Bituminous Paving Block - A Solution to Plastic and Demolished Concrete Waste Management

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Abstract

In today's world plastic, construction and demolition (C&D) waste is generated at an enormous rate. An efficient method is required to minimize the hazards causing due to these wastes. In this research work an attempt is made to manage these waste by utilizing them in manufacturing of bituminous paving block, in which natural aggregates are replaced by recycled concrete aggregate(generated by construction and demolishing waste)in various proportion with addition of 0.5% PET bottle fiber by weight of aggregate. Samples were casted and test results were evaluated to determine the approximate proportion of natural aggregates to be replaced by recycled concrete aggregates to develop low cost products, an efficient way to manage the waste and also to replace conventional concrete paving blocks.

Keywords: *PET bottle waste, C&D waste; recycle concrete aggregate, bitumen paving block s*

1. Introduction

Increase in Municipal Solid Waste (MSW) is an ever-growing environmental hazard as it contributes to pollution. Plastic waste is major constituent in MSW. Plastic when buried in landfill can leach harmful chemicals. India generates about 15,342 tons of plastic per day (TPD) out of which 9,000 tons of plastic is collected and recycled. Also India's second most populous state, Maharashtra, which produces plastic products of worth Rs. 500 billion, notified a state wide ban in April 2018 on most single use of plastic[7].

Every year India generates billion tons of construction and demolition (C&D) waste which needs to be reuse effectively otherwise which causes direct and indirect hazard to living being and careless dumping contributes to massive land pollution. Due to advanced techniques, the activity of demolition of structures is growing significantly, which generates huge amount of C&D waste. In this study the C&D waste mainly cement concrete is used in the form of aggregates by crushing and grading in various proportions. This type of aggregate which can be used as a substitute for natural aggregate is called as recycled concrete aggregate (RCA). To minimize PET bottle waste, shredded Polyethylene Terephthalate (PET) bottles used in bituminous mix for making paving blocks.

2. Literature Review

Jyoti Prakash Giri et.al. (1) explored the use of RCA and waste polyethylene from milk packaging (WPMP) in bituminous paving mixes. As RCA is highly water absorptive it was treated with bituminous emulsion to reduce its water absorption. WPMP was shredded in fragments with sizes less than 4.75mm. Mix design was carried out and six types of samples were made namely natural aggregates (NA), recycle course aggregate (RCA), pre-treated RCA (PRCA), PRCA with plastic (PRCAP), recycle course aggregate with plastic (RCAP) and natural aggregate with plastic (NAP). After observing the results, it was concluded that PRCAP mix shows highest stability, highest indirect tensile strength and highest flow number value and thus is most suited for pavement

construction. Abbaas Kareem et.al.(2) performed an experimental study to enhance the engineering properties of RCA. In this study RCA coated with cement slag paste (CSP) first and then a second layer of Sika Tite- Bituminous emulsion was applied to reduce its water and bitumen absorption and enhance the durability. It was observed that double coating decreases water absorption of DCRCA by 12.3% and 26.1% compared to uncoated RCA and RCA coated with CSP respectively. It was concluded that double coating effectively enhances moisture resistance and increases stiffness significantly.

A.R. Pasandin et.al.(3) studied the properties of hot mix asphalt (HMA) with RCA. The use of RCA in HMA was found to be suitable for flexible road pavement. The resistance to action of water decreases with increase in percentage of RCA. Fine RCA gives greater results for Marshall stability test in comparison with course aggregates. As RCA is added in HMA stiffness gets lowered due to low resilience of the attached mortar. Pre-treatment for RCA is very much essential to enhance the properties of aggregates by coating RCA with sealants like bitumen emulsion or liquid silicone resin. J. P. Forth et.al.(4) experimented the development of a novel construction unit (bitublock) composed entirely of recycled and waste aggregate bound with bitumen binder. Three samples such as pure bitumen sample, coarse aggregate mix, and fine aggregate mix were prepared. The effects of aging and curing process on compression strength of bitublock were found out by compacting the samples at 8-12 MPa pressure. The range of compressive strength during heat curing indicates the behavior of bitumen binder.

B. Shanmugavalli et.al.(5) studied the different proportions of plastic waste with quarry dust, course aggregates and ceramic waste are used and attempt was made to achieve replacement of cement with plastic waste. The aim of this project is to reduce the cost of paver blocks compared to that of concrete paver blocks. After 24 hours, plastic paving blocks of size 215x115x6 mm were tested under compression testing machine. However, the results of compression test are lower than conventional paving block therefore we can use it for non-traffic and light traffic roads. Amir Modarres et.al.(6) studied the use of waste PET plastic bottles in bitumen mix to modify it properties. A comparative study was done for PET bottles used as a bitumen modifier and SBS (styrene butadiene styrene) which is a conventional polymer additive. Materials used were PET bottles which were shredded & sieved in chips (0.425-1.18 mm), SBS in required amount & bitumen. PET bottle dosage was added directly from 2% to 10% to the mix in dry method of mixing. Fatigue Test, Resilient Modulus, Indirect Tensile Strength tests were performed to evaluate the properties of modified mix. PET as an additive showed better results of fatigue and stiffness than normal mix but not compared to SBS as an additive.

3. Materials

3.1 Polyethylene Terephthalate (PET)

Bottles made of PET can be recycled to reuse the material and to reduce the amount of waste going into landfills. PET is semi porous and absorbs molecules of the food or beverage contained, and the residue is difficult to remove. Most recycled bottles are used to make lower grade products, such as carpets. To make a food grade plastic, the bottles need to be hydrolysed down to monomers, which are purified and then re-polymerised to make new PET. Melting point of PET bottles is 260°C. Shredded PET bottles used in this study shown in fig.1 (a)

3.2 Demolished Concrete Aggregates

In C&D waste, demolished concrete waste aggregates are in major proportion. This waste includes coarse aggregates, fine aggregates and powdered dust. These aggregates have high absorptive properties and weak in strength compared to natural aggregates. Hence, pre-treatment is needed before its reuse to bring its properties to specific standards. Pre-treatment can be done by using various bitumen emulsions, resins or

cement slurry. In this study RCA was mixed with cement slurry in the ratio of 2:3 (2 parts of water and 3 parts of cement), which enhances properties of recycled concrete aggregates. 53 grade OPC cement was used to make a slurry.Pretreatment reduces absorptive properties and increases strength significantly as per various research papers.

Figure 1. a) Shredded PET Bottles b) Recycled Concrete Aggregates- 12.5mm, 10mm, 8mm, and 6mm (from left)

3.3 Bitumen Emulsion

Emulsified Bitumen usually consists of bitumen droplets suspended in water. This dispersion under normal circumstances would not take place, since bitumen and water don't mix, but if an emulsifying agent is added to the water the asphalt will remain dispersed. Most emulsions are used for surface treatments. Emulsions enable much lower application temperatures to be used range from 45°C to 70°C. This is much lower than the 150°C to 190°C used for hot mix asphalt cements. The lower application temperatures will not damage the asphalt and are much safer for field personnel. Emulsifying agents are the chemicals used to stabilize the emulsion and keep the bitumen drops separated from one another. There are two types of bitumen emulsions namely cationic emulsion and anionic emulsion. As the aggregates are silicious which is anionic in nature we would use cationic emulsion for its pre-treatment.

3.4 Bitumen

Bitumen is important constituent material in the bituminous mix as it acts as a binding material which makes the bituminous mix adhesive. This composition involves mixing of fine and coarse aggregates such as sand, gravel and crushed rock with bitumen acting as a binding agent. There are various grades of bitumen used in pavement construction depending upon favorable conditions for construction. Bitumen now-a-days mainly classified accordingly to viscosity grading (VG). In Maharashtra mainly VG-30 grade bitumen is used which has absolute viscosity of 2400 poise at 60°C, kinematic viscosity of 350°C and range of penetration value of 50-70 at 25°C as per Bureau of Indian Standards (BIS).

4. Methodology

4.1. Mix Proportion

As per MoRTH specification an excel sheet was prepared which relates every material used in bituminous paving block with varying proportions. Mix proportion and other details shown in table 1 below. Tests were carried out are as per MoRTH specifications.

Table 1 Mix proportion

Volume of bituminous block (in m^3)	0.245 x 0.125 x 0.063 = 0.00214
Bituminous concrete density (in kg/m^3)	2050
Total weight of block (in kg)	4.395
Ratio of RCA:NA	50:50
Total weight of aggregate(in kg)	3.955
Weight of RCA(in kg)	1.978
Weight of NA(in kg)	1.978
Total weight of bitumen (7%) (in kg)	0.439

4.2. Tests carried and paving block manufacturing process

Following are the tests taken on aggregates:

1. Aggregate Impact Value Test.
2. Aggregate Crushing Strength Test.
3. Specific Gravity and Water Absorption.

Following are the tests taken on bitumen:

1. Penetration Test on Bitumen.
2. Ductility Test on Bitumen.
3. Softening Point of Bitumen.

Process of manufacturing of block:

1. Decided the mix proportion as per the specification.
2. According to the gradation table, wt. of the aggregates calculated was taken into the vessel.
3. These aggregates were kept in the oven for heating at 150 to 175 °C.
4. Quantity of bitumen was calculated according to the mix proportion and was heated up to 150 °C.
5. Aggregates when heated up to required temperature were taken out from oven and hot bitumen was added to it in measured amount.
6. While the materials were mixed thoroughly, plastic was added to it in small amounts according to its wt. calculated as per its proportion.
7. The prepared mix was filled in to the mould of size 24.5cm X12.5 cm X 6 cm in layers and each layer was tamped as shown in fig.2 (d).
8. The top plate was placed and material was compacted by 75 blows of rammer (The temperature of the mix should not fall below 100 °C).Finally demoulding was done when the mix dropped to room temperature.

Figure 2. a) Pouring of bitumen b) Mixing of materials, c) Filling of mould Compaction of block (from left)

Finally the paving block was testing under compression testing machine to check the load carrying capacity.

5. Results

The average aggregate impact value for RCA and PRCA was found 26.14 & 27.37 respectively, which is satisfactory for roads as per MoRTH specification. Aggregate abrasion value (ACV) for RCA and PRCA was 28.28 & 29.19 respectively and for rigid pavement it is within limits but IRC and MoRTH have not provided any specific ACV for flexible pavement. As per MoRTH specification specific gravity of coarse aggregates used in road construction ranges from about 2.5 to 3.2. As per experimental analysis the specific gravity of both RCA and PRCA lies within 2.5 to 2.65. Specific gravity of PRCA is greater than RCA and water absorption % was less due to cement slurry coating.

Average penetration value of bitumen is 33.67, which lies between 30 to 40. Hence, grade of bitumen is 30/40. This type of bitumen can be used for warm regions. The Ductility value for bitumen was found 48cm and softening point test temperature found 48°C.Hence such bitumen can be used for the regions where average temperature is less than 40°C.

Following table 2 and figure 3 indicates the compressive strength results for various samples tested under different proportions of RCA & NA.

Table 2. Compressive Strength Test Results for Various Mix Proportions

Sample No	Load in KN	Area (mm^2)	Compressive Strength (MPa)
Compressive strength test results for RCA 30% and NA 70%			
1	335	30625	10.94
2	343	30625	11.20
3	321	30625	10.48
Compressive strength test results for RCA 50% and NA 50%			
4	260	30625	8.49
5	273	30625	8.91
6	267	30625	8.72
Compressive strength test results for RCA 70% and NA 30%			
7	215	30625	7.02
8	206	30625	6.73
9	219	30625	7.15

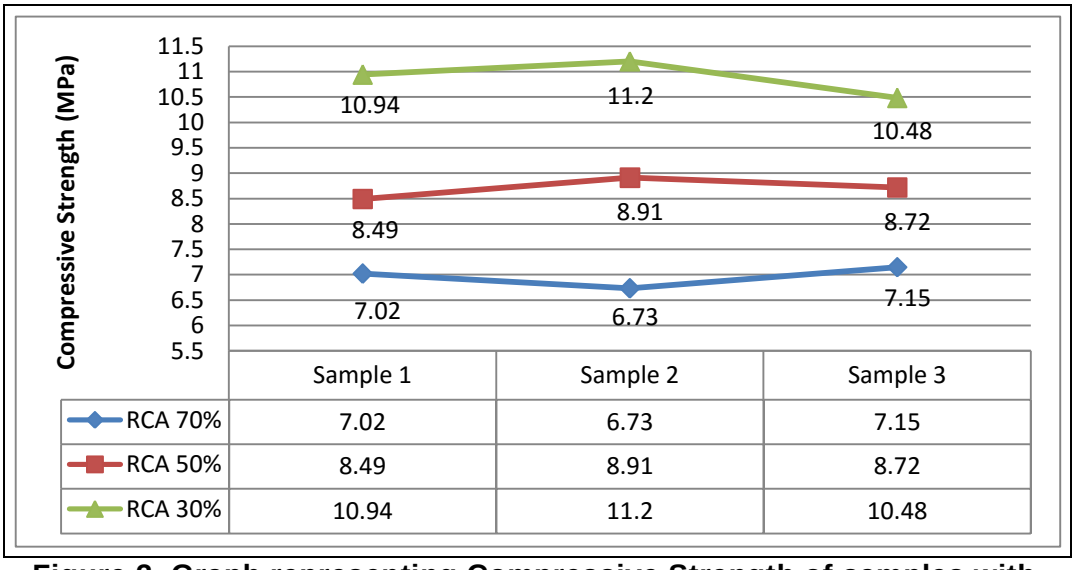

Figure 3. Graph representing Compressive Strength of samples with different RCA proportions

6. Conclusion

There was no significant change observed in the properties of RCA and PRCA. Thus, coating with cement slurry is not an effective solution for pre-treatment.

It was observed that replacement of natural aggregates by recycled concrete aggregates more than 30% reduces the required strength of paving block (i.e., 10-15 MPa). Thus, natural aggregate replacement with RCA can be effective up to 30%.

It is estimated that cost of designed bitumen paving block is Rs.11where as concrete paving block of same size is Rs.17 hence it is cost effective compared to conventional blocks used for pedestrian pavement. Each bituminous block consumed 2 no. of PET bottles of 500ml volume. So there is an effective waste management of both plastic and recycled concrete aggregate.

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8. References

8.1. Journal Article

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8.2. IS Codes

[1] Specification for road and bridge work (fifth revision, 2013 by Ministry of Road Transport and Highways)
[2] I.S 2386 (part III) 1963 (Reaffirmed 1997)
[3] I.S 2386 (part IV) 1963 (Reaffirmed 1997)
[4] IS 1203-1978
[5] IS 1205-1978
[6] IS 1208-1978