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Study on Plastic Coated Aggregate used in Bituminous Concrete

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Abstract

A synthetic man-made material that contains different types of organic polymers having heavy molecular weight such as polyethylene, PVC etc. when it is soft, it can be easily moulded to any form. And when it turns hard, it becomes rigid or slightly elastic in nature and it is called as plastic. Plastic takes a long time to degrade because of that it is durable also, this long time to degrade is because plastic can easily resist the natural process of degradation. There are two types of plastic 1) Thermoset and 2) Thermoplastics. Thermoset plastics are that kind of plastic which once set cannot be reversed by the means of heat. Whereas thermoplastics are those which can be reversed by providing heat to it.

Keywords: Organic polymers • Thermoset plastics • Bituminous concrete

Introduction

According to studies conducted, plastic has a life period of 4500 years with being unchanged on earth. There is a rise in the demand and generation of the plastic due to increasing population. Essentially from household level this is a huge generation of plastic waste. Almost about 5% of municipal solid waste has plastic of several forms, which is toxic for the nature and human being. To reduce the effect of toxicity of the plastic waste several experiments were conducted. One of them is use of plastic in the road construction. Experiment at several places can widely indicate the plastic can be used with bitumen and aggregate to provide extra durability to the pavement. The major factor of using plastic with the bitumen for the construction of road is it increases the life and smoothness of the road not only that it also makes the construction more economical, environment efficient and friendly. Any kind of material added to bitumen or mix to improve properties of the Bituminous road are called as modifiers, plastic act as a modifier to the mix, and the road constructed by adding plastic as a modifier is called as plastic road. Further stripping of road due water coming to contact is also resolved. According to studies higher the percentage of plastic used, lower is the need of bitumen. And most importantly it increases the melting point of the road made by bitumen. The abrasion and slip resistance of flexible pavement is improved significantly due to the use of plastic waste in the flexible pavement. There is a specified mixing time, mixing temperature and modifier content for all different kind of polymers, if not followed the mix bitumen will not exhibit good quality and performance in situ. Utilization of plastic waste in constructive and efficient way

is the basic aim or the basic intention.

However the main objectives are: 1) To coat aggregate with the plastic waste material, 2) To check the coated aggregate property, 3) To check the properties of bitumen mix with coated aggregate. Since 2000, the postulation of use of waste plastic for the construction of bituminous flexible pavement has been there in India. Bitumen is a binder which gets coated over aggregate in the construction of flexible pavement. The basic properties are to improve the durability and strength of road pavement which eventually increase the life of the road [1].

The plastic waste has majority of polymers as polyethylene, polypropylene, polystyrene and these are the polymers which show adhesive properties in molten state. The coated plastic aggregate and bitumen with modifier as plastic form better material for road/pavement construction and it can be seen in Marshall Stability valve and suitable Marshall Coefficient is higher for the mix. Therefore we can say that utilization of plastic waste in the construction of flexible pavement can be one of the best and easy way or method for disposal of waste plastics. Many factors suggest that use of plastic/polymer coated aggregate is better than the use of polymer modified bitumen.

The basic components of bituminous mix are bitumen and aggregates. Then going forward the aggregate is divided into three parts depending on their size *i.e.* coarse aggregate, fine aggregate and filler fractions. The following are the description of the materials used in this study.

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Coarse aggregate

For coarse aggregate, it should give out good impact and abrasion value and crushing strength also. All the stresses, due the wheels and load are delivered by the coarse aggregate. Resistance to wearing due to abrasion is one the main function of the coarse aggregate (Figure 1).



Figure 1. Portion of mix retaining on 2.36 mm sieve.

Fine aggregate

Due to coarse aggregate, there are no of unfilled voids these void are filled by fine aggregate. Therefore we can understand the function of fine aggregate that is to fill the void of coarse aggregate. The portions of aggregate which passes 2.36 mm sieve and retains on the 0.075 mm sieve were selected as fine aggregate. Crushed stone and natural sands are example of fine aggregate [2].

Plastic materials

Usually on the basis of chemical structure of the polymer's main chain and side chain, plastic is classified. Halogenated, acrylics, polyester plastics etc. are some important groups in these classifications. The types of plastics include:

- PET, polyethylene terephthalate
- HDPE, High-density polyethylene
- PVC, polyvinyl chloride
- LDPE, low-density polyethylene

Classification of polymer waste includes:

Polyethylene: LDPE (Low Density Poly-Ethylene)-Most easily available form of Low Density Poly- Ethylene is carry bags present in the store, these are very thin. HPDE (High Density Poly-Ethylene)-Generally high density poly-ethylene are basically in form of market bags, containers etc.

Polypropylene: These types of plastics are more like solid plastics depending on the use and industry needs. It is easily available in the form of plastic bottles and mat sheets etc.

Bitumen

For this research and study we use asphalt binder 60/70 and 80/100. The following properties should be followed by the bitumen of this study 1) Selection of grade of bitumen should be on the climatic

conditions and past performance, and 2) All kind of certification and clearance should be there regarding the sample.

Methodology

This particular study is divided into different stages-collection of waste polythene, mixing of optimum quantity of waste polythene and finding optimum results for the prepared sample. Collection of the waste plastics from roads and household garbage bins and rag pickers. For this project work house hold polythene was majorly collected, like used milk bags, used store polythene bags etc. the distribution of the plastic waste was based on the thickness and cleaned by washing by hot water for three to four times. After this, the clean waste is then dried and the cut into tiny pieces of size 2 mm maximum. The smaller the size of the polythene, the more is the chance of proper and good mixing.

The aggregate is heated and on controlled gas stove for few min. the polythene was added to the aggregate and some aggregate test are conducted after that bitumen is heated up to it melting points and then it is mixed and Marshall stability valve test is conducted [3].

Mixing-procedure

Mixing of the ingredients (aggregates and polymers) was done by following the procedure given below: 1) Required amount of aggregate has been taken in the pan 2) Then the aggregate is heated to temperature of 160°C evenly 3) Weighted and shredded polythene are kept in separate container 4) To maintain the temperature, the aggregates are heat on the stove for few minutes 5) The polythene was added to the aggregate and mixed for 2 minutes (Figure 2).



Figure 2. Aggregate is heated to temperature of 160°C and then polythene was added to the aggregate.

Test conducted: aggregate test

Impact value test: 1) Objective-Determination of impact value for plastic/polymer coated aggregate. 2) Theory-Toughness of a material or aggregate is the property of material or aggregate to resist impact imposed upon it. This impact is basically imposed on the aggregate by the movement of vehicles on road, which eventually causes breaking-down of smaller pieces from the aggregate which may eventually degrade the road quality. This impact value is calculated to measure the resistance of aggregate to sudden impact and shocks. The test is conducted as per IS-2386(IV)-1963. 3) Procedure-Step 1-Sieving of aggregate, passing through 12.5 mm and retaining on 10 mm sieve. Step 2-Till 1/3rd of depth of the cylindrical steel container/cup is filled and

compact it 25 No. of blows. Step 3-In the same manner repeat the step 2 till the cylindrical cup is full. Step 4- Strick of the excess aggregate from the top. Step5-Firmly fixes the cup in the base position of the impact value machine and give a gently compact the sample with 25 no. of blows with a tampering rod. Step 6-The hammer is raised till the lower face is at a height of 38 cm above the sample upper surface. Give the sample, impact of 15 blows with interval of not less than 1sec between two successive falls. Step 7-The Crushed/impacted aggregate is removed from the steel cup/ container and the crushed aggregate is then sieved through 2.36 mm IS sieve. Then weigh the fraction retained on the sieve (Figure 3 and Table 1).

and temperature. The penetration distance of the needle is measured in $1/10^{th}$ of M. Procedure includes the following steps: Step 1test Test sample has to be prepared-softening of hard bitumen by heating of bitumen till 90°C, to maintain homogeneity and free from air void/bubbles and water content through stir is required. Then the melted sample is poured into the container and then it is allowed to cool in atmospheric temp [4]. 20°C to 30°C for an hour, and it should be protected from dust and impurities, then place the container with sample to the water bath at 25°C ± 1°C. Step 2-To a depth of container fill water in the transfer dish from water bath, and then put it upon the stand of penetration apparatus. Step 3-The penetration needle has to be cleaned with benzene, dry it and

Observations	Total weight of dry sample (W_1 gm)	Weight of portion passing 2.36 mm sieve (W_2 gm)	Aggregate impact value (%)= $W_2/W_1 \times 100$
4%	558	68	13.492
3%	558	78	13.97
0%	560	106	18.92

 Table 1. Observations for aggregate impact value.

Los Angles abrasion test: Hardness property of aggregate/ material is tested by this test. The key value of carry out Los angles abrasion test is to calculate the percentage wear of aggregate/material due to relative rubbing action between the steel balls and aggregate, these steel balls are abrasion chargers. Procedure is as follows: Step 1-The sample has to be oven dried to achieve a constant weight; it should be oven at temperature of 105°C-110°C. Step 2-Then place the abrasion charger and the test sample inside the Los Angles abrasion testing machine. And the rotation speed of the machine should be 20-33 revolutions/minute. And it has to be rotated for 500 Revolutions. Step 3-Start the machine and the rotation will start, maintain the peripheral speed. Step 4-After the Completion of the test, Discharge the sample tested to a pan. And the first thing to do is sieve the sample on sieve coarser than 1.70 mm IS sieve. Step 5-The sample amount coarser then the 1.7 mm IS sieve is then oven dried to achieve a constant weight, then the weight is taken (Figure 4 and Table 2).



Figure 3. Aggregate impact value Graph.

Table 2. Observations f	for abrasion value.
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Observations	Total weight of dry sample (W_1 Kg)	Weight of portion passing 1.70 mm sieve (W Kg)	Aggregate Abrasion value (%)= $W_2/W_1 \times 100$
4%	5	1	20
3%	5	1.130	22.6
0%	5	1.41	28.2

Bitumen test

Penetration test for Bitumen: Hardness and consistency of bituminous material is measured by penetration value. It is the vertical distance traversed or penetrated by the point of a standard needle into the bituminous material under specific conditions of load, time,

attached the load. Step 4-Make adjustment to have a proper contact with the surface of sample. Step 5-The initial reading of the dial has to be noted down. Step 6- For exactly 5 seconds release the needle to allow penetration. Step 7-Now measure the distance penetrated (Figure 5 and Table 3).



Figure 4. Graph showing abrasion value.



Figure 5. Penetrometer to measure dial reading.

Table 3. Tests conducted for penetration value.

Penetrometer dial reading	Test 1	Test 2	Test 3
Initial	140	209	275
Final	209	275	345
Penetration Value	69	66	70

Note: Mean penetration value-68.33, Readings are taken as units of penetration Where, unit=(1/10) mm *i.e.* If penetration value is N, N=68.33, Distance penetrated=(N/10) mm, Distance Penetrated=68.33/10=6.833 mm.

Ductility test for bitumen: The property to lengthen under traffic load without getting broken in pavement construction. Estimation of ductility test is done in distance of elongation in Centimeter (cm). This test provides the measure of bitumen adhesive properties and stretch ability of bitumen. For the flexible pavement, it is necessary that binder should form a thin ductile film around aggregate so that to provide a perfect interlocking. Procedure includes following steps: Step 1-At a Temperature of 75°C to 100°C heat the bitumen sample to make it in melt and become in liquid form.

Step 2-Pour the Melted Bitumen in the mould and place it on the brass plate. Step 3-Keep the brass plate assembly inside the water bath after 30 minutes to 40 minutes for $\frac{1}{2}$ an hour. Step 4-Remove the sample from the water bath and strike off the extra sample with a hot knife. Step 5-Removing the sides of the mould hook the mould or chip carefully on to the machine without causing any initial strain. Step 6-Start the machine, it pulls the clip at a rate of 50 mm/minute in horizontal direction. Step 7-Note the Distance in centimeter (Table 4).

Table 4. Tests conducted for ductility.

SNo	Details of sample	Test 1	Test 2	Test 3	
1	Initial Reading (W_1 cm)	0	0	0	
2	Final Reading (W_2 cm)	69	70.5	72.6	
3	Ductility (W1-W2)	69	70.5	72.6	
Note: Mean -70 7					

Results and Discussion

On analyzing several test result at different places and on the above methodology, we will know discuss various aspect regarding the polymer coated aggregate.

Aggregate test

Aggregate impact value: As we see in the test the impact values of

the vehicle over the pavement. The percentage of wear and tear is given by this test. After conducting this test it showed that plastic coated aggregate had less percentage of wear and tear as compared to plain aggregate [5]. According to the test for 4% plastic coating the abrasion value is 20% whereas for 3% is 22.6% and for 0% (plain aggregate) is 28.2%. This shows major improvement in accordance to wear and tear of aggregate (Table 6).

Table 5. Experiment conducted for 0%, 3% and 4% of plastic (The above data suggest the plastic coated mixture is less susceptible to fracturing in the occurrence of heavy load or large force).

Observations	Total weight of dry sample (W_1 gm)	Weight of portion passing 2.36 mm sieve (W_2 gm)	Aggregate Impact Value (percent)= $W_2/W_1 \times 100$
4%	558	68	13.492
3%	558	78	13.97
0%	560	106	18.92

different aggregate sample coated with plastic, for 4%-13.492, For 3%-13.97 and For 0%-18.92%, these values shows the impact of plastic coating over the aggregate, There is an improvement in the aggregate impact value, due to the coating of plastics over the aggregate, additionally we can say that coating poor quality aggregate can make them useful.

Bitumen test

Penetration test: As per the test on Bitumen we can see the average penetration value is 68.33Which as per the IS Code 73:2006 2006; Grade -A65 (Table 7).

Table 6. Experiment conducted for 0%, 3% and 4% of plastic (This data suggest us that the plastic coating improves abrasion resistance very efficiently).

Observations	Total weight of dry sample (W ₁ Kg)	Weight of portion passing 1.70 mm sieve (W Kg)	Aggregate Abrasion value (percent)= $W_2/W_1 \times 100$
4%	5	1	20
3%	5	1.130	22.6
0%	5	1.41	28.2

Thereby it eventually increases the quality of flexible pavement. Therefore we can also say that the toughness of the aggregate also increases to face the impact (Table 5).

Los angles abrasion value: Wear and tear over the surface of the bitumen pavement is caused due to repeated movement of **Ductility test for bitumen:** As per the test on Bitumen we get the ductility value of given bitumen is 70.7cm, so tested bitumen sample is suitable for highway construction and pavement construction as per IS code. The Grade of given bitumen sample is S45/S65/S90 (Table 8).

Table 7. Tests conducted for penetration value.

Penetrometer dial reading	Test 1	Test 2	Test 3
Initial	140	209	275
Final	209	275	345
Penetration Value	69	66	70

Note: Mean value -68.33, Readings are taken as units of penetration Where, 1 unit=(1/10) mm, *i.e.* If penetration value is N, N=68.33, Distance penetrated=(N/10) mm, Distance penetrated=68.33/10=6.833 mm, Hence the given bitumen 60/70 grade, in the above table 69, 66 and 70 are shown as tenths of a mm, in fact 6.9 mm, 6.6 mm and 7.0 mm penetrations respectively.

S No	Details of sample	Test 1	Test 2	Test 3
1	Initial Reading (W_1 cm)	0	0	0
2	Final Reading (W ₂ cm)	69	70.5	72.6
3	Ductility (W1-W2)	69	70.5	72.6

Table 8. Tests conducted for ductility.

Note: Here the mean value of ductility is coming out to be 70.7 cm.

Comparison

The comparison between ordinary and polymer or plastic road using different properties (Table 9).

Table 9. Comparison of roads using different properties.

of pavement. As per the considerations the performance of road is far better than normal road when plastic coated aggregates are used (Figure 6).

Properties	Ordinary	Polymer/Plastic roads
Binding property	Good	Better
Softening point	More	Less
Penetration point	Less	More
Tensile strength	Less	High
Stripping	More	No
Seepage of water	Yes	No
Durability of roads	Good	Better
Cost of pavement	Normal	Less
Maintenance cost	More	Almost nil
Environment friendly	No	Yes

Under my project, the plastic content I have picked up is 0%(which is the plain aggregate), 3%, and 4% which eventually increase the quality of the aggregate and its resistance to impact, and resistance to wear and tear, which will help in increasing the quality of pavement, thereby increasing the durability of pavement. Which carry forward the plastic content value study, which eventually helps in increasing the strength and durability of the bituminous pavement. The helps in utilization of waste plastic materials even more [6]. This study must be carried forward by doing, Marshall stability test which due to unavailability of equipment was not carried forward which is eventually so the quality



Figure 6. Performance of normal road and plastic road.

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Because of plastic coating there is an increase in the bonding and increase in the contact area, due to which there is a better binding of bitumen and plastic coated aggregate [7]. As there is an increase in the plastic content there is reduction in the amount of voids which protects the aggregate form the moisture absorption and oxidation of bitumen eventually enhances the road quality. Results show that there is a reduction in formation of ruts, pot holes on the pavement. Durability and load withstand capacity of the pavement is also increased by adding the polymers [8].

Looking at all the results of the tests-

For aggregate impact value there is an reduction of about 5%-9% in the mass loss, just by adding about 3% of plastic, so increasing this percentage of plastic content can eventually decrease the amount of mass loss.

During Los Angeles abrasion test we noticed a reduction of about 9%-10% mass loss. This concludes that hardness of aggregate has increased.

Moisture/water absorption is reduced to nil for all the plastic coated aggregates.

Conclusion

In the conclusion we can say that, there will be a reduction in the need of the bitumen by 10% to 12% with increase in strength of the pavement and better performance of the pavement with the use of plastic or polymer. It also helps in avoid use of extra agents like anti stripping agent etc. regarding the environmental factors it helps in avoid disposal of waste by incineration and land filling. And ultimately we can say it is ecofriendly and developed method to increase the performance of pavement and reduce the amount of plastic waste. Plastic Roads means of prevention and ultimately will be the cure.

Since aggregate is performing well under different situation and tests which predicts the performance of pavement constructed by using this plastic coated aggregate but to perfectly acknowledge the properties and stability of the pavement, Marshall stability has to be conducted which was not conducted due to unavailability of equipment. But as per the study till date plastic coated aggregate can be an effective way to increase the durability, strength and performance of pavement, and it also help in reducing the amount of plastic present in outside environment, which makes it more environment friendly.

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