

Compressive Strength Index of Different Types of Light Weight Plastic Aggregate Concrete

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Abstract

The study on potential usage of industrial waste products and other wastes in the concrete is going on globally. In this study an attempt has been carried out to explore the utilization of plastic wastes in concrete. Four different types of Light Weight Plastic Aggregates (LWPA) are prepared from the non-recyclable plastic bags of size 20-40 μ thick by heating on a container at 120-150 oC. 100% replacement of Natural Aggregate (NA) with different types of LWPA is carried out, based on trail mix a suitable mix proportion was arrived. The compressive strength and Ultrasonic Pulse Velocity (UPV) tests for different types of plastic aggregate and conventional aggregate concrete are carried and outcomes are analyzed. The replacement of NA with LWPA reduces the density of the concrete and overcome the double issue of safe disposal and raw material shortage of non-recyclable plastic wastes.

Keywords: Compressive Strength, Density, Light Weight Plastic Aggregate, Non-Recyclable Plastic

1. Introduction

Concrete is one of the most widely used materials next to water. Presently Indian concrete industry is producing about 300 million m³ of concrete every year and it is expected, that it shall reach about 580 million m³ by 2022¹. For the production of this huge amount of concrete, a huge amount of natural resources are required, which diminishes the country side. In this regard alternative materials are required to substitute the conventional materials in the concrete. Here an attempt has been carried out to utilize waste plastic of thickness 20-40 μ as the material for the preparation of different types of LWPA.

Plastic is a widely used material in the world. It is used in almost all the industries and its production and usage is

increasing rapidly due to its feasibility, low cost and long life. The waste produced also increasing with its usage. Among the various types of plastic waste generated, the largest component of the plastic waste is Low Density Polyethylene (LDPE) at about 23%, followed by 17.3% of high density polyethylene, 18.5% of polypropylene, 12.3% of polystyrene, 10.7% of polyvinyl chloride, 8.5% polyethylene terephthalate and 9.7% of other types⁴. At present about one trillion plastic bags are being used around the world every year^{1,2}. Regarding the resistance to temperature, Behjat Tajeddin et al, 2009⁵, proved that the mass loss of LDPE starts at 310.44 °C. Above 400 °C, mass loss takes place very rapidly and the quantity of LDPE residue is very low (0.33%) due to further breakdown of it into gaseous products at higher temperature.

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As the usage is increasing and no proper economical methods for recycling LDPE wastes is accessible. Its safe disposal is a major problem in developed cities as plastic is stable and non-biodegradable material. Most of the LDPE wastes are generated from the domestic households and packing industries and most often they end up in open burning or land filling. If this plastic wastes are utilized for the preparation of LWPA it would reduce the density of concrete and overcome the double issue of safe disposal and raw material shortage.

2. Method of Preparation of Aggregate

In the present study four different types of plastic aggregates were prepared. Firstly the non-recyclable plastic bags of size 20-40 μ were gathered then heated on a container at 120-150°C for about 15-20 seconds, the plastic material gets densities then it is cooled at room temperature for about one minute. The shape of the aggregates obtained was non-homogeneous and the texture obtained was slightly irregular. The size of the aggregates prepared was in the range of 12.5-20 mm down. The different types of aggregates prepared are shown in the Figure 1. For the preparation of first kind of Plastic Aggregates (PA1) the plastic material was directly heated on the container. For second type (PA2) the plastic material was heated on the sand passing 600 μ and retained on 300 μ IS Sieve and for third type (PA3) it was heated on sand passing 300 μ IS Sieve. For the fourth type (PA4) it was heated on the scrap iron pieces passing 2.36 IS Sieve which is usually obtained from threading operation in lathes. The microscopic images of the four different types of plastic aggregate are shown in the Figure 2. UV spectrometer analysis was carried out for the plastic material before and after heating. From the UV spectrometer analysis we came to know that there are a lot of variations in the physical and micro structure characteristics of plastic material before and after heating. The behaviour of material before and after heating for different wavelengths is shown in the Figures 3 & 4.

3. Materials

OPC of 53 Grade conforming to IS: 12269-1987, portable

water conforming to IS: 3025-1964, fine aggregate conforming to zone IV, coarse aggregate of size 20mm down conforming to IS: 383-1970, different types of prepared LWPA and super plasticizer are used in the present study.

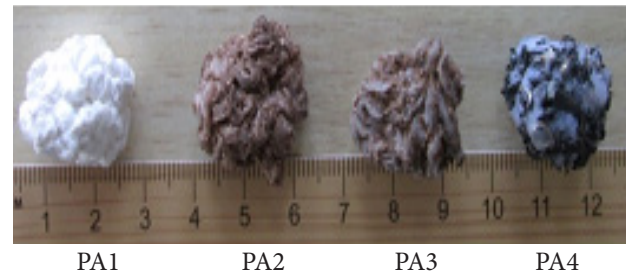
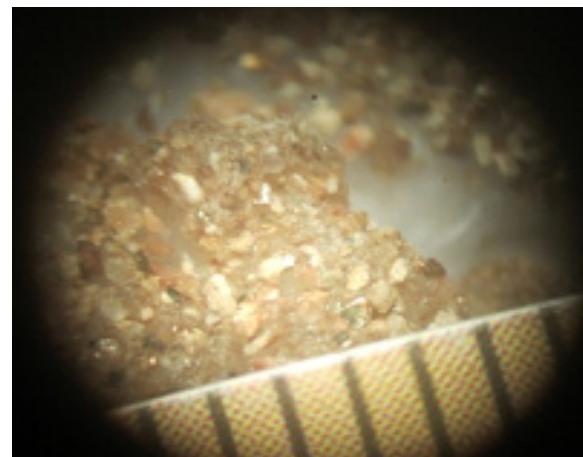


Figure 1. Different types of LWPA.



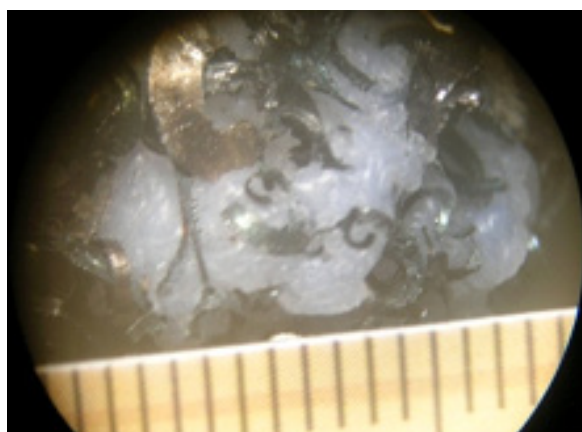
PA1



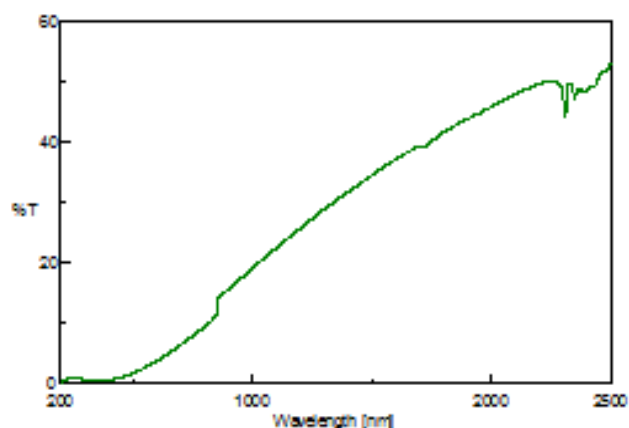
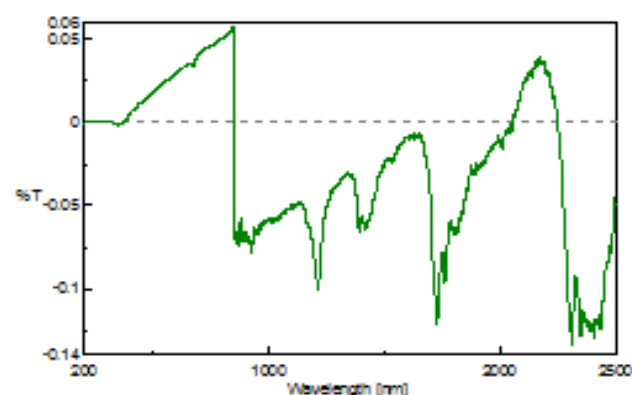
PA2



PA3



PA4

Figure 2. Microscopic images of different types of LWPA.**Figure 3.** Shows behaviour of plastic material for different wavelengths before heating.**Figure 4.** Shows behaviour of plastic material for different wavelengths after heating.

4. Properties of Aggregate

As the prepared plastic aggregate was very light in weight, irregular in shape and was floating on water as the specific gravity of first two types was less than water. The determination of specific gravity by regular procedure was not possible. So the specific gravity was determined by using shrinkage limit apparatus, which is based on Archimedes' principle. The specific gravity, water absorption and maximum packing for all the four types of aggregates are shown in the Table 1.

Table 1. Effect of nitrogen levels on vegetative parameters of potato

Property	PA1	PA2	PA3	PA4
Specific gravity	0.76	0.95	1.05	1.5
Water absorption %	0.0	3.48	4.11	2.33
Max packing %	48.1	46.7	48.5	45.6

The maximum packing for all types of aggregates were found to get the most economical mix proportions.

5. Experimental Procedure

In the present study 100% replacement of NA with different types of LWPA of same grade was done to know the behaviour of the LWPA instead of NA in concrete. Based on many trials a mix proportion was obtained taking 40% LWPA and 60% matrix by volume with a w/c ratio of 0.35. The mix proportions are tabulated in the Table 2. For each type 4 cube specimen were casted,

2 cube specimens for 7 days and 2 cube specimens for 28 days to determine the respective compressive strength. Before that UPV test was conducted to determine the pulse velocity. The compression test and UPV test was conducted simultaneously to determine the variation of dynamic modulus of elasticity with incremental loading.

The dynamic modulus of Elasticity (E_d) is determined by ultrasonic pulse velocity, where the dynamic modulus is directly proportional to the pulse velocity. The pulse velocity is determined by measuring the time required to pass the ultrasonic pulse through a known length of the specimen. The dynamic modulus of elasticity was calculated by the equation given below

$$E_d = \frac{v^2 \rho}{v^2 \rho}$$

Table 2. Mix proportions

Parameter	Mix Proportions				
	PA1C	PA2C	PA3C	PA4C	NAC
W/C ratio	0.35	0.35	0.35	0.35	0.35
Cement kg/m ³	450	450	450	450	450
Water kg/m ³	157.5	157.5	157.5	157.5	157.5
FA kg/m ³	787.52	787.52	787.52	787.52	787.5
CA kg/m ³	-	-	-	-	1111.9
PA kg/m ³	308.40	381.44	426.08	608.68	-
C : FA :	1:1.75:	1:1.75:	1:1.75:	1:1.75:	1:1.75:
CA : PA	0:0.68	0:0.85	0:0.95	0:1.35	2.47:0

C=Cement, FA=Fine Aggregate, CA=Coarse Aggregate, PA=Plastic Aggregate NAC=Natural Aggregate Concrete

Where E_d is the dynamic modulus of elasticity, v is the pulse velocity and ρ is the density of hardened concrete⁹.

6. Result and Discussion

The density, compressive strength, ultrasonic pulse

velocity test results, compressive strength to density ratio and relative compressive strength of different LWPA and NA concrete are tabulated in the Table 3. The density of light weight concrete depends on the density and the amount of LWPA considered. In all the above cases considered the density of concrete is less than 2000 kg/m³ which is within the limits of structural light weight concrete.

With the increase in density there is increase in the ultrasonic pulse velocity and thus dynamic modulus of elasticity. The pulse velocity for all the four different type of LWPA concrete is in between 3.0-3.5 Km/s which indicates the concrete is of medium quality grade.

The variation of compression strength of four different types of LWPA and NA concrete for 7 and 28 days are shown in the Figure 5.

The variation of compressive strength and density with respect to different types of LWPA and NA concrete is shown in Figure 6.

The compressive strength, Compressive strength to density ratio and relative compression strength are increasing with the increase of density and surface property of aggregates as shown in the Table 3. This is due to improvement of transitional zone between aggregate and matrix. But there is no much improvement in the compressive strength as plastic is ductile and deforms more when load is applied as shown in Figure 7. Hence for all types of LWPA concrete the crack was propagating around the aggregates as shown in Figure 8.

The percentage relative compressive strength at 7 days is more than 28 days. It is because till 7 days the strength relies on the hydration of cement but between 7 to 28 days the strength relies on transitional zone between aggregate and matrix.

The variation of dynamic modulus of elasticity with respect to increasing loading is almost linear as shown in Figure 9. For all types of plastic aggregate concrete.

Table 3. Comparison of results

Mix	7days					28 days				
	Density (Kg/m ³)	CS in MPa	UPV velocity Km/s	CS/Density ratio	Relative CS in %	Density (Kg/m ³)	CS in MPa	UPV velocity Km/s	CS/Density ratio	Relative CS in %
NAC	2458	26.3	3.676	1.091	100.00	2463	39.1	4.008	1.618	100.00
PA1C	1711	11.2	2.785	0.667	42.59	1719	14.3	3.086	0.848	36.57
PA2C	1785	14.2	2.985	0.811	53.99	1791	16.1	3.289	0.916	41.18
PA3C	1849	14.9	3.125	0.821	56.65	1855	17.7	3.246	0.973	45.27
PA4C	1970	16.9	3.144	0.874	64.26	1972	22.8	3.412	1.179	58.31

CS = Compressive Strength

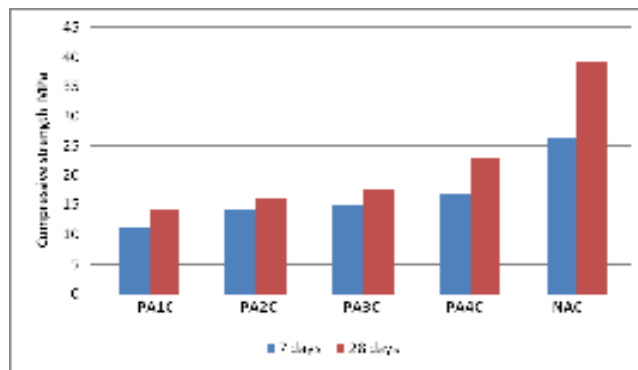


Figure 5. Variation of CS of 7 and 28 days for different types of LWPA and NA concrete.

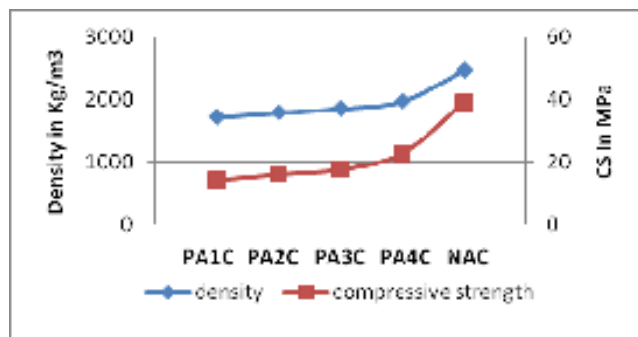


Figure 6. Variation of density and CS for different types of LWPA and NA concrete.

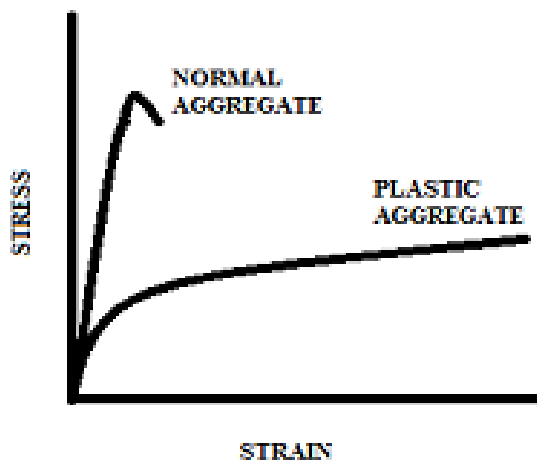


Figure 7. The variation of Stress v/strain for LWPA and NA.

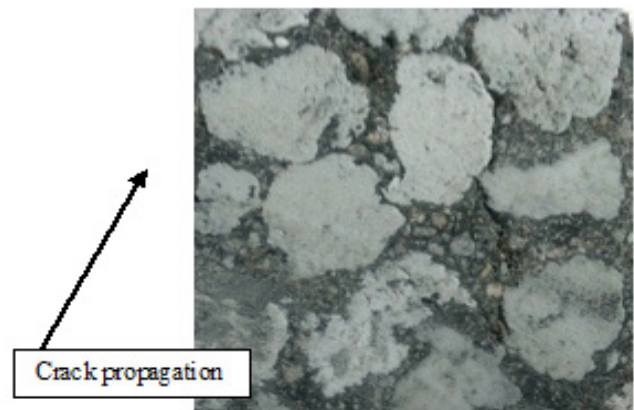


Figure 8. Crack propagation around the LWPA.

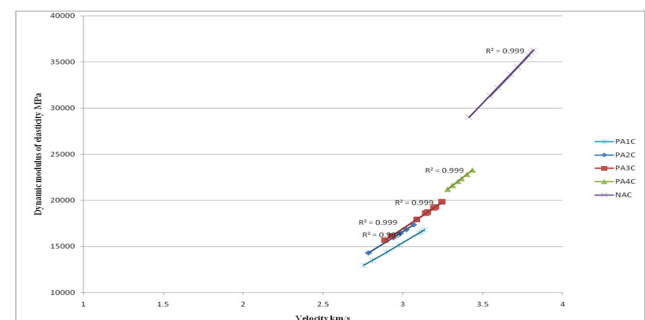


Figure 9. Variation of dynamic modulus of elasticity for incremental loading.

7. Conclusion

- LWPA concrete reduces the unit weight of concrete, which would help in reduces the dead load.
- The density of concrete is less than 2000 kg/m³ which is within the limits of structural light weight concrete.
- LWPA has lower thermal conductivity than the natural aggregates. Hence it exhibits better thermal insulation properties than conventional concrete
- With the change of surface properties also there is only a slight increase in the strength, this is because the plastic aggregate is ductile and deforms more when load is applied
- It would be an environmental friendly method for safe disposal of non-recyclable plastic waste.
- It would overcome the issue of safe disposal and raw material shortage.
- However further study is required to know the behaviour at higher temperatures

8. References

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