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Development of construction material from waste plastics and fly ash

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Abstract- With advancement of civilization, use of plastic is increasing. Consequently a huge amount of plastic waste is generated. In India 26000 tonnes per day of plastic waste was generated in 2017-18. Polyethylene and expanded polystyrene foam are extensively used for packaging which create environmental pollution when discarded. Fly-ash is another solid waste generated from thermal power plants. This particulate solid waste contaminates air water and soil. Aim of the present research was to prepare a value-added product from all these waste materials to establish a waste-to-wealth process.
A tile-like structure has been prepared my melt-mixing and subsequent compression-moulding using plastic carry-bags, thermocol (expanded polystyrene foam) and fly-ash. Tensile and flexural strengths along with the solvent absorption capacity were determined and compared with ceramic wall tiles.

Keywords- Waste plastic; Fly ash; Wall Tiles; Tensile strength; MOR

1. INTRODUCTION

Substantial growth in the consumption of plastic is observed all over the world in recent years, which also increased the production of plastic related wastes. The plastic waste is now a serious environmental threat to modern civilization. Plastic is composed of several toxic chemicals, and therefore plastic pollutes soil, air and water. Since plastic is a non-biodegradable material, landfilling using plastic would mean preserving the harmful material forever. The hazards that plastics pose are numerous. They may block the drainage system of a city. The blocked drains provide excellent breeding grounds for disease-causing mosquitoes and water borne diseases besides causing flood.

Recycling plastics is a possible option. As plastic is an organic hydrocarbon-based material, its high calorific value can be used for incineration or in other high temperature processes. But, burning of plastics releases a variety of poisonous chemicals into the air, including dioxins, one of the most toxic substances. Plastic waste can also be used to produce new plastic based products after processing. However it is not an economical process as the recycled plastic degrades in quality and necessitates new plastic to make the original product. Although these alternatives are feasible except for land filling, recycling of plastic waste to produce new materials, such as composite construction materials appears as one of the best solution for disposing of plastic waste, due to its economic and ecological advantages [1].
Again, the biggest source of electricity in India is thermal power plants; India has one of the largest coal reserves in the world but the coal mined here is high in ash content and low calorific value which is a major problem as well. Since about 70% of the electricity is generated by burning of coal, India has a huge problem of fly ash disposal which is a solid waste from thermal power plant. The generation of fly ash in

India has increased from 68.88 million tons in 1996-97 to 163.56 million tons in 2012-13, of which only 100.37 million ton was utilized. Fly ash causes air, water and soil pollution when it is exposed to the environment. Construction industry is one of the major sectors which can utilize large amount of fly ash to produce light bricks. If any plastic material is used with fly-ash, it is expected that some properties like water-resistance may be enhanced [2].

Among various types of plastics, expanded polystyrene foam (trade name thermocol) is extensively used for packing and food containers. Discarded thermocol occupies large volume and due to its light weight it floats on water bodies. One of its utilization may be in construction industries. There are several papers which depicted the use of these waste plastics to produce tile like structure. Konin et al. [3] investigated the use of polypropylene based wastes along with sand to make tiles. These tiles showed better mechanical strength and lower porosity to water than the conventional micro concrete tiles. Liu et al. [4] showed the use of waste rubber tire powder and plastic wastes (mainly polypropylene) to produce tiles. Tiles with equal amount of rubber tire powder and plastic waste showed better mechanical properties. Dhawan et al. [5] investigated the use of waste plastic bags and fly ash to produce tiles with reduced flammability and improved tensile strength.

Aim of the present research is to produce a value-added product from the above notorious solid waste materials namely fly-ash, plastic carry-bags and waste expanded polystyrene foam so that they are utilized in construction.

2. EXPERIMENTAL WORK

2.1 *Materials:*

Plastic bags available in market were collected; Thermocol (Expanded polystyrene foam) plates used for serving food were used as the source of polystyrene; Fly ash was collected from thermal power plant wastes.

Generally fly-ash from lignite coal contains silica (15-45% wt), alumina (10-25%wt), sodium carbonate (0-6%wt), oxides of calcium (15-40% wt), magnesium (3-10% wt), sulphur (0-10%wt) and potassium (0-4%wt). Average particle size range is 50-80 micron [6]. FTIR spectra (not shown here) shows that it may be a blend of polyethylene and polypropylene.

2.2 Method:

The plastic bags were washed, dried and shredded into small pieces. Thermocol utensils were also cleaned, dried and ground in a grinder. These two waste plastics, along with fly ash, were mixed in a dry mixer in definite proportions as mentioned in Table-1.

After that the mixtures were melt- mixed by Brabender measuring mixer at a temperature of 130°C. The Brabender mixers are connected to a Plastograph. Heating/cooling is done either through a cold circulation thermostat or electrically with air cooling. The user-optimized WINMIX software provides evaluation of the results according to the latest standards [7].

Five different compositions were prepared. The table below shows the different compositions of the sample. A blank set without fly-ash was prepared to see the uniformity of the polymer matrix.

Table 1: Different compositions for the composite

Set	Fly ash (wt %)	Polystyrene (wt %)	Plastic (wt %)
1	32.5	32.5	35
2	19.5	45.5	35
3	32.5	48	19.5
4	32.5	19.5	48
B	0	50	50

The aggregates produced by melt-mixing were then subjected to compression moulding at 150^{o}C and 1000kN/m^2 pressure using compression moulding machine (make & model). Small dumbbell shaped samples were prepared for tensile strength determination. Rectangular samples were prepared in a similar manner. In all cases, silicon oil was used for demoulding. Rectangular strips were used to determine the modulus or rapture (MOR) or flexural strength.

Tensile strength was determined using Universal Testing Machine, UTM (Make & model???) under standard conditions. Flexural strength also known as modulus of rupture or bend strength is a material property, defined as the stress in material just before it yields in a flexure test.

The sample was placed in between two supporting blocks of the MOR testing machine and the load was applied at the centre of the sample. The maximum load at which the sample broke was determined. The MOR was calculated as: $MOR = \frac{3WL}{2bd^2}$ (1)

W= load; L= length of the sample; b= width of the sample; d= height of the sample [8].

Absorption characteristics of the samples were evaluated by swelling test. For this purpose samples of specific sizes were collected. Initial weight of the sample was determined and then the sample was dipped into 50 ml toluene solution. The weight of the swelled sample was determined at different interval of time. Swelling percentage of the sample was calculated as:

$$\frac{Swollen\ \ weight - Initial\ \ weight}{Initial\ \ weight} \times 100 \qquad (2)$$

3. RESULTS

For application of any material in construction, it is highly important to study its various strengths. To determine the tensile strength and breaking load, UTM was used as described before.

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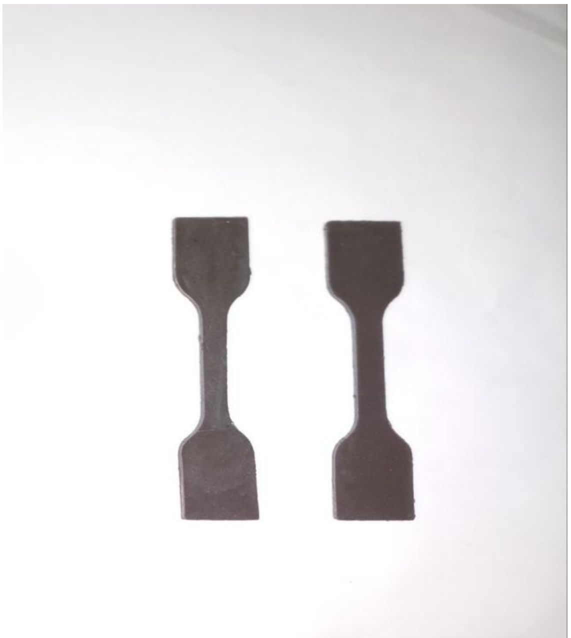
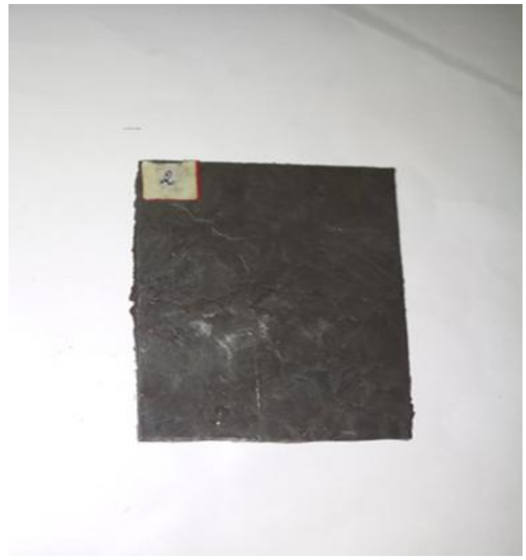


Figure- 2(a) Aggregate of the composite material



(b) square shaped tile made of the composite material

Table 2: Mechanical properties of the samples

Set	Gauge length (mm)	Width (mm)	Thickness (mm)	Area (mm^2)	Load at break (KN)	Stress at break (MPa)	Tensile strength (MPa)	Average tensile strength (MPa)
1A	30	5	1.93	9.65	0.1332	13.8040	13.804	15.515
1B	30	5	1.93	9.65	0.1662	17.2267	17.226	
2A	30	5.03	2.1	10.563	0.1172	11.1011	11.101	13.061
2B	30	5.03	2.1	10.563	0.1899	17.9806	18.534	
2C	30	6.08	2.4	14.592	0.1550	10.6245	10.624	
2D	30	6.08	2.4	14.592	0.1749	11.9863	11.986	
3A	30	5.55	2.33	12.9315	0.1855	14.3463	14.346	15.385
3B	30	6.2	2.2	13.64	0.2701	19.8063	19.806	
3C	30	6.67	2.31	15.40	0.0307	19.9750	13.681	
3D	30	4.29	2.37	10.167	-	-	13.708	
4A	30	5.19	2.07	10.743	0.1910	17.7863	17.786	15.957

4B	30	5.19	2.07	10.743	0.1910	17.7863	17.786	
4C	30	6.3	2.07	13.041	0.2184	16.7503	16.750	
4D	30	4.95	2	9.9	0.1408	14.2290	14.229	
B1	30	5.33	2.58	13.7514	0.03418	2.4862	18.5308	19.176
B2	30	5	2.29	11.45	0.07651	6.6828	27.5191	
B3	30	5.35	2.41	12.8935	0.02238	1.7360	14.4290	
B4	30	6	2.38	14.28	0.23169	16.2249	16.2249	

It was observed from Table-2 that the set of composite having highest plastic content exhibited the maximum tensile strength. Interestingly, the blank set without fly-ash showed more tensile strength than those with fly-ash. It may be attributed to the efficient bonding of the two polymers [8, 9]

The MOR (Modulus of Rupture) values of the samples are tabulated below.

Table 3 Modulus of rupture values of the samples

Sample	Length (cm)	Width (cm)	Thickness (cm)	Area (cm^2)	Load (kg/cm^2)	Modulus of rupture (N/mm^2)
1	2.197	1.465	0.1586	3.218	2	56.44
2	2.211	1.191	0.158	2.632	1.8	51.81
3	2.221	1.330	0.167	2.954	1.9	49.43
4	2.193	1.258	0.158	2.759	2.1	59.51

From Table-3, it is observed that the composite with highest amount of plastic has the highest MOR or flexural strength.

Result of the swelling test is tabulated below.

Table 4 Solvent absorption test results

Sample	Initial weight (gm)	Swollen weight (gm)	Time (min)	Swelling percentage (%)	Average swelling percentage (%)
1	1.1234	1.1313	1	0.703	1.2546
		1.1340	3	0.943	
		1.1378	5	1.281	
		1.1402	7	1.495	
		1.1442	9	1.851	
2	1.1902	1.1986	1	0.705	1.6296
		1.2019	3	0.983	
		1.2089	5	1.571	

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		1.2158	7	2.150	
		1.2228	9	2.739	
3	1.1556	1.1617	1	0.528	1.1452
		1.1652	3	0.830	
		1.1689	5	1.150	
		1.1723	7	1.445	
		1.1761	9	1.773	
4	1.1423	1.1471	1	0.420	1.1250
		1.1512	3	0.779	
		1.1556	5	1.164	
		1.1592	7	1.479	
		1.1627	9	1.785	

It is observed from Table-4 that the composite having the highest percentage of polystyrene and the lowest percentage of fly-ash swelled the maximum. Since polystyrene is soluble in toluene, it swelled much in toluene. However polystyrene is insoluble in water.

There is no standard available for tiles of such a composite. IS 15622-2006 for ceramic tiles has been referred to for comparison. A few properties have been compared as below since all tests for ceramic tiles are not applicable for polymer composite tiles.

Table-5: Comparison with standard for ceramic tiles

Property	IS-15622-20006 Table-11	Our composite tile
Water absorption (% by weight)	Less than equal to 3	Completely water resistant. Toluene absorption is 1.63 (max)
Breaking load (N)	600 (For less than equal to 7.5 mm thickness)	117-218 (for 3mm thickness)
MOR (N/mm^2)	38	50-60

From Table-5 it is observed that the mechanical properties are comparable with the ceramic tiles. MOR and water resistance are even better than the ceramic tiles. Since we have identified the application as wall tiles, less mechanical strength will be required. To be applied as wall tile, we have tested the bonding with wall using toluene and the tiles adhered well with concrete wall.

4. CONCLUSION

Use of plastic is increasing day by day and as a result a huge amount of waste plastic is being generated. Since plastic is a non- biodegradable material, plastic waste disposal is becoming one of the biggest problems all over the world today. Again, most of the thermal power plants produce large amount of fly ash daily and this fly ash is one of the main reasons behind air pollution especially in India. In this paper we have focused on constructing tile-like structure using waste plastics and fly ash as the main ingredients that can be used for construction purpose.

We have moulded 150mm × 150mm tile using the composite material comprising fly ash, waste plastic and expanded polystyrene foam. It was observed that the tile was water-resistant and has strength comparable to the ceramic tiles. This tile may be considered for application as wall tiles. By this the waste disposal problem will be solved satisfactorily as well as we will be able to add value to the wastes. Moreover top soil taken indiscriminately for manufacturing conventional tiles will be saved as well.
In addition, such tiles may be impregnated with photo catalysts that may help in the control of water and air-pollution. However that part of work is considered for future.

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