. HDPE with fine aggregate gives better results.

Keywords Plastic waste · Composite construction material · Recycling · Polyethylene

Introduction

Nowadays, the development and transformation of human lifestyle play an important role in the production of a large number of wastes disposed of each year (Bajracharya et al. 2014). The generation of huge waste is mainly due to the increased use of materials by the people hence increase in manufacturing industries these wastes are managed by land disposal in the forms of landfills. These wastes are mainly produced due to the activities of people in manufacturing industries and the utilisation of materials. With the help of disposal into landfills, these wastes are managed. Still, there are some restrictions on managing these wastes, like in less developed places with their uselessness, consumption

of land space, and high costs that are consumed by landfills (Zulkernain et al. 2021). In the last couple of years, the capacity of solid waste production has increased. However, only a few recycling and landfilling processes are carried out, and a massive amount of waste, primarily plastic waste (PW), is either directly or indirectly dumped into the marine environment (Aziz et al. 2019). One of the most dangerous solid wastes that is produced in this environment is plastic waste. When these wastes enter into the ocean, they wreak havoc on the economy, ecology, and aesthetics of the environment (Belmokaddem et al. 2020). Yearly, almost 300 million metric tonnes of plastic waste are produced by the manufacturing units (Jones et al. 2018). Mostly, a huge quantity of plastic waste is produced by several industries such as packaging, manufacturing, health care, and automotive industries, which are located all over the world. India generates approximately 26,000 tonnes of plastic a day, according to a report by the CPCB, and of those 26,000 tonnes of plastic waste, 10,000 tonnes of plastic waste remain uncollected (Bhogayata and Arora 2019). Uncollected plastic waste is eventually thrown into the natural environment in our seas and oceans or piles up on our land. The environmental protection agency submitted a report which shows that of the produced plastic waste, only 8% is incinerated, 7% is recycled, and the balance of wastes are landfilled (More et al. 2021; Ghulamsakhi and Amit 2018).

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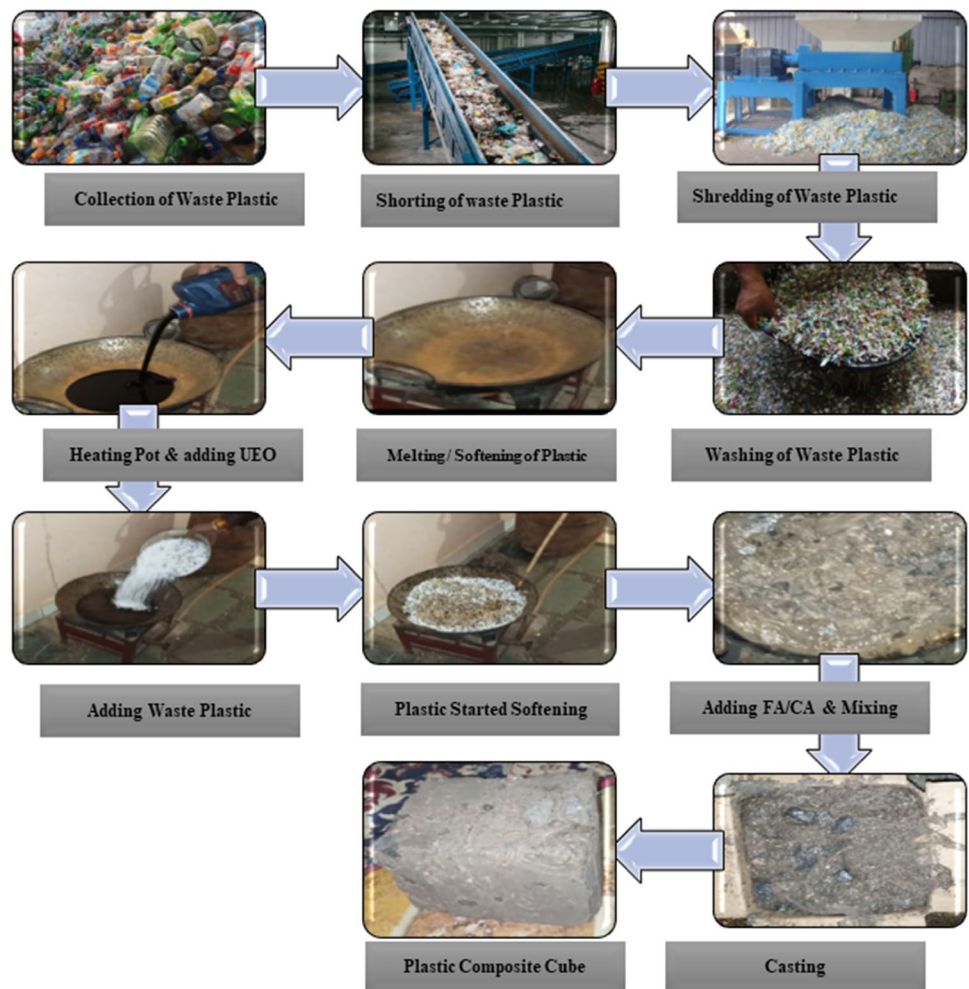
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Plastic is a widely used material, PET, HDPE, and LDPE are types of plastic. PET, HDPE, and LDPE are Thermoplastics or Thermo-softening plastics, which soften on heating and can be moulded into any desired shape. HDPE plastic is used in a wide variety of applications, including plastic bottles, milk jugs, shampoo bottles, bleach bottles, cutting boards, and piping. LDPE plastic is widely used for plastic wraps, squeezable bottles, plastic grocery bags, cable coverings, hot–cold beverage cups, garbage bags, etc. LDPE plastic and PETE are widely used for water bottles, jars, rope, food trays, etc. The waste plastics are also further utilised to make construction materials. Unsaturated polyester-resin (UPER) is made by utilising the waste PET bottles in the glycolysis process. The UPER acts as a binding agent to yield mortar polymers (Miranda Vidales et al. 2014). Waste LDPE may be converted into a useful local resource using LDPE-bonded sand, which is a resource-efficient substance. Water sachets manufactured from LDPE are an issue since recycling alternatives for this material are typically limited, and they have a negative influence on public health and the environment. LDPE-bonded sand can be made using LDPE water sachets and other materials. This takes minimal processing and yields a long-lasting, lightweight material. The manufacturing procedure does not necessitate the use of water. The sand particle size, compaction process, and cooling pace are all important factors in achieving optimal characteristics. To reach the maximum compressive strength, 75 wt% of sand was used. Optimal LDPE-bonded sand has a compressive strength that is comparable to M20/25 concrete and higher than ordinary Portland cement sandcrete. The qualities of LDPE-bonded sand make it appropriate for a variety of applications. It is now utilised to make paving blocks for hard-surface areas and pavements. It could be used to make roofing tiles and partition walls. In compression, LDPE-bonded sand acts like a viscoelastic material akin to asphalt. Although LDPE-bonded sand samples fail in shear, they retain at least 30% of their load after failure. The manufacturing of LDPE-bonded sand has the potential to have significant social, public health, and environmental benefits. This simple method has the potential to provide local jobs, clean up the environment, develop new construction materials, and drastically reduce the amount of trash LDPE entering the oceans by converting waste plastics into a useful resource (Kumi-Larbi et al. 2018). The workability of the concrete decreased as the PET percentage increased. When compared to the control concrete, the compressive strength of the 5% by weight PET concrete was the optimal compressive strength at 28 days of curing. As the percentage of PET in the concrete grew, the flexural strength of the concrete gradually decreased. Because of the maximum compressive strength of 33.4 N/mm² attained, the use of 5% PET concrete in structural applications is encouraged. When waste PET is used in concrete, it can provide a number of

benefits, including trash disposal, energy savings, and pollution prevention (Umasabor and Daniel 2020). Plastic cement is produced by mixing high-density polyethylene waste with Portland cement and examining the effects of the replacement of sand with fine polyethylene waste. The sand was replaced with various percentages of the product properties. The investigation is done with the help of polyethylene packaging waste that contains food crates and bottles in the proportion of 10% to 80%. The optimum percentage found for plastic cement production from polyethylene waste and Portland cement is 60% and 40%, respectively (Jassim 2017). Plastic waste is also used in manufacturing concrete paver blocks. When melted waste plastic is added to the concrete mix up to 10% by total weight without water, the plastic paver block possesses almost equal compressive strength as that of ordinary blocks. Therefore, the plastic paver block can be utilised in the yard, footpath, and park, and it is also utilised in commercial buildings (Ghughe et al. 2019). The replacement of cement by plastic waste in paver blocks is done to reduce the cost of the paver blocks. The degradation of plastic waste is a time-consuming process. Therefore, the author utilises the plastic waste in various proportions along with coarse aggregate, ceramic waste, and quarry dust to reduce the plastic waste. The use of plastic waste in paver block production is a productive way of disposing of plastic waste (Musau et al. 2020). It is feasible to include PVC waste into the composition of building materials. When 25% of the sand is substituted with PVC in the conventional mix. The result shows that this mortar comes into the masonry mortar class M20 in terms of compressive strength at 28 days of curing, as well as having the best adhesion to the substrate. This mix belongs to the plastering mortar class CSIV in terms of mechanical strength. This mortar is classified as class W0 in terms of water absorption through capillarity, however it has a nearly 65 per cent lower thermal conductivity coefficient than the conventional recipe. It can be used as a plastering mortar, although it is not advised for use on inside surfaces due to its response to open fire (Aciu et al. 2018). Thermoplastics are biodegradable plastics that include (Awoyera and Adesina 2020); PET (Polyethylene Terephthalate), LDPE (Low Density Polyethylene), PVC (Polyvinyl Chloride), HDPE (High Density Polyethylene), PP (Polypropylene), PS (Polystyrene), and others. Mainly, environmental concerns about three types of plastic (HDPE, LDPE, and PETE). Because these types of plastics only contribute to the world's waste and usage (Cagnetta et al. 2018), (Eriksen et al. 2019). To protect our environment, it needs to be recycled for a long time (Goli et al. 2020). The research community and industries have been trying to address the recycling process as an essential process and have focused on conducting recycling on the waste stream of plastic materials (Seghiri et al. 2017). With the proliferation of recycling plastic waste, the recycling



Fig. 1 Brief methodology for manufacturing PCCM

process has undergone a spectacular transformation over the past decades (Goli et al. 2020). Still, the challenges related to recycling plastic materials are adequately severe while binding new plastic products.

The main objectives of this research are to utilise waste plastic, convert it into a plastic composite construction material, and compare it with conventional construction materials.

Materials and Methods

Methodology

Plastics production and disposal cause significant greenhouse gas emissions and, when poorly managed, plastic pollution in the natural environment. Furthermore, the loss of natural resources as a result of current waste management

systems represents a lost economic opportunity. The present work encompasses three dissimilar plastic waste materials, namely HDPE, LDPE, and PETE, for the recycling process. The recycling of these plastic materials helps in making PCCM, and its methodology is explained through flow diagram (Fig. 1) to be treated in hierarchy.

Collection of plastics

Effective collection of plastic waste can be done by identifying the sources of plastic waste and the contributors of the plastic waste. There are two main sources in which plastic waste finds its way into the environment. These are post-consumer plastics (used by people) and post-industrial plastics (from the industries). Plastic waste can be collected for recycling by people in residential areas by putting recycling plastic waste bins in vantage places for easy collection later, and also by collecting it from the roadside. With industrial plastic wastes, these can be collected from the industry's defective plastic products and wastes.

Sorting

After collecting the plastic waste from the various collection points and bringing it to the recycling site or laboratory, the next action is sorting. Sorting of plastic waste can be done manually. In this study, three types of plastic have been utilised to manufacture plastic composite materials. These plastics are high-density polythene (HDPE) is used to manufacture milk jugs, recycling bins, agricultural pipe, but also playground equipment, lids, and shampoo bottles. For this study, milk jugs, juice containers, motor oil containers, shampoo and conditioner bottles, soap bottles, detergent containers, and toys are collected from the trash. Low-density polythene (LDPE) is used to manufacture plastic bags, containers, dispensing bottles, and plastic wraps. For this study, squeezable bottles, plastic bags, containers, and dispensing bottles are collected from trash. For this study, soda bottles, water bottles, dressing bottles, jars, and combs are collected from trash. Polyethylene terephthalate (PETE) is used to manufacture soda bottles, water bottles, jars, ropes, combs, tote bags, and food trays for this study soda bottles, water bottles, jars, ropes, and food trays are collected from trash.

Chipping or shredding

The sorted plastic waste is then sent to the chipper or the shredder to be cut into small plastic flakes. In the case of big plastic bottles, it is important to cut the bottles into small sizes before feeding them into the chipper or the shredder. The length and width of the plastic particle after shredding is approximately 4–6 mm.

Washing

In the recycling of plastic waste, one critical thing that must be done is the washing of the recycled plastic flakes. The washing of the plastic waste is done manually. A well-constructed washing tank means the dirty water can drain out easily. Since the plastic waste is already contaminated with a lot of dirt such as grease, oil, and dust, it is important to use the required surfactants (detergents) and water (cold or hot) to loosen and remove the contaminants from the plastic materials with manual washing. After washing, this plastic is left to dry in the open air for 10–12 h.

Melting of plastic

For melting plastic, a set-up is made which includes a pan and a stove. First, used engine oil is added to the pan. When the oil in the pan gets heated up to 100 °C, shredded waste plastic is added to the pan, and then the pan is covered with a plate. Check this mix in every 5 min. After 10/15 min, until

the plastic looks sticky and has converted into a semi-liquid state. The HDPE melting range varies between 125 and 133 °C (Kumar and Singh 2013; Alaerts et al. 2018), while the PETE melting range varies between 250 and 260 °C (Sarker et al. 2011), and the LDPE melting range varies between 108 and 121 °C (Li et al. 2019; Jordan et al. 2016). Waste plastics softening points vary between 80 and 180 °C, and it is also observed that when plastic gets softened with used engine Oil (UEO), it does not produce any toxic gases during the melting process. For the current study, UEO is collected from local mechanic shops. For this study, HDPE is heated up to 110 °C, LDPE to 100 °C and PETE to 220 °C and then other ingredients are added, and this mixture is further heated during the mixing so that plastic-aggregate makes a strong bond.

Mixing other ingredients

When HDPE is heated up to 110 °C, LDPE to 100 °C and PETE to 220 °C, other ingredients like fine aggregate (sand) and coarse aggregate (crushed stone) are mixed with the melted plastic in the pan. The mix is stirred well with a rod while heating. The properties of fine and coarse aggregate are given in Table 1. Mixing is done in the pan only. This mixture needs to be mixed properly to make a homogenous mixture. The mixing process should be completed within 2–3 min. For this experimental work, three types of plastic waste are taken, such as HDPE, LDPE, and PETE. The mixing process of the concrete is performed in nine different mixing operations for each plastic waste type (a total of 27 mixes were made). This nine mixing process contains three with FA, another three with CA, and the remaining three with FA and CA. Mix designations along with proportions are given in Table 2.

Casting

After mixing, the mix is poured into the mould of 150*150*150 mm cube, cylinders of 150 mm in diameter and a height of 300 mm, and a beam of 150*150*700 mm.

Table 1 Properties of aggregate

Properties	Fine aggregate (Sand)	Coarse aggregate (Crushed aggregate)
Fineness modulus	0.06 mm–4.75 mm	10 mm–12.5 mm
Specific gravity	2.44	2.62
Unit weight	1580 (kg/m ³)	1600 (kg/m ³)
Water absorption	0.36%	0.25%

Table 2 Mix proportion of various mixes of PCCM

S.N	Mix	FA %	CA %	HDPE %	LDPE %	PETE %	UEO %	FA (Kg/m3)	CA (Kg/m3)	HDPE (Kg/m3)	LDPE (Kg/m3)	PETE (Kg/m3)	UEO (kg/m3)
1	M1 A	70	-	30	-	-	equal to plastic	514.71	-	323.53	-	-	323.53
2	M1 B	70	-	-	30	-	-	514.71	-	-	323.53	-	323.53
3	M1 C	70	-	-	-	30	-	514.71	-	-	-	323.53	323.53
4	M2 A	50	-	50	-	-	-	397.06	-	367.65	-	-	367.65
5	M2 B	50	-	-	50	-	-	397.06	-	-	367.65	-	367.65
6	M2 C	50	-	-	-	50	-	397.06	-	-	-	367.65	367.65
7	M3 A	30	-	70	-	-	-	255.88	-	441.18	-	-	441.18
8	M3 B	30	-	-	70	-	-	255.88	-	-	441.18	-	441.18
9	M3 C	30	-	-	-	70	-	255.88	-	-	-	441.18	441.18
10	M4 A	-	70	30	-	-	-	-	632.35	323.53	-	-	323.53
11	M4 B	-	70	-	30	-	-	-	632.35	-	323.53	-	323.53
12	M4 C	-	70	-	-	30	-	-	632.35	-	-	323.53	323.53
13	M5 A	-	50	50	-	-	-	-	479.41	367.65	-	-	367.65
14	M5 B	-	50	-	50	-	-	-	479.41	-	367.65	-	367.65
15	M5 C	-	50	-	-	50	-	-	479.41	-	-	367.65	367.65
16	M6 A	-	30	70	-	-	-	-	279.41	441.18	-	-	441.18
17	M6 B	-	30	-	70	-	-	-	279.41	-	441.18	-	441.18
18	M6 C	-	30	-	-	70	-	-	279.41	-	-	441.18	441.18
19	M7 A	20	30	50	-	-	-	179.41	279.41	367.65	-	-	367.65
20	M7 B	20	30	-	50	-	-	179.41	279.41	-	367.65	-	367.65
21	M7 C	20	30	-	-	50	-	179.41	279.41	-	-	367.65	367.65
22	M8 A	30	20	50	-	-	-	255.88	220.59	367.65	-	-	367.65
23	M8 B	30	20	-	50	-	-	255.88	220.59	-	367.65	-	367.65
24	M8 C	30	20	-	-	50	-	255.88	220.59	-	-	367.65	367.65
25	M9 A	40	10	50	-	-	-	367.65	94.12	367.65	-	-	367.65
26	M9 B	40	10	-	50	-	-	367.65	94.12	-	367.65	-	367.65
27	M9 C	40	10	-	-	50	-	367.65	94.12	-	-	367.65	367.65



Drying

Newly cast PCCM is left to dry for 3–4 h in the open air. During this time, the plastic temperature goes down and PCCM gains strength. Once the plastic reaches at room temperature and takes the desired shape, the specimens are demoulded.

Limitation and recommendation

Because the mixture is less workable at high temperatures, proper mixing of all ingredients is critical in achieving a homogeneous PCCM mix. PCCM casting is a difficult task since it hardens quickly. As a result, the needed casting must be completed in a shorter amount of time. The temperature

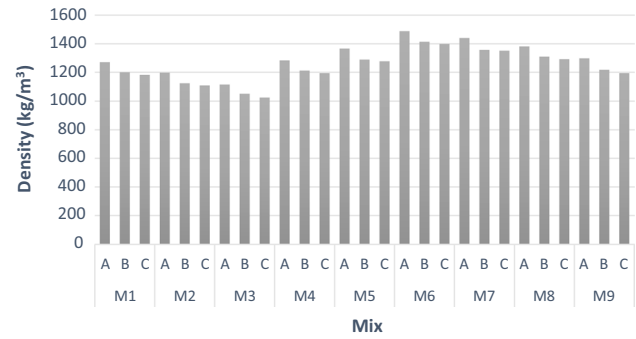


Fig. 2 Density of PCCM

Table 3 Results obtained for different mixes of PCCM

S.N	Mix		Density (kg/m ³)	Water absorption %	Compressive strength (Cube) N/mm ²	Compressive strength (Cylinders) N/mm ²	Split tensile strength N/mm ²	Flexural strength N/mm ²
1	M1	A	1271.11	0.18	7.88	6.98	1.18	3.12
2	M1	B	1200	0.55	7.85	6.96	1.18	3.11
3	M1	C	1182.22	0.54	7.78	6.89	1.17	3.09
4	M2	A	1197.04	0.07	10.29	9.12	1.55	3.64
5	M2	B	1122.96	0.44	10.28	9.11	1.5	3.64
6	M2	C	1108.15	0.55	10.22	9.05	1.49	3.63
7	M3	A	1114.07	0.05	12.6	11.16	1.85	4.15
8	M3	B	1051.85	0.42	12.55	11.12	1.81	4.13
9	M3	C	1025.19	0.62	12.45	11.03	1.79	4.11
10	M4	A	1282.96	0.06	6.11	5.41	0.94	2.73
11	M4	B	1211.85	0.43	6.01	5.32	0.93	2.71
12	M4	C	1194.07	0.78	5.93	5.25	0.92	2.69
13	M5	A	1365.93	0.13	6.85	6.07	1.08	2.89
14	M5	B	1288.89	0.5	6.8	6.02	1.04	2.88
15	M5	C	1277.04	0.72	6.77	6	1.03	2.87
16	M6	A	1487.41	0.29	7.72	6.84	1.16	3.08
17	M6	B	1413.33	0.66	7.7	6.82	1.16	3.08
18	M6	C	1398.52	0.7	7.69	6.81	1.12	3.07
19	M7	A	1440	0.23	6.39	5.66	0.98	2.79
20	M7	B	1357.04	0.6	6.38	5.65	0.98	2.79
21	M7	C	1351.11	0.63	6.36	5.63	0.94	2.78
22	M8	A	1380.74	0.21	7.85	6.96	1.18	3.11
23	M8	B	1309.63	0.58	7.81	6.92	1.17	3.1
24	M8	C	1291.85	0.66	7.79	6.9	1.13	3.1
25	M9	A	1297.78	0.14	9.63	8.53	1.42	3.5
26	M9	B	1217.78	0.51	9.6	8.51	1.41	3.49
27	M9	C	1194.07	0.67	9.55	8.46	1.4	3.48



of the mix is maintained in the pan during the mixing of ingredients. The pan is covered properly during the melting process.

Results and Discussion

Evaluation

Cast specimens of plastic composite material have been tested for various evaluation of properties, i.e. density, water absorption, compressive strength, flexural strength, and split tensile strength. The results of the test performed on 27 samples are shown in Table 3.

Density

The density of any material defined as mass value that is present in the unit volume of the material. Density is calculated by the calculation of the mass of the specimen to an accuracy of 0.01% per unit volume. Evaluated values of

densities for PCCM are compared through graph as shown in Fig. 2. The mixing with FA has density value of 1194.07, 1124.94, and 1105.19 kg/m³ for HDPE, LDPE, and PETE, respectively. Similarly, 1378.77, 1304.69, and 1289.88 kg/m³ are the average density values of mixing with CA for HDPE, LDPE, and PETE, respectively. As well as, mixing with FA and CA has the average density value of 1372.84, 1294.82, and 1279.01 for HDPE, LDPE, and PETE, respectively. These values clearly show that the density of HDPE plastic waste mixed with CA is higher than that of other plastic waste mixes.

Water absorption

The absorption percentage of the water for the implemented plastic waste is shown in Fig. 3. The test procedure involves drying a specimen in the open air and weighing it, then immersing it in water for 24 h, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption (in percent). When mixed with FA, the water absorption percentage of HDPE, LDPE, and PETE is 0.10, 0.47, and 0.57%, respectively. For HDPE, LDPE, and PETE, the average water absorption percentage value for mixing with CA is 0.16, 0.53, and 0.73%, respectively. Similarly, mixing with FA and CA has an average value of 0.19, 0.56, and 0.65% for HDPE, LDPE, and PETE, respectively. From this analysis, the HDPE with FA mix has the lowest water absorption percentage value when compared to the other plastic waste mixes. Water absorption depends upon the availability of pores in the specimens. When a mix is cast into FA without CA, the chances of pores in the specimen are reduced because of its small particle size, and when softened HDPE plastic is mixed with FA, due to the unavailability of CA, the mix is closely packed, and the chances of pores formation are reduced. When softened plastic is mixed with FA, the plastic forms a layer over the particle which binds the particles. This quality of binding increases with increase in density, and HDPE is a dense

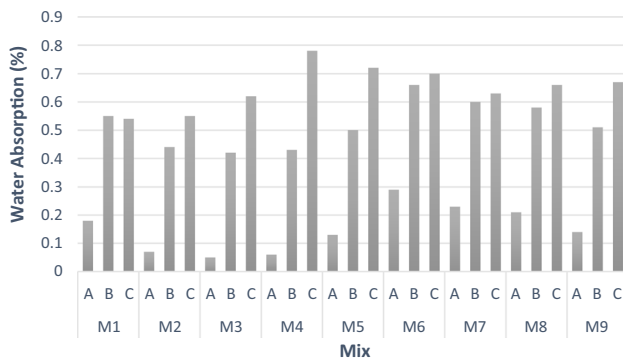
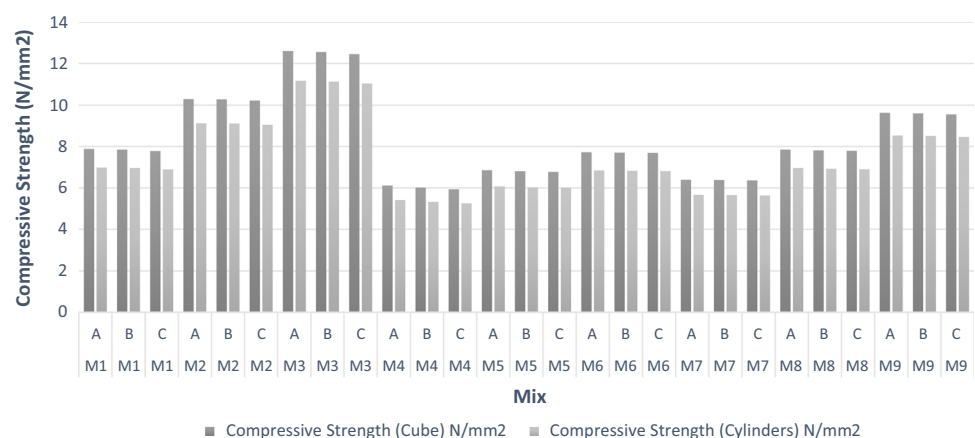


Fig. 3 Water Absorption of PCCM

Fig. 4 Compressive strength of PCCM



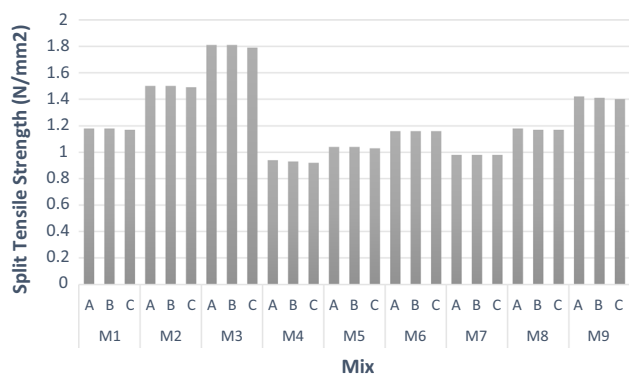


Fig. 5 Split tensile strength of PCCM

plastic as compared to LDPE and PETE. Therefore, the HDPE with FA mix has the lowest water absorption percentage value when compared to the other plastic waste mixes.

Compressive strength

Cubes of 150*150*150 mm and cylinders of 150*300 mm are casted to determine the compressive strength of a plastic composite material. Specimens are tested on compressive strength testing machine. The specimen's surfaces are smoothed before it is placed on the compressive testing machine. Now specimens are placed between the machine's plates, and a uniform load is applied to the specimen. The maximum load is recorded and divided by the cross-sectional area of the specimen's bearing surface. Figure 4 depicts the compressive strength of a cube as a result of the experiment. The compressive strength of cube in the mix with FA is 10.26 N/mm², 10.23 N/mm², and 10.15 N/mm² for HDPE, LDPE, and PETE, respectively. In this mixture, HDPE plastic waste has a higher compressive strength than the other two plastic wastes. HDPE, LDPE, and PETE have compressive strengths of 6.89, 6.84, and 6.8 N/mm² when mixed with CA, respectively. Because of this mixing, HDPE has a higher compressive strength than the other two plastic wastes. The average compressive strength of HDPE, LDPE, and PETE when mixed with FA and CA is 7.96, 7.93, and 7.9 N/mm², respectively. Overall, HDPE plastic waste has a higher compressive strength than LDPE and PETE. The compressive strength of HDPE mixed with FA is greater than that of HDPE mixed with CA and mixing with FA and CA. Figure 5 depicts the compressive strength results for a cylindrical specimen. When cylinders are mixed with FA, the compressive strength values for HDPE, LDPE, and PETE are 9.09, 9.06, and 8.99 N/mm², respectively. When mixed with CA, the compressive strength of HDPE, LDPE, and PETE is 6.11, 6.06, and 6.02 N/mm², respectively. The compressive strength values for HDPE, LDPE, and PETE in mix with FA and CA are 7.05, 7.03, and 7 N/mm²,

respectively. In comparison to LDPE and PETE, HDPE plastic waste performed well overall. When mixed, the HDPE mix with FA has a higher compressive strength than the HDPE mix with CA and the mix with FA and CA.

Split tensile strength

For split tensile strength, 15 * 30 cm cylinders are cast and before testing, note the dimension and weight of the specimen. Then place plywood strips above and below the specimen. After that place the specimen in the testing machine and apply load gradually to the specimen. Record the load at which the specimen breaks and the split tensile strength is calculated. The obtained results for split tensile strength of the plastic composite construction material are plotted as a bar diagram in Fig. 5.

The obtained results show that HDPE has a higher average value of 1.25 N/mm² than LDPE and PETE. The average value of the LDPE and PETE is 1.24 and 1.23 N/mm², respectively. Also, mixing-wise, HDPA with FA and LDPA with FA are performed almost identically compared to the other mixing methods.

Flexural strength

To determine the flexural strength test, beam specimens of 700 * 150 * 150 mm are casted and placed in the machine for testing. The bed of the testing machine shall be provided with two steel rollers on which the specimen is to be supported. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially. Centre the loading system in relation to the applied force. Bring the block applying force into contact with the specimen surface at the loading points. Load the specimen continuously without shock till the point of failure at a constant rate and calculate the flexural strength. Figure 6 shows the obtained results of the flexural strength tests. The results show that HDPA

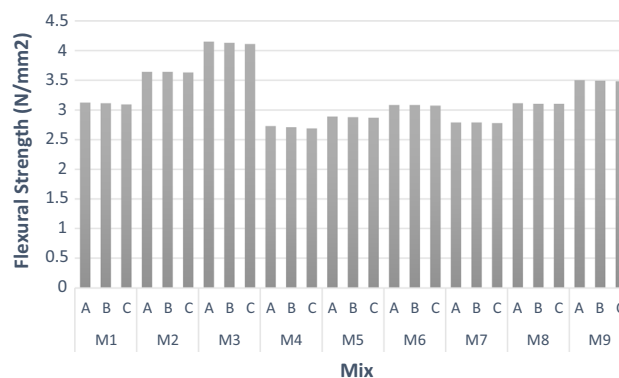


Fig. 6 Flexural strength of PCCM

Table 4 Compressive strength values of construction specimens

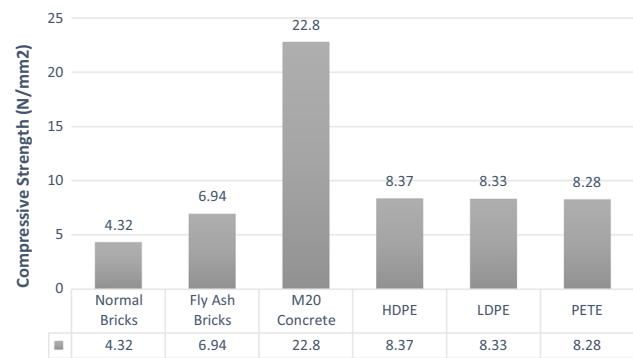
Construction specimens	Average compressive strength (N/mm ²)
Normal bricks	4.32
Fly ash bricks	6.94
M20 grade concrete cube	22.8

performed well compared to the other plastic wastes, with an average value of 3.22 N/mm². Also, mixing-wise, HDPA with FA and LDPA with FA are performed almost similarly to the other mixing methods, such as mixing with CA and mixing with FA and CA.

Validation

This section focuses on the comparative analysis of used plastic wastes such as HDPE, LDPE, and PETE. The performance of these plastic wastes has been compared to casted specimens typically used in construction. Here, normal bricks, fly ash bricks, and M20 grade concrete have been used for the comparative analysis. In the laboratory, M20 grade concrete is made by adding the appropriate ingredients, while normal bricks, and fly ash bricks, are collected from a local vendor. After that the specimens are tested on the compressive strength testing machine to analyse the compressive strength of each specimen. Table 4 shows the values of compressive strength of bricks and M20 concrete.

The results given in Table 3 were compared for discussion of the use and performance of plastic waste. Here, two types of shapes, i.e. cubes and cylinders, are manufactured and tested for plastic waste. Still, the compressive strength of the cube has been taken for the comparative analysis. The HDPE mix has an 8.37 N/mm² compressive strength value. Normal bricks and fly ash bricks have 4.32 and 6.94 N/mm² of compressive strength value, respectively. So, the implemented HDPE mix is performed efficiently compared to the normal brick and fly ash bricks. But, the M20 grade concrete has a 22.8 N/mm² compressive strength value, which is higher than the implemented HDPE mix. The value of the LDPE mix average compressive strength is 8.33 N/mm², which is obtained from the test. This mix also performed well compared to the normal bricks and fly ash bricks, but it is not higher than the M20 grade of concrete. PETE has 8.28 N/mm² average compressive strength value that is higher than the normal bricks and fly ash bricks average compressive strength values. Therefore, this PETE mix also performed efficiently compared to the normal bricks and fly ash bricks. But it is also not achieving the M20 grade

**Fig. 7** Validation of Plastic Composite Construction Mixing

concrete average compressive strength value. From the above three validations, all the implemented plastic waste mixes, such as HDPE, LDPE, and PETE, performed well when compared to the normal bricks and fly ash bricks. But they have not achieved the compressive strength value of M20 grade concrete. To achieve this value, industrial waste, agricultural wastes, or fibres need to be added to the plastic waste mix. This will help to increase the compressive strength of the implemented plastic waste to achieve the compressive strength value of M20 grade concrete. Values of the comparative analysis are shown in Fig. 7. When plastic sachets (LDPE) are melted to make sand bonded blocks, to make blocks 14.7% to 50% melted plastic sachets (LDPE) are mixed with sand and the result shows that the compressive strength of the blocks is 12 to 27.3 MPa, which is much higher than clay bricks or regular bricks and fly ash bricks and 75% sand possess maximum compressive strength, which is also comparable to M20 concrete (Kumi-Larbi et al. 2018). Plastic waste (LDPE) is melted and made into paver blocks and blocks with melted plastic, along with waste material and aggregates. The result shows compressive strength in the range of 9.33 MPa to 16.05 MPa (Shanmugavalli 2017; Ghuge et al. 2019), which have better compressive strength than clay bricks or regular bricks and fly ash bricks.

Conclusion

It has been found that plastic wastes soften at 80 to 180 °C with UEO, during the softening of plastic with UEO, no toxic gas is produced. This softened plastic forms a film-like structure on the surface of the aggregate. On the basis of this finding, a composite construction material using HDPE, LDPE, and PETE has been made with coarse and fine aggregate. A mix with fine aggregate is better than other mixes. The results show that as plastic increases in the mix, the properties of PCCM get better and it also been observed that M3A mix shows better properties than other mixes. HDPE

shows better results than LDPE and PETE. LDPE shows better results than PETE, and HDPE with fine aggregate performs better than other mixes. On the basis of compressive strength, the newly formed plastic composite construction material has been compared with conventional normal bricks, fly ash bricks, and M20 concrete. PCCM achieved higher compressive strength than conventional normal bricks and fly ash bricks but is unable to achieve the level of compressive strength of concrete.

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