EXPERIMENTAL INVESTIGATION ON USE OF LOW DENSITY POLYETHYLENE (LDPE) IN BITUMINOUS ROAD CONSTRUCTION

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ABSTRACT*- Civilization produces waste products. Disposal issue of the waste products is a challenge. Some of these materials are non-biodegradable and often leads to waste disposal crisis and environmental pollution. As a result amount of waste plastic also increases. Plastic wastes consisting of carry bags, cups and other utilized plastic can be used as a coating over aggregate and this coated stone can be used for road construction. Traditionally soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. If these materials can be suitably utilized in highway construction, the pollution and disposal problems may be partly reduced. In the absence of other outlets, these solid wastes have occupied several acres of land around plants throughout the country. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low volume roads in different parts of country.*

Keywords- Bituminous road, Coated Aggregates, LDPE, Plain Aggregates.

I. INTRODUCTION

The threat of disposal of plastic will not solve until the practical steps are not initiated at the ground level. It is possible to improve the performance of bituminous mixed used in the surfacing course of roads. Studies reported in the used of re-cycled plastic, mainly polyethylene, in the manufacture of blended indicated reduced permanent deformation in the form of rutting and reduced low – temperature cracking of the pavement surfacing [9]. The field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems [7].

Plastic is a very versatile material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers found that the material can remain on earth for 4500 years without degradation [4].

Several studies have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc., Looking forward the scenario of present life style a complete ban on the use of plastic cannot be put, although the waste plastic taking the face of devil for the present and future generation. We cannot ban use of plastic but we can reuse the plastic waste.

II. OBJECTIVE

The present study deals with the use of waste plastic as coating over aggregates. The highlights of the study are:

- To evaluate the properties of aggregates by coating plastic over it.
- To evaluate the properties of polymer modified bitumen for different ratios of Low Density Polyethylene (varying from 2.5-12.5% volume fraction).

III. SCOPE

The range of materials used and tests carried out by us in our project were:

- Bitumen- (IS: 1205-1978 IS: 1208-1978 IS: 1212-1978 IS: 1211-1978 IS: 1210-1978 IS: 1209-1978 IS: 1206-1978 IS: 1202-1978 IS: 1203-1978)
- Polythene- Low Density Polyethylene (LDPE)
- Aggregates- (IS 2368)

IV. PAVEMENT MATERIALS: AGGREGATES

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such

as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete.
Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often a bye product of other manufacturing industries.

A. Desirable Properties [5]

- Strength

The aggregates used in top layers are subjected to
(i) Stress action due to wheel load,
(ii) Wear and tear,
(iii) Crushing.
For a high quality pavement, the aggregates should possess high resistance to crushing, and to withstand the stresses due to traffic wheel load.

- Hardness

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyre vehicles moves over the aggregates exposed at the top surface.

- Toughness

Resistance of the aggregates to impact is termed as toughness. Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyre wheels from one particle to another at different levels cause severe impact on the aggregates.

- Shape Of Aggregates

Aggregates which happen to fall in a particular size range may have rounded cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

- Adhesion With Bitumen

The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials; otherwise the bituminous coating on the aggregate will be stripped off in presence of water.

- Durability

The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action.

- Aggregate Tests

In order to decide the suitability of the aggregate for use in pavement construction, following tests are carried out:

- Crushing test
- Abrasion test
- Impact test
- Soundness test
- Shape test
- Specific gravity and water absorption test
- Bitumen adhesion test

V. PAVEMENT MATERIALS: BITUMEN

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous substances consists high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

A. Production of Bitumen

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

B. Different Forms of Bitumen

- Cutback Bitumen

A suitable solvent is mixed to reduce viscosity. Bitumen Emulsion: bitumen is suspended in finely divided condition in aqueous medium 60% bitumen and 40% water.

- Bituminous Primers

Mixing of penetration bitumen with petroleum distillate.

- Modified Bitumen

Blend of bitumen with waste plastics & or crumb rubber.

C. Various Grades Of Bitumen Used For Pavement Purpose

Grade: 30/40; Grade: 60/70; Grade: 80/100

D. The Desirable Property of Bitumen For Pavement

- Good cohesive and adhesive binding property.
- Water repellent property.
- It is its thermoplastic nature, (stiff when cold liquid when hot), that makes bitumen so useful.

E. Tests on Bitumen [5]

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

- Penetration test
- Ductility test
- Softening point test
- Specific gravity test
- Viscosity test
- Flash and Fire point test
- Float test
- Water content test
- Loss on heating test

VI. PLASTIC WASTE CLASSIFICATION

Plastics can be classified in many ways, but most commonly by their physical properties. Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibres. But depending on their physical properties, may be classified as thermoplastic and thermosetting materials. Thermoplastic materials can be formed into desired shapes under heat and pressure and become solids on cooling. If they are subjected to the same conditions of heat and pressure, they can be remoulded thermosetting materials which once shaped cannot be softened/remoulded by the application of heat.

Most of thermoplastics on heating soften at temperature between 130-140^{o}C. The TGA analysis of thermoplastics has proven that there is no gas evolution in the temperature range of 130-180^{o}C and beyond 180^{o}C gas evolution and thermal degradation may occur. Thus the waste plastic can easily be blended with the bitumen as the process for road construction using bitumen is carried out in the range of 155-165^{o}C.

VII. WHY PLASTIC? - AS A BINDER AND MODIFIER [2]

- Soften at around 130^{o}C.
- Have a binding property hence used as a binder.
- Can also be mixed with binder like bitumen to enhance their binding property.

A. Characteristics of Plastic Coated Aggregate (Used For Flexible Pavement)

- Moisture Absorption And Void Measurement

For the flexible pavement, hot stone aggregate (170^{o}C) is mixed with hot bitumen (160^{o}C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and visco elastic property.

The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

- Aggregated Impact Value

A study on the effect of plastic coating was extended to study on the aggregate impact value. Aggregate was coated with 2.5% & 12.5% plastics by weight and the plastic coated aggregate was submitted to Aggregate Impact Value test and the values were compared with values for non coated aggregate.

- Los Angel's Abrasion Test

The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study. Under this study the percentage of wear and tear values of the plastic coated aggregate is found to be in varying order with respect to the percentage of plastics. When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic coated aggregate the values are less for polymer coated aggregate.

- Penetration Index Test

It is measured using Penetrometer. The penetration of a bituminous material is the distance in tenths of a millimeter, which a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.

- Ductility Index Test

The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature.

VIII. PROCESSES FOR MANUFACTURING BITUMEN MIX ROAD USING WASTE PLASTIC

There are two important processes namely dry process and wet process used for bitumen mix flexible pavement [1].

A. Dry Process

[6] For the flexible pavement, hot stone aggregate (170^{o}C) is mixed with hot bitumen (160^{o}C) and the mix is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding property, penetration value and visco-elastic property. The aggregate, when coated with plastics improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

- Advantages Of Dry Process

- Plastic is coated over stones – improving surface property of aggregates.
- Coating is not so easy & temperature required is same as road laying temp.
- Use of waste plastic more than 15% is not possible.
- Flexible films of all types of plastics can be used.
- Doubles the binding property of aggregates.
- No new equipment is required.
- Bitumen bonding is strong than normal.
- The coated aggregates show increased strength.
- As replacing bitumen to 12.5% higher cost efficiency is possible.
- No degradation of roads even after 5-6 yrs after construction.
- Can be practiced in all type of climatic conditions.
- No evolution of any toxic gases as maximum temperature is 180^{o}C.

B. Wet Process

[8] Waste plastic is ground and made into powder; 2.5to 12.5% plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life. Use of shredded plastic waste acts as a strong binding agent to make tar asphalt last long. By mixing plastic with bitumen the ability of the bitumen to withstand high temperature increases. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5^{o}C but when plastic is mixed, it remains stable even at 55^{o}C. The vigorous tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement. There was a substantial increase in Marshall Stability value of the mix, of the order of two to three times higher value in comparison with the untreated or ordinary bitumen. Another important observation is that the bituminous mixes prepared using the treated binder could withstand adverse soaking conditions under water for longer duration.

- Advantages Of Wet Process

This Process can be utilized for recycling of any type, size, shape of waste material (Plastics, Rubber etc.)

IX. MARSHAL STABILITY TEST

i) Bitumen was heated with plastic separately up to 70^{o}C.

ii) Aggregates and Bitumen were mixed thoroughly at 170^{o}C and the mixed material was transferred thoroughly to the compaction mould arranged on the compaction pedestal.

iii) 105 blows were given on the both sides of the specimen mix with a standard hammer (45cm, 4.86kg).

iv) The specimen was removed from the mould by ejector.

v) A series of specimens were prepared by a similar method with varying quantities of plastic content, with an increment of 2.5% (3 specimens of each).
vi) Before testing of the mould, the moulds were kept in the water bath for half an hour at 60^{o}C.
vii) The stability of the mould was then checked on the Marshall Stability apparatus using proving ring.

X. **RESULTS AND DISCUSSION**

Table-1: Results of Impact Value, Crushing Value, Los Angeles Abrasion Values W.R.T. Percent Variation of LDPE

% PLASTIC	IMPACT TEST VALUE	CRUSHING TEST VALUE	ABRASION TEST VALUE
0	9.67	24.74	24.74
2.5	6.19	13.79	10.32
5	5.3	13.39	19.39
7.5	6.87	9.2	15.6
10	8.25	14.85	18.16
12.5	10.12	14.17	14.17

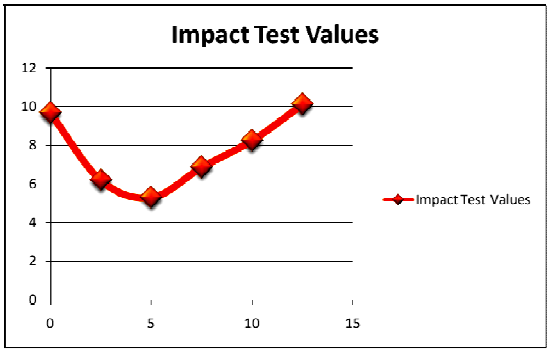

Figure-1: Variation of Impact Test Value with Different % of Plastic.

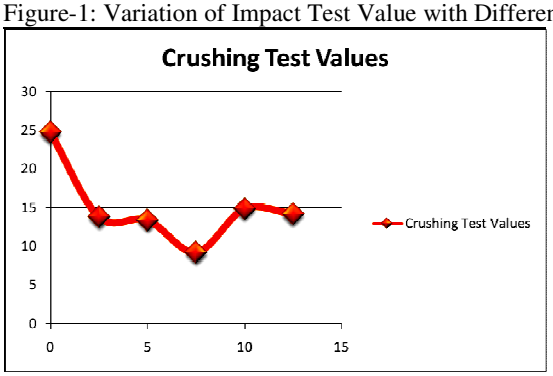

Figure-2: Variation of Crushing Value with Different % Of Plastic.

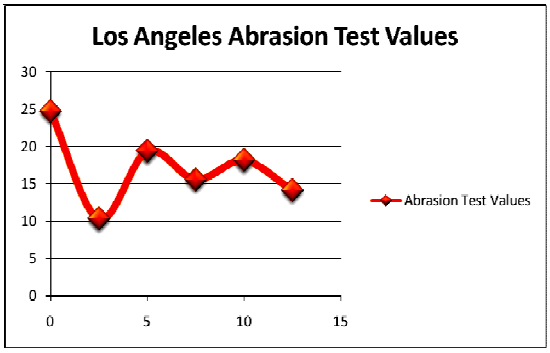

Figure-3: Variation of Los Angeles Abrasion Test Value with Different % of Plastic.

Table-2: Results of Impact Value, Crushing Value, Los Angeles Abrasion Values and Marshal Stability Value W.R.T. Percent Variation of LDPE

% Plastic	Marshal Stability Value	% Increase In Stability	% Decrease In Impact Value	% Decrease In Crushing Value	% Decrease In Abrasion Value
0	11.39	-	-	-	-
2.5	21.53	89.0	36.0	44.3	58.3
5	33.55	194.6	45.2	45.9	21.6
7.5	32.47	185.1	29.0	62.8	36.9
10	31.5	176.6	14.7	40.0	26.6
12.5	26.4	131.8	-4.7	42.7	42.7

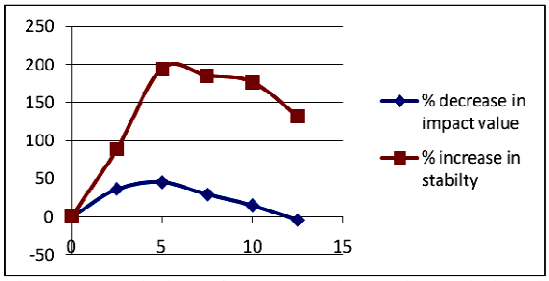

Figure-4: Variation of Impact Value and Marshal Stability Value W. R. T. Percent Variation of LDPE

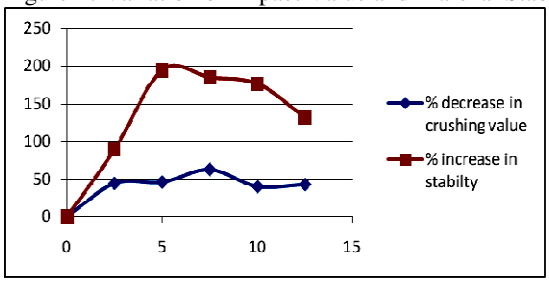

Figure-5: Variation of Crushing Value and Marshal Stability Value W. R. T. Percent Variation of LDPE

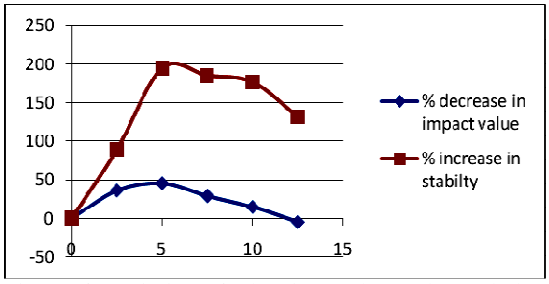

Figure-6: Variation of Abrasion Value and Marshal Stability Value W. R. T. Percent Variation of LDPE

XI. **CASE STUDIES IN INDIA**

- Laboratory studies were carried out at the Centre for Transportation Engineering of Bangalore University, in which the plastic was used as an additive with heated bitumen in different proportions (ranging from zero to 12% by weight of bitumen) The results of the laboratory investigations indicated that, the addition of processed plastic of about 8.8% by weight of bitumen, helps in substantially improving the stability, strength, fatigue life and other desirable properties of bituminous concrete mix, even under adverse water-logging conditions. The additions of 8.0% by weight of processed plastic for the preparation of modified bitumen results in a saving of 0.4% bitumen by weight of the mix or about 9.6% bitumen per cubic meter of BC mix [7].
- In Tamil Nadu, length of roads around 1000 m in various stretches were constructed using waste plastic as an additive in bituminous mix under the scheme "1000 Km Plastic Tar Road", and found that, the performance of all the road stretches are satisfactory [4].
- The performance of the road stretches constructed using waster plastic in Karnataka is also found to be satisfactory. The construction of roads using waste plastic in the above states is based on the guidelines developed by Bangalore University. CRRI and College of Engineering, Madurai. However, standard specifications are not available on the use of waste plastic in bituminous road Construction. In this regard, IRC was specially requested by NRRDA for the preparation of such Guidelines for enabling the construction of rural roads under PMGSY using waste plastic. In order to facilitate the development of guidelines on this, an expert group has been appointed by NRRDA for preparation of interim guidelines for the use of waste plastic which will be sent to IRC for approval and releasing as IRC guidelines.

XII. CONCLUSION

- Our Project intended to find the effective ways to utilize the low density plastic as bitumen modifier for flexible pavements.
- The addition of plastic modifies the properties of bitumen.
- The modified bitumen shows good result when compared to standard results.
- The optimum content of plastic to be used is between the ranges of 2.5% to 12.5%.
- The use of plastic in pavement asphalt represents a valuable outlet for such materials.
- The use of modified bitumen with the addition of processed plastic of about 7.5% by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with marginal saving in bitumen usage.
- The process is environment friendly.
- All over, process is socially highly relevant, giving better infrastructure.

XIII. FUTURE SCOPE

- To check the amount of plastic content bounded to the aggregate.
- Floating test can be conducted.
- The test can be conducted by varying the percent of plastic content.
- The type of material used as binder in our project (i.e., plastic) can be replaced by any other material like rubber, fly-ash, slag furnace, etc.
- Tests can be conducted by changing the density of plastic.
- Tests can be conducted by varying the percentage of bitumen.
- Tests can be conducted by varying the grade of bitumen.
- Alterations can be done for mixing process of aggregate and bitumen with plastic.
- The chemical test on plastic mix in bitumen can be carried out.

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