Reuse of Polycarbonate Waste Coated Aggregates - Bitumen Mix Composite for Road Application

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Abstract— Disposal of polycarbonate waste has become a serious problem for human health and waste plastics are burnt for disposal which causes environmental pollution. Polycarbonates are not eco-friendly and as they are non-biodegradable. Generally, it is disposed by way of land filling or incineration of materials which are hazardous. To deal with the problem, study on use of polycarbonate waste as partial replacement to bitumen in flexible pavement is considered in the present work. Road surface with neat bitumen can cause bleeding in hot climate, may develop cracks in cold climate, possess fewer load bearing capacity and can cause serious damages because of higher axle load in present conditions due to rapid infrastructure development and also natural materials quantity is declining gradually. Thus the cost of extracting good quality of natural material is increasing. The present study consists of an experimental approach towards effective waste management, finding alternative to conventional materials in flexible pavements and can promote value addition to the waste plastic. The objective of work is to investigate the effect of polycarbonate waste in flexible pavement and to suggest the optimum percentage of bitumen that can be replaced by polycarbonate waste for the improvement of roads with substantial saving in cost.

Key words: Bitumen, Polycarbonate, Aggregates

I. INTRODUCTION

Poly (Bisphenol-A) carbonate is a plastomer thermoplastic material and it is non-biodegradable. Bisphenol-A (BPA) is the molecular building block for polycarbonate plastics and epoxy resins. Around 86 tonnes of polycarbonate waste are disposed annually in kodungaiyur dumping yard, Chennai.

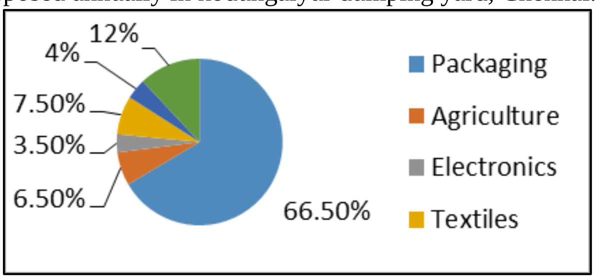

Fig. 1: Polycarbonate Consumption in Various Industries

BPA based polycarbonate plastics are made into a variety of common consumer goods, such as five gallon water bottles, infant feeding bottles, compact discs and digital versatile discs, impact-resistant safety equipments, eyeglass lenses, sports equipments, household electronic gadgets, foundry casting and medical devices. Bisphenol - A has the potential to have a wide range of health effects such as decline in human sperm count and quality, genital abnormalities, early onset of puberty in females, effects on fertility, miscarriage and birth defects, increasing neurobehavioral problems, high blood pressure, stroke, pulmonary blood clot, asthma, pancreatitis, liver cirrhosis, etc., BPA can also enter the environment either directly or indirectly leaching from plastic, paper and metal waste in landfills. Ubiquity makes BPA an important soil pollutant. BPA can currently be found also in municipal waste water. It affects reproduction in aquatic and terrestrial annelids, molluscs, insects, crustaceans, fish and amphibians. In singapore coastal lines the BPA was detected on the maximum concentration is 2.47μg/L and the BPA concentration as high as 25 μg/L have been measured, particularly new point sources such as outfalls from pulp mills, sewage treatment plants or landfills. The study focus on the disposal of polycarbonate wastes without impacts of human and environment. Hence the investigation was carried out with baby bottles and five gallon water storage containers which contain polycarbonate. It is a valuable dumping alternative for the highway sector.

a) Five Gallon Water b)Medical Device Bottle

c) Compact Discs Digital Versatile Discs d) Baby Bottles

Fig. 2: Polycarbonate Wastes

II. NEED FOR STUDY

BPA-containing polycarbonate plastics are included in the "other" category, and are not recycled. There are no waste collection provisions for these products and no recycling programs and it also occurs for many reasons such as inconvenience and various waste management practices such as collection, recycling, and redistribution costs are so high. The price of virgin resin has recently been 40% lower than that of recycled resin. The Environmental Protection Agency, the Food and Drug Administration, the Consumer Product Safety Commission and the Occupational Safety and Health Administration have insufficient information to set environmental standards that would assure health and environmental protection. There is still a lot of research to be done to determine what levels of BPA are safe for adults, children, and animals as well as the environment. Polycarbonate wastes are clear and rigid which contains the monomer of BPA with non- biodegradable and non-recyclable. BPA having insufficient data on how much BPA leaches from polycarbonate baby bottles and what level of BPA exposure may be harmful to a child. BPA leaching from baby bottles in the last ten years, studies have varying detection limits, migration scenarios, and other assumptions, and have reached inconsistent conclusions. The most recent study published by Environment California Research and Policy Center found that BPA leached from five brands of polycarbonate baby bottles leaches up to 10 ppb and the FDA's found the amount of BPA migrate at room temperature from polycarbonate water containers in to bottled water at levels as high as 4.7ng/l, the migration levels are increased with respect to time. Flexible pavements with bituminous surfacing are widely used in India. IRC SP-53 2010 guidelines are allowed to use the various types of polymer and rubber based modified bitumen in road construction to avoid the distress like rutting, cracking, bleeding, shoving and potholing of bituminous surfacing due to the over loading and seasonal variations and enhance the life of the surfacing and extend the time of the next renewal when compared to the conventional bitumen. This study is based on the disposal of polycarbonate waste in eco-friendly way, increasing the strength of flexible pavement, and reducing the cost of bitumen.

III. Objectives

The objectives of the study are

1) To assess the polycarbonate waste generation in dumping yards of Chennai.
2) To assess the possibility of utilizing water storage container as modified bitumen in asphalt mixtures for the construction of flexible pavements.
3) To dispose the polycarbonate wastes in eco-friendly way.
4) To reduce the cost of conventional materials by using poly carbonate waste for the replacement of natural bitumen.

IV. Materials and Methods

A. Bitumen – VG 40 Grade:

The bitumen used in this study is VG 40 grade which is most commonly used for road construction in India. This bitumen sample is collected from Hincol private limited, irungattukottai.

B. Aggregate:

The natural aggregate used in this study have been collected from various quarries near Chennai. The tests were carried out on aggregate the results obtained are shown in Table I.

C. Polycarbonate wastes

Polycarbonate wastes were collected from kodungaiyur waste dumping yard, Chennai. Wastes were crushed by using plastic crusher machine and sieved to the size of below 4.75mm.

D. Mixing procedure:

Plastics waste like baby bottles, five gallon water storage containers are made out of Polycarbonates are crushed and sieved to the size of below 4.75mm by using shredding machine. The aggregate mix is heated to 1750C and then it is transferred to mixing chamber. Similarly the bitumen is to be heated up to a maximum of 1600C. This is done so as to obtain a good binding and to prevent weak bonding. During this process monitoring the temperature is very important. At the mixing chamber, the shredded plastics waste is added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 seconds. It gives an oily coated look to the aggregate. The plastics waste coated aggregate is mixed with hot bitumen (VG- 40 Grade). The mixing temperature maintained was about 160oC. Then this final resulted mix is used for laying roads.

Fig. 3: Polycarbonate Waste In To Crushed Form

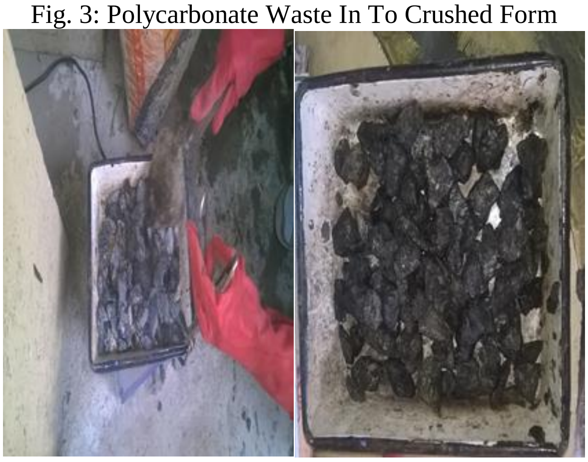

Fig. 4: Preparation of Plastic Coated Aggregates

V. RESULTS AND DISCUSSION

A. Polycarbonate waste characterization:

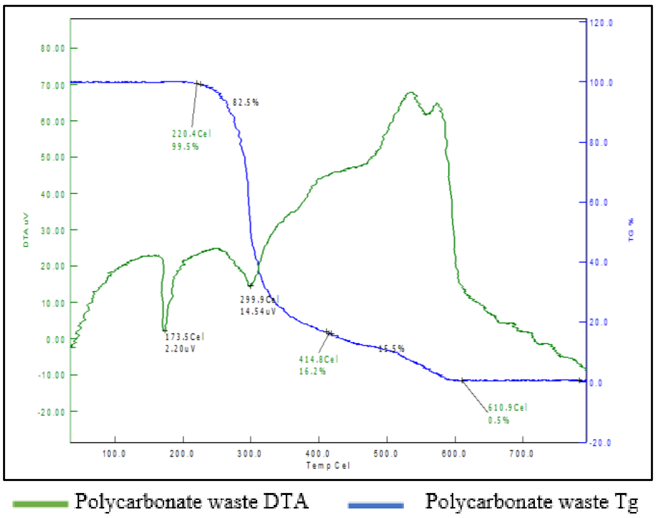

Fig. 5: Thermal Analysis Graph

Fig. 5 consists of two curves are Thermo gravimetry curve and Differential Thermal Analysis curve. Initially, the DTA curve will go down when the temperature increases and it attains the softening point of polycarbonate plastics at the range of 173.50 c and the TG curve will also go down when the temperature increases and it attains the decomposition point of polycarbonate plastic at the range of 220.40c with initial loss such as 0.5% and the temperature increases frequently, it attains the ignition point of polycarbonate plastics at the range of 610.90c with final loss such as 99.5%.

B. Aggregate characterization:

S.No.	Test	Specification	Plain aggregate	Plastic coated aggregate			
				1%	2%	3%	9 %
1	Specific Gravity	-	2.69	2.73	2.78	2.82	
2	Aggregate Impact value	Max 27 %	26.87	23.26	19.32	17.09	
	Aggregate Crushing value	Max 30 %	24.52	21.54	20.09	16.55	
	Abrasion value	Max 35 %	36.55	34	31.02	26.78	
4	Water absorption	Max 2%	2.79	1.8	1.18	0.85	
5	Coating and Stripping of Bitumen Aggregate mix	Min retained Coating 95%	97				100

Table 1: Physical Properties of Aggregate

Table 1 shows significant improvement in the strength properties of the aggregates change to coated with molten plastics. This is due to the fact that when the plastic was coated over the aggregate, the aggregate surface is covered with the thin film of polymer. The film of polymer also fills the pores at the surface and there is no water absorption. Hence there is significant improvement in the general properties of the aggregate like specific gravity, impact value, crushing value, abrasion resistance and stripping value.

C. Normal Mix:

Marshall test was conducted on three normal mix specimens prepared with bitumen contents of 4 percent, 4.5 percent, 5 percent and 5.5 percent respectively. Various Marshall parameters computed are shown in Table II.

% by Wt. of Binder Content	Bulk Specific Gravity, g/cc	Theoretical Specific Gravity, g/cc	Air Voids %	VMA, %	VFB, %	Stability (kg)	Flow (mm)
4 %	2.381	2.53	5.84	14.89	60.77	1287	3.20
4.5 %	2.404	2.51	4.25	14.48	70.64	1326	3.65
5%	2.406	2.49	3.50	14.82	76.41	1268	4.24
5.5%	2.411	2.48	2.62	15.04	82.56	1245	5.22

Table 2: Volumetric Properties of Normal Mix

D. Optimum Binder Content:

A Graph is plotted for Binder Content (% by Wt. of the aggregate) versus % Air voids as shown in fig. The binder content corresponding to 4 % air voids is considered as Optimum Binder Content.

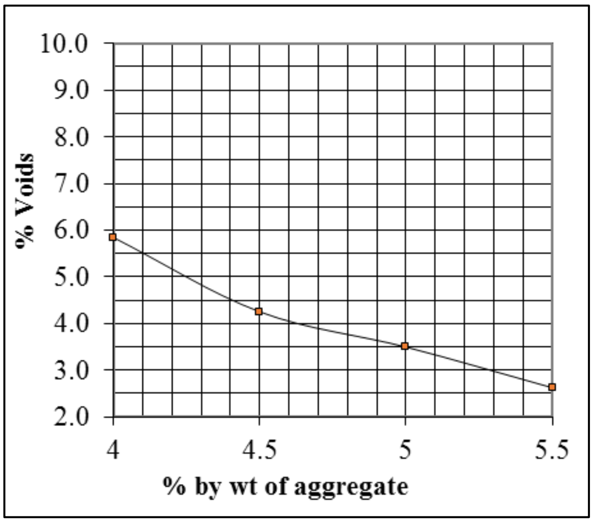

Fig. 6: OBC Obtained for Normal Mix

From plot, OBC obtained for normal mix is 4.62 % by wt. of the aggregate.

S.No	Property	Test Results at OBC
1	Stability in kg	1335.360
2	Flow in mm	3.758
4	Voids in Mix (Va) (%)	3.869

5	V.F.B. (%)	73.013
6	V.M.A. (%)	14.382
7	Binder Content by Wt.of Mix (%) for (minimum)	4.42
8	Binder Content by Wt.of Aggregate (%)	4.62

Table 3: Volumetric Properties of OBC for Normal Mix

E. Plastic Modified Mix:

Marshall Test was conducted on four plastic modified mix specimens prepared with varying plastic contents of 3 percent, 6 percent, 9 percent and 12 percent respectively. Various Marshall parameters computed for plastic modified mixes are shown in Table IV and Fig. 7

S. No	Property	3% of PC	6% of PC	9% of PC	12% of PC
1	Stability in kg	1368	1454	1551	1388
2	Flow in mm	3.79	3.84	3.96	4.13
4	Voids in Mix (%)	3.81	3.69	3.53	3.77
5	V.F.B (%)	73.42	74.06	74.93	73.63
6	V.M.A (%)	14.33	14.22	14.08	14.29
7	Binder Content by Wt.of Mix (%)	4.28	4.16	4.03	3.88
8	Binder Content by Wt.of Aggregate (%)	4.48	4.34	4.20	4.06

Table 4: Marshall Properties of Various Polycarbonate Modified Asphalt Mixes

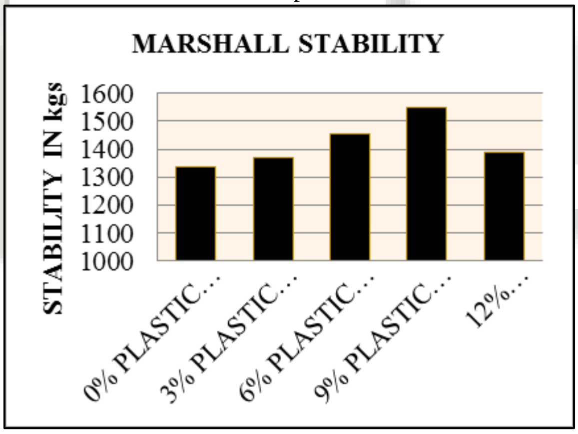

Fig. 7: Marshall Stability Values for conventional and Polycarbonate Modified Asphalt Mixes

From the Table and Figure, it was inferred that the values obtained for Marshall Stability Value (kN) and Flow Value (mm) were obtained for plain aggregate bituminous mixes and polymer coated aggregate bituminous mixes of varied compositions are 3%, 6%, 9% respectively.

From the experimental results, the percentage of the waste plastics coated increases the Marshall Stability value is also increased. Higher percentage of plastics (more than 9%) results in lesser compatibility with bitumen and lesser bonding resulting in lower Marshall Stability Value. So the 9% replacement of polycarbonate modified Asphalt mix was found to be very much satisfactory.

F. Cost Analysis:

From an environmental and economic standpoint, the use of waste plastic as a bitumen-modifying agent may contribute to solving a waste disposal problem and to improving the quality of road pavements. Table 4.11 shows the economic analysis of pavement and the total savings due to use of plastic waste.

S.No	Description	Qty	Cost in Rs.
1.	Cost of plastic waste	1 ton	5000.00
2.	Cost of bitumen	1 ton	36, 844.00
3.	Cost of bitumen required per Km road (without plastic)	10 tons	3, 68, 440.00
4.	Cost of bitumen required per Km road of 3.75 m width (with 9% plastic)	10 tons	3, 39, 780.40
5.	Total savings per Km of road	-	28659.60

Table 5: Cost Analysis Of Per Km Flexible Pavement

VI. CONCLUSION

The following conclusions are drawn from the study:

1) Optimum plastic content was obtained as 9 percent by weight of bitumen.
2) The Marshall Stability value of plastic modified mix was found to be 16.14 percent more than that for the normal mix which indicates an increase in load carrying capacity.
3) Aggregate Impact value of control specimen was 26.87%. It reduced to 23.26% for PCA 1%, 19.32% for PCA 2% and 17.09% for PCA3%. Reduction in value was 13.43% for PCA 1%, 28.09% for PCA 2% and 36.39% for PCA 3%. This shows that the toughness of the aggregate was increased to face the impacts.
4) Crushing Value was reduced from 24.52% to 21.54%, 20.09%, and 16.55% for PCA 1%, PCA 2%, and PCA 3% respectively. Value reduced by 12.15% for PCA 1%, 18.06% for PCA 2% and 32.50% for PCA 3%. Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low.
5) Specific Gravity of the aggregate increases from 2.69 for control specimen to 2.73 for PCA 1%, 2.78 for PCA 2% and 2.85 for PCA 3% due to plastic coating. This shows that coated aggregates are more strength when compared to plain aggregates.
6) Stripping Value was reduced from 3% for control specimen to nil for PCA 9%. This shows that coated aggregates are more suitable for bituminous construction than plain aggregates.
7) Water Absorption is also reduced to 1.8%, 1.18% and 0.85% for PCA 1%, PCA 2% and PCA 3% from 2.79% for control specimen.
8) Los Angeles Abrasion Value was reduced from 36.55% to 34%, 31.02%, and 26.78% for PCA 1%, PCA 2%, and PCA 3% respectively. Value reduced by 7% for PCA 1%, 15.12% for PCA 2% and 26.73% for PCA 3%. This indicates the hardness of the aggregate.
9) Replacement of bitumen with plastic reduces the cost of construction is around Rs. 28700 per km of single lane road as on date.

By using plastics-waste coated aggregate in road construction, helps to reduce the need of bitumen by 9%, increase the strength and performance of road, avoid use of anti stripping agent, avoid disposal of plastic waste by incineration and land filling and ultimately develop a technology, which is eco friendly. This process gives value to plastic waste which would sustain the effective waste management Increased traffic conditions will and are reducing the life span of roads. Plastic roads are means of prevention and ultimately will be the cure. It will save millions of dollars in future and reduce the amount of resources used for construction.

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