Melt-Densified Post Consumer Recycled Plastic Bags Used As Light Weight Aggregate In Concrete

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ABSTRACT

Present investigation melt-densified material used as light weight coarse aggregate in concrete. Melt-Densified Aggregates (MDA) were prepared from post consumer recycled plastic bags by melting in a laboratory Muffle Furnace at 160°C. Reference specimen using conventional aggregates and four mixture specimens (M1-M4) made with part replacement by MDA aggregate were prepared. The studies were conducted on an M40 mix with the selected w/c ratio: 0.32 and compressive strength test has been carried out as per recommended procedures of relevant codes. The compressive strength results are compared with reference specimen. MDA can be used to replace part of aggregates in a concrete mixture. This contributes to reducing the unit weight of the concrete and attracts a growing ecological interest especially due to the increasing volume of polymer wastes.

Keywords*:* **Melt-densified Aggregates (MDA), Low-density polyethylene (LDPE), Post Consumer Recycled Plastic Bags, Compressive Strength, Density.**

I. INTRODUCTION

Disposal of waste plastic consumer bags from the domestic has become a major problem to the agencies in the town and cities. The waste plastic bags available in the domestic waste mainly consist of low density polyethylene (LDPE). Plastic bags dumped in the dustbins find their way into the drainage system and clog them. Often, these are burnt along the roadside, which produces fumes causing air pollution.

Panigrahi et al., 2005, described as the post-consumer plastic are the materials arising from products that have undergone a first full service life prior to being recovered. The biggest source of plastic waste is households. It is a big challenge though to collect and sort the plastic waste. The processes of separating materials according to resin types are very important because most resin types are thermodynamically incompatible with other resins. Mixed plastics molded product generally has poor, brittle properties unless a modifier is added to improve compatibility. Recycling plastic usually involves processes such as melting, shredding or granulation of waste plastics. Plastic waste, as ethylene vinyl acetate (EVA), has been used with relative success to produce concrete, lightweight concrete and components of construction (Siddique et al., 2008; Panyakpo et al., 2007).

Post consumer recycled plastic bags present formidable problems as they are at present not biodegradable and can resist incineration and in fact incineration may not be possible due to production of toxic fumes. It is also reported that the formation of dioxins and furans (cyclic compounds) is favorable when the temperatures are between 300-500^{0}C (Rao et al., 2010). It is obvious that dioxin formation occurred at temperatures above 450^{0}C and was reduced significantly at temperatures above 850^{0}C (Shibamoto et al., 2007).

Behjat Tajeddin et al, 2009, proved that the mass loss of LDPE starts at 310.44 ºC and continues very slowly at temperature below 400ºC. Above 400ºC, mass loss takes place very rapidly and the quantity of LDPE residue is very low (equal 0.33%) due to further breakdown of it into gaseous products at higher temperature. The thermal degradation of LDPE starts at 310.44ºC, and finishes at 501.13 ºC with a peak at 450.86 ºC.

Fetra Venny Riza et al., 2008, was investigates the possibility of making polystyrene as lightweight aggregate. Low density is the advantage of polystyrene. Waste polystyrene foam is modified and sintered in the furnace at the temperatures varying from 130 °C to 220 °C.

Bhogayata et al., 2012, was looking to the global issue of environmental pollution by post-consumer plastic waste, research efforts have been focused on consuming this waste on massive scale in efficient and environmental friendly manner. Researchers planned to use plastic waste in form of concrete ingredient as the concrete is second most sought material by human beings after water. The use of post-consumer plastic waste in concrete will not only be its safe disposal method, but may also improve the concrete properties like tensile strength, chemical resistance, drying shrinkage and creep on short and long term basis.

Naik et al., 1996, investigated the effect of post-consumer waste plastic in concrete as soft filler. The compressive strength decreased with increase in the amount of the plastic in concrete, particularly above 0.5% plastic addition. Therefore, in order to maintain a particular compressive strength level, plastic concentration in concrete must be controlled. However, the amount of plastic addition can be increased substantially if particles are further processed to improve the bond area and stress transfer capacity of the particles. The effect of various treatments on plastics was also studied and it was concluded that out of the three treatments (water, bleach, and alkaline bleach) used, the highest compressive strength was achieved when the plastic was treated with alkaline bleach, and the lowest when treated with bleach alone.

Meg Calkins, 2009, says that plastics offer several benefits for site construction. Some can be durable, waterproof, decay resistant, flexible, integrally colored, inexpensive, and low maintenance. They can incorporate substantial recycled content, can be recycled themselves, and are relatively lightweight, conserving transportation energy use. Low-density polyethylene (LDPE) has been used by many to modify asphalt cement and to improve the properties of bituminous mixes as an asphalt modifier in order to improve the performance and extend the lifetime of asphalt pavement mixtures. LDPE is a thermoplastic polymer consisting of long chains of the monomer ethylene. It is created through polymerization of ethane (Kahovec et al. 2002).

III. SCOPE OF WORK

The use of MDA of concrete has economical and ecological impact due large amount of waste produced annually. For structural applications of lightweight concrete, the structural efficiency is more important than only a consideration of strength. A decreased density for the same strength level reduces the self-weight, foundation size, and construction costs. The use of lightweight concrete permit greater design flexibility and substantial cost savings, reducing dead load, improved cyclic loading structural response, longer spans, thinner sections, smaller size structural members, less reinforcing steel, and lower foundation costs.

The present investigation reveals that the MDA, which can be used as part replacement of coarse aggregate in concrete and their effect on compressive strength and density properties of concrete.

III. MATERIALS

3.1 Cement

Ordinary Portland Cement (OPC) of 53 grade UltraTech conforming to IS:12269-1987 was used. The physical properties of cement used were given in Table 1.

Table 1. Physical Properties of Cement

Type of cement	Specific Gravity	Normal Consistency (%)	Setting Time in minutes		Compressive Strength in MPa		
			Initial	Final	3 days	7 days	28 days
UltraTech OPC 53	3.09	33	48	240	25.5	36	53.5

3.2 Water

Potable water conforming to IS: 3025-1964 is used for mixing.

3.3 Conventional Aggregates

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work

3.4 Melt-Densified Aggregates (MDA)

Polyethylene consumer bags were gathered from residential houses and from retail shops. The plastic waste sheet was shaped as desired, e.g., as a ball with a diameter of 30-40 mm. The melting temperature was maintained at 160°C in Muffle Furnace. The plastic waste aggregates were densified by heat treatment, which consisted of heating it at temperatures 160°C for 20 seconds in the Muffle Furnace. Then, the hot aggregate was removed from the furnace and allowed to cool at room temperature. Thus, the heating process induced changes in the physical characteristics of the plastic wastes (shrinkage) and in the microstructure. The spherical diameters of the sample plastic waste shrunk to the range of 18 – 25 mm. The shapes and textures of the samples were not homogenous or circular, but they were a mixture of angular shapes and round shapes, much like crushed stone and thus making of MDA.

Present study MDA materials of more or less 20 mm were replaced as part of conventional coarse aggregates to make mixture specimens (M_1-M_4). Generally specific gravity of LDPE was 1.05. Fig. 1 shows pictorial representation of LDPE before and after melt-densification it gives the information of size of aggregate.

3.5 Preparation of Concrete Specimens

The fresh concretes were cast into 15 cm cube molds with vibration following the procedure prescribed by ASTM, C31-84. The tests are carried out on water-cement ratio of 0.32. The concrete specimens were separated out from the mold after 24 hours of molding and kept in water for 7-28 days for curing. Average 28 days compressive strength of at least three 15 cm concrete cubes.
The control mix (M_{40}) is designed with the Indian Standard Code guidelines (IS: 10262:2009). A reference specimen without MDA was proportioned to obtain the 28-day compressive strength of 44 MPa. Other mixture specimens M1-M4 with part replacement of MDA were also proportioned. The MDA were added to the mixture in various amounts ranging between 5- 20% of weight of the conventional aggregates. Table 2 shows the mix proportion of MDA concrete and conventional concrete.

Figure 1. Pictorial representation of LDPE before and after melt-densification.

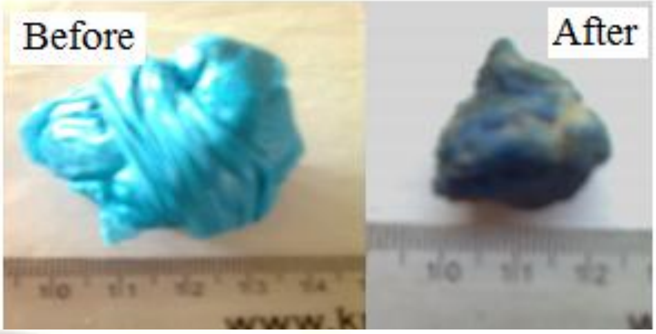

Table 2. Mix proportion of MDA concrete and conventional concrete

Parameter	**Concrete Specimen proportions**				
	Reference Mix (0%)	M_1 (5%)	M_2 (10%)	M_3 (15%)	M_4 (20%)
W/C Ratio (%)	0.32	0.32	0.32	0.32	0.32
Water (Kg/m^3)	191.58	191.58	191.58	191.58	191.58
Cement (Kg/m^3)	598.68	598.68	598.68	598.68	598.68
FA (Kg/m^3)	429.044	429.044	429.044	429.044	429.044
CA (Kg/m^3)	1147.56	1090.182	1032.804	975.426	918.06
MDA (Kg/m^3)	0	57.378	114.756	172.134	229.50
Mix Proportions (C: FA: CA: P)	1 : 0.716: 1.916 : 0	1 : 0.716: 1.820:0.095	1 : 0.716: 1.725:0.191	1 : 0.716: 1.63:0.287	1 :0.716: 1.533: 0.383

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C=Cement; FA= Fine Aggregates; CA= Coarse Aggregates; P= MDA material

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IV. RESULTS AND DISCUSSION

Table 3 shows the results of compressive strength and density for all concrete mixtures and Fig. 2 and Fig.3 shows the graphical representation of results of compressive strength and density. The density of concrete decreased with the increase in the MDA content. When 20% of the coarse aggregate was replaced with the MDA, the density was reduced from 2366 to 2290 kg/m3. This corresponds to a reduction of 3.2% in density. As expected, the reference specimen achieved 44 MPa at 28 days and the corresponding strength for concrete specimens with 5%, 10 %, 15% and 20% coarse aggregate replacements with the MDA are 40.5, 36.0, 29.5 and 25.5 MPa, respectively. An increase in MDA replacement from 0% to 20% caused the 28-day compressive strength to drop from 44 to 25.5 MPa. Therefore, an increase in part replacement of 20% resulted in 44.31% reduction in the compressive strength and part replacement of 5% resulted in 7.95% reduction in the compressive strength, for that reason, the strength of MDA concrete is controlled mainly by its percentage replacement of MDA.

Table 3. Results of compressive strength and density for all concrete mixtures.

Specimen type	W/C ratio	Density (Kg/m3)	Compressive strength (MPa)	
			7 days	28 days
Reference	0.32	2366	38.0	44.0
M_1	0.32	2342	35.0	40.5
M_2	0.32	2324	30.5	36.0
M_3	0.32	2296	26.0	29.5
M_4	0.32	2278	19.5	25.5

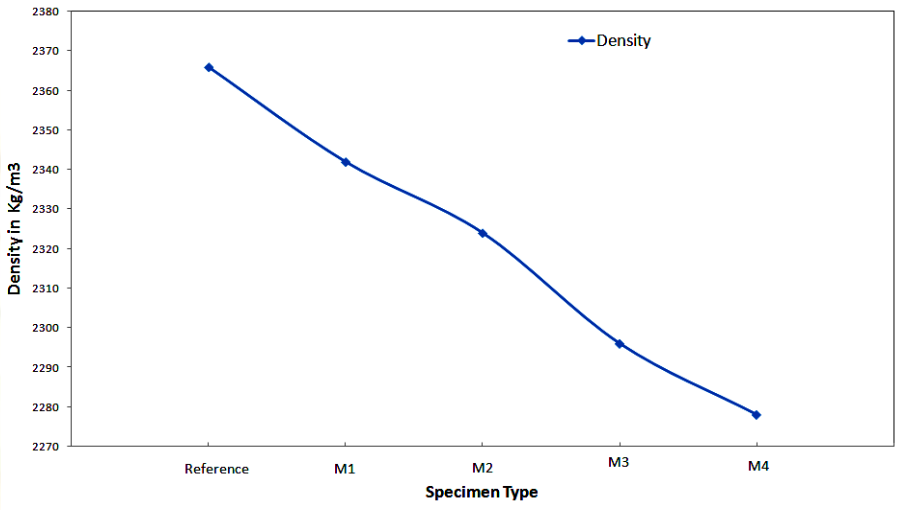

Figure 2.Results of compressive strength for all specimens

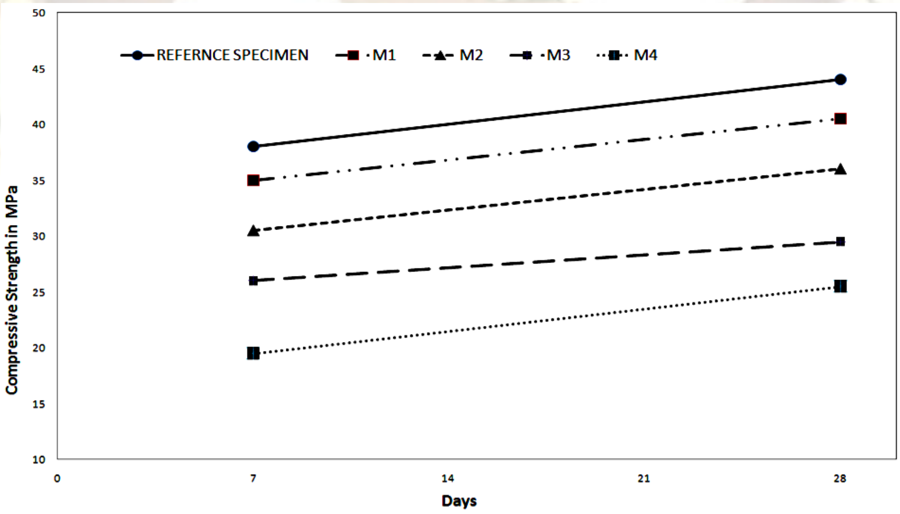

Figure 3. Results of Density for all specimens

CONCLUSIONS

The MDA can be used to replace part of conventional aggregates in a concrete mixture. This contributes to reducing the unit weight of the concrete and attracts a growing ecological interest especially due to the increasing volume of polymer wastes. The use of post-consumer plastic waste as MDA in concrete will be one of the safe disposal method.

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