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Plastic modified Flexible Pavement Construction

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Abstract - *Municipal solid waste management is the severe issue nowadays due to the increasing population and modern era of life. MSW is classified into two types as organic and inorganic waste. From this two types the inorganic waste is the harmful one to the nature. That inorganic waste contains plastic, rubber, metal, glass, etc. This paper deals with the effective management of plastic waste, which is a threat to the environment. In this study, the plastic waste is properly utilised in the Pavment Construction by an eco-friendly manner. The plastic which is collected at the dumping yard is separated out from MSW, cleaned and cut down into small pieces. The shredded plastic of size 2.36 to 4.75 mm is then Coated over the aggregate and this aggregate is utilised for the flexible pavement construction. Which results in strengthening the pavment characteristics, helps in reduction of overall cost of the road length and the main advantage is the significant reduction of quantity of plastics from the dumping yards.*

Key Words: **plastic coated aggregate, polymer modified bitumen, plastic waste, aggregates, bitumen, flexible pavement, roads, environment, eco-friendly.**

1.INTRODUCTION

Solid waste is classified as agricultural Waste, Municipal solid waste, Biomedical Waste, Industrial waste and hazardous waste. Focusing on the Municipal solid waste it is classified into Organic and Inorganic waste. And Inorganic waste contains different materials such as plastic, glass, rubber and metal, etc. Particularly dealing with Plastic Waste which is a severe issue these days. Therefore, the need of today's era is to manage the plastic waste properly. For managing the waste plastic properly, as a civil engineer we have come up with the idea to utilise the waste plastic in the construction of road. As on March 2017, India is having a road network of 58,97,671 km the second largest in the world. The 85% of passenger traffic and 65% of freight is carried by road transport only. This clearly shows that roads are playing major contribution in overall transportation process in India. Roads are basically classified into two types flexible and rigid pavement and we can utilised the waste plastic in both the type of road construction by coating it over the aggregate.In this paper we have dealt with the flexible pavement construction using plastic waste as modifier in the construction material. The plastic scrap which is collected in a dumping yards can not be used directly. So that plastic scrap is need to be shredded with the help of Plastic Shredder machine.

1.1 Pavement

Pavement is a durable surface material laid on an area which supports vehicular traffic. It is hard surface covered by concrete or asphalt or bitumen. The primary function of pavement is to provide a means of transportation of goods, vehicular traffic and of people. Construction of pavement acts to the overall development of that area by enhancing the communication route of different area.

Pavement are classified into two types as flexible pavement and rigid pavement:

Flexible Pavement: A flexible pavement is a structure that distribute the load to subgrade upon the aggregate interlock, particle friction and cohesion for stability by maintaining intimate contact with a consecutive layers. Load is transfer from grain to grain contact of granules material in a compressive way.

Rigid Pavement: Rigid Pavement are those which distribute the stress concentration uniformly to the area under slab. Load is transmitted through beam action of the slab. The beam strength is able to bridge over the localized subgrade failures and areas of inadequate support.

1.2 Waste Plastic Modifiers:

The properties of aggregate and bitumen used in the road construction has been modified because of addition of plastic with it. The waste plastic is collected from dump yard consist of carry bags, water bottles, milk packets, glasses, cups and etc. which can be used as an certain replacement of construction material like bitumen and aggregate. This waste plastic cannot be used directly, it has to be shredded into pieces of size ranging from 2.36mm to 4.75mm then only this plastic can be melted to formed coating over aggregate and to blend with bitumen.

Processing details

Plastic has to be collected from dump yards, garbage truck, compost plants or from school collection program or waste has to be purchased at Rs.5 to 6 per kg from scrap keepers. The collected waste plastic litters like use and throw cups, thin pins, carry bags has to be sorted, dusted and wash if necessary and has to be dried if necessary. Then waste plastic has to be shredded from shredder machine. Mixing of aggregate, bitumen and waste plastic mix in a central mixing plant. The aggregate are heated at

160 degree C similarly bitumen is also heated at 160 degree C, 8 to 10% weight of bitumen is replaced by shredded plastic in the conveyor belt or a mechanical device is developed which can blend this plastic with construction materials. The better control of temperature and homogeneous mixing of this material can be achieved in the central mixing plant to have a uniform coating and heated bitumen spraying.

Description about plastics

Plastic waste can be classified according to their physical properties and their chemical sources. Plastic on their physical properties classified as thermoplastic and thermosetting material. Thermoplastic can be molded into desired shape on heating and applying pressure and transform into solid on cooling. Thermosetting material once shaped cannot be remolded on application of heat. Thermoplastic material at temperature ranging from 130 degree to 140 degree C. In temperature range 130 degree to 180 degree there is no gas evaluation by thermoplastic but the same can evaluate gas can higher temperature of 180 degree C and can also lead to thermal degradation. This waste plastic can be easily blended with bitumen at temperature 155 degree to 165 degree C.

2. TEST CONDUCTED ON PLASTIC COATED AGGREGATE AND POLYMER MODIFIED BITUMEN:

1. Aggregate Impact Test

The resistance of aggregate to fracture under repeated loading impact and the toughness of stone aggregate is evaluated by this test. A hammer of weight 14kg is used and 15 blows of hammer are given on aggregate sample and the crushed aggregate are made to passed on 2.36mm sieve. The aggregate impact value is the percentage of crushed aggregate sample are passing from 2.36mm sieve to the total weight of aggregate sample taken. The value should not exceed 30% for wearing coarse of pavement, 35% of bituminous macadam and 40% of waterbound macadam. The voids and air cavities of the aggregate were reduced by coating of waste polymer over it. The plastic film formed over the aggregate can prevent its cracking under load stone toughness was increased the impact value of plastic coated aggregate which is less in comparision with plain aggregate.

2. Marshall Stability Test

This is the basic study on the stability of mix with the application of load. Marshall Stability value is the indicative of load withstanding property of flexible pavement. By making the use of plastic coated aggregate in the Marshall Stability test the various properties of the aggregate are found to be varied in comparison with normal aggregate. The Marshall Stability value of the mix was found to be increased by the use of plastic coated aggregate. As the Marshall stability value was increasing by increasing the percent of plastic coating over aggregate. More than the 15% of plastic should not be used on coating over aggregate. This can result in lesser bonding and also less compactibility with bitumen finally given lower Marshall Stability value. Marshall Stability value was found to increase by use polypropylene rather than polyethylene. In the preparation of this sample 10% of bitumen can be replace by plastic effectively. The tolerance value of voids filled with bitumen and the flow value are within the limit. The Marshall Stability value of plastic coated aggregate bitumen mix is 50% to 60% higher than polymer modified bitumen. The property of bitumen and aggregate were modified in terms of higher bulk density and specific gravity: The voids filled with mineral aggregate, air voids, voids filled with bitumen and the voids of mix were reduced by making use of plastic with aggregate and bitumen.

3. Los Angeles Abrasion Test

The percentage wear between aggregate sample and steel balls used as abrasive charges is evaluated by this test. The value should be less than 30% for pavement. The difference in weight of original sample and sample retained on 1.7mm sieve is reported as a percent of original weight due to relative rubbing action of aggregate over steel ball and is called percent loss. As the plastic coated aggregate shows the better resistance to wear and tear due to load coating of polymer over aggregate gives better adhesion properties. This polymer coating reduces the roughness of aggregate ultimately in resulting in reduction in abrasion over its surface.

4. Stripping value

The binding strength of aggregate and bitumen can be determined by stripping value. In this test the bitumen coated aggregate sample is immersed in water at 40degree C at 24 hours. The water penetrates into the voids of aggregated resulting the peeling of bitumen this results in loosening of aggregate and potholes and strength of bond between aggregate and bitumen can be determined by stripping value. No pores are formed due to the uniform coating of polymer film over the surface of aggregate. The polymer not only strongly binds with the bitumen but it also reduces the voids of aggregate and binds the bitumen and aggregate together forming an organic bonding. In case of plastic coated aggregate peeling out of bitumen is nill after 96 hours showing better stripping value.

5. Soundness Test

The stability towards weathering of aggregate and its chemical resistance is determined by the soundness test. If the plain aggregate is stagnant water then the water can penetrate inside the pores. The salts present in the water can get crystalized and expand the pores during the evaporation of water and breaking the aggregate. This test directly determined the amount of voids and porosity of

the aggregates. The average loss in weight of aggregate should not exceed 12% for 5 cycles when tested with sodium sulphate. Plastic coated aggregate did not show any value for soundness. The coating of plastic has covered all the void of aggregate and that's why water cannot penetrate into aggregate so the salts cannot deposit in it that's why, plastic coated aggregate does not show any disintegration.

6. Crushing Test

This test is used to determine the resistance of aggregate to crushing under gradually applied compressive load. The aggregate sample is subjected to a uniform load at the rate of i.e, 7.5KN/Sec the value till the applied load turn to be 400 KN. The crushing value should not exceed 30% when used as a dense mix carpet. This test is performed by using compression testing machine. It is the percentage of the weight of crushed sample passing through 2.36mm sieve to the weight of the original sample taken. It is numerical index of strength of aggregate. As the polymer film is formed over the plastic coated aggregate the void and the pores are reduced that's why crushing strength of plastic coated aggregate is low.

Properties	Normal aggregate	Plastic coated aggregate
Impact Value (%)	7.89	8.03
Water Absorption (%)	0.97	0.45
Specific Gravity (%)	2.94	2.07
Abrasion Test (%)	6.18	7.81
Crushing test (%)	7.70	8.15

Table-1: The studied values of aggregate test.

7. Binding property

The plastic coated aggregate in a block showed compressive strength not less than 130 tons. This shows plastic coated aggregate has a good adhesion property .The increase in value of compression strength, bending strength shows that it can be used as binder. Polyethylene, polypropylene and polystyrene plastic shows the above properties.

8. Softening test

The temperature at which the substances attaining the particular degree of softening under specified condition of test. It is the temperature at which phase change occur in the bituminous binders. This test is performed by using ring and ball apparatus. It is temperature in 0 degree C at which the standard ball passes through bituminous sample and falls from a height of 2.5cm when heated under water of specified condition. This helps to know fluidity of bitumen before it can be used in road application.

9. Ductility Test

It is necessary that bitumen binder should formed ductile thin film around an aggregate. Ductility is determined as the distance in which the bitumen from standard brick weight mould is stretched before its breaks. This test is conducted by using ductility testing machine. The rate of cool is 50 mm/min and is conducted at a 27degree C in a water bath. Thus, it measures the adhesive property of bitumen and its ability to stretched so that the physical interlocking of aggregate with bitumen is improved.

10. Viscosity

The resistance for the flow of fluid to the internal friction is measured by this viscosity test. It is one of the property of fluid determined the time taken by a 50cc of bitumen sample to flow into a cup under specified temperature condition. The viscosity affect the ability binder to spread and fill the voids between the aggregates. Highly viscous binder cannot fill the void completely resulting in poor density of mix at the same time lower viscous binder cannot hold aggregate and acts as a lubricant. That's why it is necessary to maintain temperature for so that viscosity of bitumen binder does not fall as the temperature rise. This test is performed by using tar viscometer.

11. Penetration Test

This test is performed to determine the consistency and hardness of bitumen material. The penetration value is determined as the vertical distance travelled by a standard needle to penetrate into bituminous material under specific condition of time, load and temperature. From this test we can determine the bituminous grade of bituminous sample. The penetration distance is measured as $1/10^{th}$ of millimeter. This test is performed by using penetrometer. Bitumen grading helps us to find its suitability of its use in different climatic condition and for different type of construction.

3. PROPERTIES OF POLYMER MODIFIED BITUMEN:

Polymer modified bitumen occur performance benefit of the physical properties of bitumen are improved without changing its chemical nature. Modified bituminous binder have produced softer mixer at low service temperature to minimize thermal cracking associated with non-loading condition. Bitumen Mix have showed improvement in fatigue resistance. Overall performance of bitumen binder under heavy traffic condition and under extreme climatic condition was improved. The lifecycle cost of pavement was also reduced. Polymer modified bitumen increases viscosity and elasticity of mix at higher temperature

increase elasticity of the mix is reduces the residual stress deformation of the pavement of the pavement and also helps increase viscosity and helps to reflect deflection under loading. The elastic surface layer covers the cracks of unmodified maintaining watertight condition for the asphalt and protecting the underlying pavement. The PMB is able to without 4 to 10 times more loading cycle before its ruts out in various specified depth. This shows that PMB have a good rutting resistance and interconnecting matrix of the polymer prove the bitumen is formed. This is the matrix long chain molecules that modifies physical properties of bitumen and the addition of polymer can increase the elasticity and decrease the brittle point and increase the softening point of bitumen. This modified bituminous mix can show greater stiffness at highest temperature and high flexibility at low temperature.

Table-2: The studied values of Bitumen Test.

Properties	Plain bitumen	Polymer modified bitumen
Penetration at 25° (unit)	70	68.67
Softening point(°C)	43.75	63
Ductility (cm)	82	100
Optimum Bitumen Content	4.74%	5.02%
Marshall Stability (kN)	18.55	23.50

3.1 Optimum bitumen content

Marshall Stability Test method of mix design was used to study the properties of bituminous mix prepared with 60/70 grade bitumen and polymer modified bitumen 70-grade. Bitumen content of 4.5, 5.0 and 5.5 was taken for the preparation of specimen. It was found the optimum binder content of 60/70 grade bitumen is 4.74% whereas optimum binder content of PMB -70 Grade is 5.02%. Though the bitumen content for PMB-70 grade is higher but the stability value is 23.50 KN. This value is 27% higher than the stability value of 60/70 grade bitumen.

3.2 Advantages of polymer modified bitumen:

1. Stronger road with increased Marshall Stability Value.
2. The removal of bitumen from aggregate and there is no removal bitumen from showing the stripping value nil.
3. Potholes are not formed showing better resistance towards water stagnation.
4. Pores in aggregate have been reduced showing better bonding and binding of the mix.
5. For 1km road construction having 3.75m width 1 ton of plastic is required saving 1 ton of bitumen.
6. The use of PMB in road construction can saves Rs.5000/km. of single lane road.
7. Plastic increased the melting point of bitumen.

4. PROCESS OF BITUMEN MIX FLEXIBLE PAVEMENT CONSTRUCTION:

4.1 Dry process:

The collected polypropylene plastic from the recycle plants is clean and wash and cut into fine pieces as describe earlier. The pieces passing from 4.75mm sieve and retained on 2.36mm are taken. Aggregate is heated to temperature of 160 degree to 170 degree C the shredded polypropylene plastic is added on the hot aggregate uniform coating of plastic on aggregate is insured within 30 to 45 second the aggregate looks to have an only coating on it. This polypropylene plastic coated aggregate are mixed with bitumen at temperature 120 degree to 130 degree C then final resulted mix can be used in the construction of roads.

Advantages of dry process:

1. Physical properties of aggregate can be improved.
2. 15% of plastic are used in road construction
3. All type of plastic and flexible film can be used.
4. Plastic coated aggregate can improve the strength at 130 degree to 140 degree C.
5. No toxic gases are evaluated.
6. The pavement is capable to withstand all the change in climatic condition upto 4 to 5 years roads cannot degrade and no maintenance cost.

4.2 Wet process:

The powder waste plastic is blended with bitumen upto 8 to 10% by its weight. Addition of plastic expands the softening point of bitumen and rates the road to hold its adaptability for more season about its long life. Plastic blended with bitumen increase the capacity of bitumen to withstand high temperature the destroyed waste plastic it utilized as a solid restricting specialist for tar making. The plastic waste bitumen is blended with bitumen 155 degree to 165 degree C the mix also remain at stable at. The powder waste plastic is first directly mix the bitumen before adding to the aggregate. The prepared mixture is added to 110 degree C so that air pockets are not formed and the mixture of polymer modified bitumen and aggregate is uniform throughout. Then this mixture is used for laying on road.

Advantages of wet process

1. This process can be used for recycling of any type, shape of waste materials.

Disadvantages of wet process:

1. It replaces huge amount of bitumen from pavement construction.
2. Additional cooling is require to avoid formation of air pockets due to improper addition of bitumen

blending of plastic with bitumen takes lot of time so it is time consuming process and powerful mechanism is required to performed the process.

4.3 Benefits of using PCA and PMB in flexible pavement construction:

1. The addition of process plastic 8 to 10% of weight bitumen helps to substantially improve the stability, strength and rutting life of other properties of bituminous concrete mix under adverse water logging condition.
2. The use of recyclable plastic waste in pavement asphalt represents materials as this addition of waste improve the strength, performance of the construction materials.
3. It is found that the road strength is twice stronger than the normal roads. This leads to ecofriendly method of construction helping in maintain the balance of environment the night time visibility of a driving on roads is increase due to contrast between pavement and stripping.
4. The resistance to the surface initiated cracking is improved due to high binder content.
5. The maintenance cost of pavement have been reduced due to improved quality of pavement.
6. The durational maintenance year have been doubled.
7. Implementation of this technique has elongated the maintenance duration from 4 year to 8 years.
8. Rs.45000 can be saved for per km of road construction.
9. The pavement can sustain high temperature ranging above 50 degree C without showing any change in their properties.

5. CONCLUSIONS

The main objective of the research is to manage the waste plastic in Effective and Eco-friendly manner and to promote the concept of best from waste. Utilization of plastic in road construction results in several benefits such as Reduction of plastics from dumping yards, Reduction in the cost of the road length, Reduction in the greenhouse gas emission from the dumping yards. Helps in the economical management & also raises the waste plastic value above zero.

Particularly utilization of waste plastic in the Bituminous road construction results in water resistance, reduction in potholes formation and stripping and helps in creating better binding of bitumen with aggregate. The dry process if adopted help in managing 80% of plastic waste in eco friendly manner.

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