Waste Polymeric Packaging Material Use In Bituminous Roads

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Abstract- *The quantum of plastic waste in municipal solid waste (MSW) is increasing due to increase in population, urbanization, development activities and changes in life style which leading widespread littering on the landscape. Thus, disposal of waste plastic is a menace and become a serious problem globally due to their non-biodegradability and an aesthetic view. Since these are not disposed scientifically & possibility to create ground and water pollution.*

Rutting is caused by accumulation of permanent deformations caused by repeated applications of traffic loads and it is a stress controlled cyclic loading phenomenon. The process of deformation of bituminous surfacing is accelerated by increase of pavement temperature, reduction in stiffness of mix and increase in traffic loads. The aim of this project is to report findings of study on increase in stiffness modulus of bituminous mixes by incorporation of waste polymeric packaging material (WPPM) to enhance pavement performance as well as to protect environment

Keywords- Plastic Waste, Non-Biodegradability, Bitumen mix roads, Waste Polymeric Packaging material, Rutting..

I. INTRODUCTION

1.1 GENERAL

Any nation's progress is directly dependent on infrastructure. India is on the threshold of a major forward thrust in the transportation infrastructure. Now-a-days disposal of different waste produced from different industries is a great problem. These materials cause environmentally pollution in the nearby locality because many of them are non-biodegradable. Traditionally soil, aggregates, sand, bitumen, cement, etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and industrial wastes product is one such category. If these materials can be suitably utilized in 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 construction, in which higher economic returns may be possible. The possible use of these materials should be developed for low volume of construction and different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximize the use of solid wastes in different levels. Bituminous binders are widely used by paving industry. In general pavements are categorized into two groups, i.e. flexible and rigid pavement.

Flexible Pavement

Flexible pavements are those, which on the whole have low flexural strength and rather flexible in their structural action under loads. These types of pavement layers reflect the deformation of lower layers on-to the surface of the layer.

Rigid Pavement

If the surface course of a pavement is of plain cement concrete then it is called as rigid pavement since the total pavement structure can't bend or deflect due to traffic loads. Pavement design and the mix design are two major considerations in case of pavement engineering. The present study is only related to the mix design of flexible pavement considerations. The design of asphalt paving mixtures is a multi-step process of selecting binders and aggregate materials and proportioning them to provide an appropriate compromise among several variables that affect mixture behavior, considering external factors such as traffic loading and climatic conditions.

1.2 BITUMINOUS MIX DESIGN

Overview

The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregate, and coarse

aggregates to produce a mix which is workable, strong, durable and economical. There are two types of the mix design, i.e. dry mix design and wet mix design.

Objective of Bituminous Mix Design

Main objectives of bituminous mix design are to find:

1. Optimum bitumen content to ensure a durable pavement.
2. Sufficient strength to resist shear deformation under traffic at higher temperature.
3. Proper amount of air voids in the compacted bitumen to allow for additional compaction done by traffic.
4. Sufficient workability, and
5. Sufficient flexibility to avoid cracking due to repeated traffic load.

Requirements of Bituminous Mixes

Bituminous mixture used in construction of flexible pavement should have following properties: 1. Stability 2. Durability 3. Flexibility 4. Skid resistance 5. Workability

1.3 PROBLEM IDENTIFICATION

1.3.1 Present Scenario

Bituminous binders are widely used in road in road paving and their viscoelastic properties are dependent on their chemical composition. Now-a-days, the increment in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature put us in a situation to think about some alternative ways for the improvement of the pavement characteristics and quality by applying some necessary modifications which shall satisfy both strength as well as economical aspects. Bitumen can also be modified by adding different types of additives to achieve the present requirement. One of these additives is the polymers.

1.3.2 Waste Packaging Plastic Material: The Problems

Today availability of plastic waste is enormous. The use of plastic materials such as carry bags, cups, etc is constantly increasing. Nearly 50% to 60% of total plastic are consumed for packing. Once used plastic packing materials are thrown outside and they remain as waste plastic wastes are durable and non-biodegradable. The improper disposal of plastic may cause breast cancer, reproductive problems in humans and animals, genital abnormalities and much more. These plastic wastes get mixed with water, disintegrate, and take the forms of small pallets which cause the death of fishes and other aquatic life who mistake them as food material. Sometimes they are either land filled or incinerated. Plastic waste gets mixed with the municipal solid waste or thrown over a land area. All the above process is not the municipal eco-friendly as they pollute land, air and water. Under these circumstances, an alternative use of this plastic waste is required. So, any method that can use this plastic waste for purpose of construction is always welcome.

1.3.3 Role of Polyethylene in Bituminous Pavement

Use of polyethylene in road construction is not new. Some aggregates are highly hydrophilic (Water loving). Like bitumen polyethylene is hydrophobic (water heating) in nature. So, the addition of hydrophobic polymers by dry or wet mixing process to asphalt mix lead to improvement of strength, water repellent property of the mix. Polyethylene get added to hot bitumen mixture and the mixture is laid on the road surface like a normal tar road. Plastic road mainly uses plastic carry-bags, disposable cups, polyethylene packets and PET bottles that are collected from garbage as important ingredients of the construction material. Polymer modification can be consideration as one the solution to improvise the fatigue life, reduce the rutting and thermal cracking in the pavement. Creating a modification, a modified bituminous mixture by using recycles a polymer which enhances properties of HMA mixtures would not only produce a more durable pavement, but also provide a beneficial way of disposal of a large amount of recycled plastics.

1.4 OBJECTIVES OF PRESENT INVESTIGATION

A comparative study has been made in this investigation of DBM mixes with varying binder contents (3.5%-7%) and polyethylene content (10%-30%).

The objectives of this investigation are to observe the followings:

- The effect of polyethylene as admixture on the strength of bituminous mix with different filler and replacing some percentage of fine aggregate by slag.
- The performance of bituminous mix under water with and without polyethylene admixtures with different filler and replacing some percentage of fine aggregate by waste shredded plastic.
- To study resistance to permanent deformation of mixes with and without waste polymeric material.
- Stone of Marshall Properties of mixes using both.
- Use Stone dust as filler.

II. LITERATURE REVIEW

Naveen and Pardeep (2019) studied how Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of bitumen (used as a binder) or asphalt and mineral aggregate which are mixed together & laid down in layers then compacted the significant variation in daily and seasonal temperature put us in a demanding situation to think of some alternatives for the improvisation of the pavement characteristics and quality by applying some necessary modifications which shall satisfy both the strength as well as economical aspects.

Priyanshi Bhargava and Tapas Singh (2018) indicated that Bituminous mixes are most typically used everywhere the world in flexible pavement construction. It consists of asphalt or bitumen (used as a binder) and mineral combination that is mixed along, set down in layers and so compacted. Today's asphaltic concrete pavements are expected to perform higher as they're experiencing the increased volume of traffic, accrued loads and increased variations in daily or seasonal temperature over what has been experienced within the past. Additionally, the performance of bituminous pavements is found to be terribly poor in wet induced situations. Low density polyethylene (LDPE) has been found to be a good modifier of bitumen. Even, the reclaimed polyethylene originally made of LDPE has been observed to modify bitumen.

Kalpana and D. Surendaran (2018) gave a review that Disposal of waste materials together with waste plastic baggage has become a significant drawback and waste plastics area unit burnt for apparent disposal that cause environmental pollution. The utilization of the innovative technology won't solely strengthen the construction however conjointly increase the road life yet as can facilitate to boost the surroundings. Plastic roads would be a boon for India's hot and very wet climate, wherever temperatures oft cross 50°C and torrential rains produce disturbance, departure most of the roads with massive potholes.

Maz Allah Khan et al., (2017) studied Plastic found in different forms is almost 5% amongst municipal solid waste, which can prove to be toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and another type of plastic packing material littering the roads as well as drains. Due to its biodegradability, it creates stagnation of water and associated hygiene problems. Therefore, it is proposed that we may use waste plastic in the construction of Rural Roads.

Huda Shafiq and Ansar Humid (2016) stated that Plastics are the non-biodegradable materials and so a means to degrade our environment. Plastic wastes have proved to be a source of health hazard as it is toxic in nature. Plastic waste is a big nuisance in today's world. So, this plastic waste should be reused to eliminate the threat to the surroundings. One such reuse can be in the construction of flexible pavements. Moreover, the bond between these plastic-coated aggregates and the bitumen is also very strong due to increased contact area between plastic (polymers) and bitumen. Such roads show better performance and have increased life spans.

Sunil J Kulkarni (2016) stated that the disposal of biodegradable waste can be carried out in open dumping, sanitary landfill or composting methods. Incineration can also be used for solid waste treatment. Pre-treatment of agricultural waste and vermicomposting are effective ways to convert solid waste into manure and combustible gases. The optimum quantity of the waste plastic in bitumen was reported to be 10 percent in most of the investigations. With increase in plastic share, the strength and flow property increase. The cost of construction materials also decreases considerably due to use of waste plastic.

YashMenaria and RupalSankhla (2015) suggested that Wrappers of betel nuts, chocolates, chips, hand bags, cold drink bottles and all other forms of plastic create significant environmental and economic problem. They consume massive energy and other natural resources, depleting the environment in various ways. In manufacturing firms, construction industries and products delivery services, use of plastic is a priority to handle and pack things comfortably due to its light weight, cost effectiveness and strength. It is made up of various chemical elements and is regarded as a highly pestilent material which does not easily degrade in the natural environment after its usage.

Gawande et al. (2012) gave on overview on waste plastic utilization in asphalting road by using both wet and dry method. They said that use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in improving the according to them use of waste plastics in the manufacture of roads and laminated roofing also help to consume large quantity of waste plastics. Thus, these processes are socially highly relevant, giving better infrastructure.

Pareek et al. (2012) carried out experimental study on conventional bitumen and polymer modified binder and observed a significant improvement in case of rutting resistance, indirect tensile strength and resilient modulus of the bituminous concrete mix with polymer modified bitumen.

They also concluded that polymer modified bitumen results a high elastic recovery (79%) and better age resistance (the loss in weight on heating in thin film oven is 6 times higher as compared to conventional bitumen of 60\70).

Moghaddam and Karim et al., (2012) reported that the utilization of waste material in asphalt pavement would be beneficial in order to find an alternative solution to increase service life of asphalt pavement and reduce environmental pollution as well. From their study it is concluded that Polyethylene Terephthalate (PET) reinforced mixtures possess higher stability value, flow, and fatigue life in comparison with the mixtures without PET.

Sangita et al. (2011) suggested a novel approach to improve road quality by utilizing plastic waste in road construction. According to them India spends Rs 35,000 crores a year on road construction and repairs, including Rs 100,000 crores a year just on maintenance and roads by bitumen modification lasts 2-3 times longer, which will save us Rs 33,000 crores a year in repairs, plus reduced vehicle wear and tear.

P. K. Jain et al., (2011) studied mitigation of rutting in bituminous roads by use of waste polymeric packaging materials and concluded that rutting of bituminous mix can be reduced to 3.6 mm from a value of 16.2 mm after application of 20,000 cycles, by adding optimum quantity of polyethylene in bituminous mix for road construction, ultimately improves pavement performance, besides alleviating disposal problem of WPPM for clean and safe environment.

Bindu and Beena (2010) studied how Waste plastic acts as a stabilizing additive in stone Mastic Asphalt when the mixtures were subjected to performance tests including Marshall Stability, tensile strength, compressive strength tests and Tri-axial tests. There results indicated that flexible pavement with high performance and durability can be obtained with 10% shredded plastic.

III. METHODOLOGY

Waste plastic is made power and varying percent plastic is mixed with bitumen. Plastic increase the melting point of the bitumen and makes the road flexible during winters resulting in its long life. Use of shredded plastic waste acts as a strong binding agent for tar making the asphalt last long. By mixing plastic with bitumen the brittleness was overcome and elastic nature enhances. The plastic waste is melted and mixed with bitumen in a particular ratio.

There are two important processes used for bitumen mix flexible pavement.

1 Dry process

For the flexible pavement, hot stone aggregate (180˚ C) is mixed with hot bitumen (160˚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-elastics 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 improper 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 easy and temperature required is same as road laying temperature.
- Use of waste plastic more than 15% is 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 15% higher cost efficiency is possible.
- No degradation of roads even after 5-6 years after construction.
- Can be practiced in all type of climatic conditions.
- No evolution of any toxic gases as maximum temperature is 180˚C.

Disadvantages of Dry Process

- The process is applicable to plastic waste material only.

2 Wet Process

These are the method used for formation of polymer based modified bitumen, in which the waste polymer directly added with bitumen and heated up to temperature of 160˚C so that proper blend is to be formed with proper dispersion of waste polymer into bitumen, then the hot mix is then cooled up to 120˚C into another chamber, which is then added to the aggregate in paddling chamber. The mix is to be cooled because when hot mix poured on aggregate then there are chances to form air pocket into small gap of aggregate and

chances in lower the strength of roads and chances of rutting of roads. After addition of modified bitumen at 110˚C on aggregate, it is then laid on the road and then spreader material is compacted by 8 tone rollers.

Advantages of Wet Process

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

Disadvantages of Wet Process

- The consuming more energy for blending.
- Powerful mechanical is required.
- Additional cooling is required as improper addition of bitumen may cause air pockets in roads. Maximum % of waste plastic can be added around 8%.

3.3 Raw Material

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95% of the mixture weight and contributes to most of the load bearing and strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregates should have to be used in pavement are shown below

1. Aggregate should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable should be limited to almost 1%
2. Durability or resistance to weathering should be measured by sulphate soundness testing.
3. The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 and a minimum of 0.6.
4. It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes.
5. Aggregates are of the two types are follows: -

a) Coarse Aggregate (CA)
b) Fine Aggregate (FA)

3.4 Important Test Carried Out for Plastic Coated Flexible Pavement

Following are the important test carried out for plastic coated flexible pavement is: -

1. Aggregate Impact Value Test
2. Abrasion Value Test (Aggregate Crushing Value Test)
3. Moisture Absorption Test
4. Marshall Stability Test

3.5 Important test carried out of bitumen

Following are the important test carried out for Bitumen: -

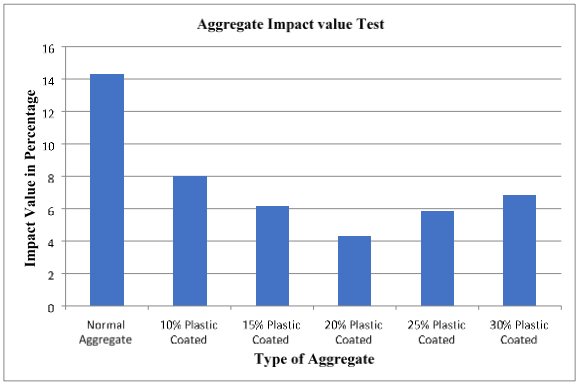
1. Softening point test
2. Penetration index test
3. Ductility index test

IV. ANALYSISOFDATACOLLECTED

4.1 Important Test Carried Out for Plastic Coated Flexible Pavement

4.1.1 Aggregate Impact Value Test

A study on the effect of plastic coating was extended to study on the aggregate impact value. Aggregate was coated with 1% and 2% plastics by weight and the aggregate was submitted to Aggregate Impact Value test and the values were compared with values for non-coated aggregate.



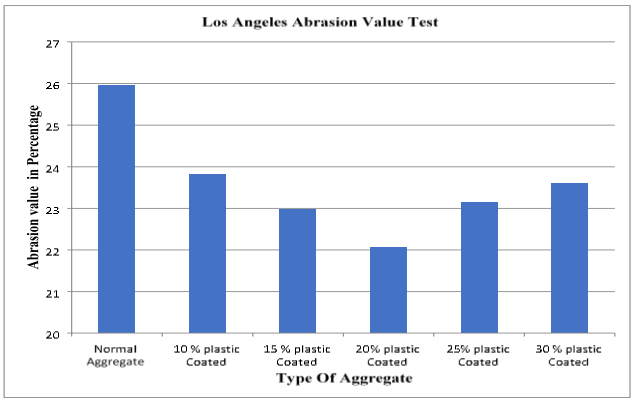
Graph No. 1. Overall Result of Impact Value Test

As per the test conducted result shows as compare to normal aggregate impact value the 20% plastic coated aggregate impact value is less.

4.1.2 Abrasion Value Test (Aggregate Crushing Value Test)

The aggregate crushing value (A.C.V.) of an aggregate is the mass of material, expressed as a percentage of the test sample which is crushed finer than a 2.36 mm sieve when a sample of aggregate passing the 1.76 mm IS sieve is

subjected to crushing under a gradually applied compressive load of 400 KN.

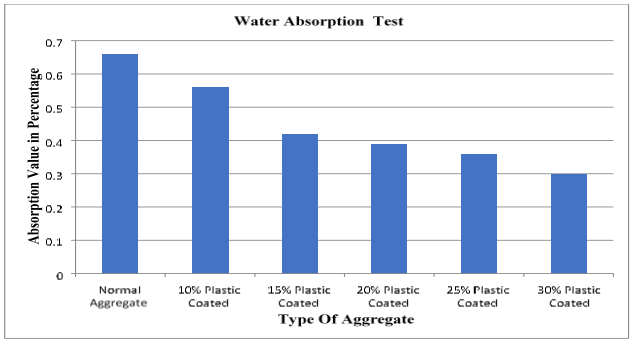


Graph No. 2.Overall result of Abrasion value test

As per the test conducted result shows as compare to normal aggregate abrasion value the 20% plastic coated aggregate abrasion value is less.

4.1.3 Moisture Absorption Test

For the flexible pavement, hot stone aggregate (170˚ C) is mixed with hot bitumen (160˚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 viscoelastic 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.

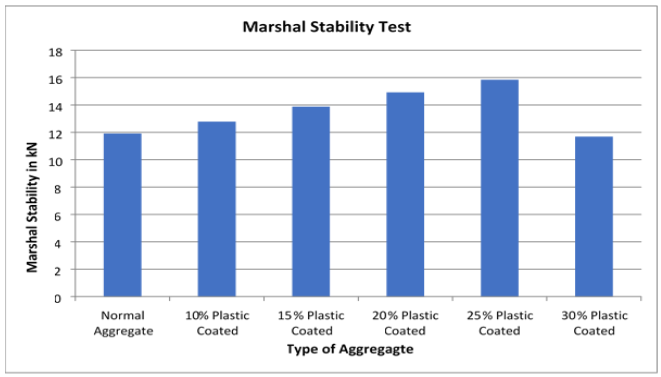


Graph No. 3. Overall result of Absorption Value Test

As per the test conducted result shows as compare to normal aggregate moisture absorption value the 30% plastic coated aggregate moisture absorption value is less.

4.1.4 Marshall Stability

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/min. Marshall Stability is related to the resistance of bituminous materials to distribution, displacement, rutting and shearing stresses.



Graph No. 4 Overall result of Marshall Stability Test

As per the test conducted result shows as compare to normal aggregate Marshall Value the 25% plastic coated aggregate Marshall value is more.

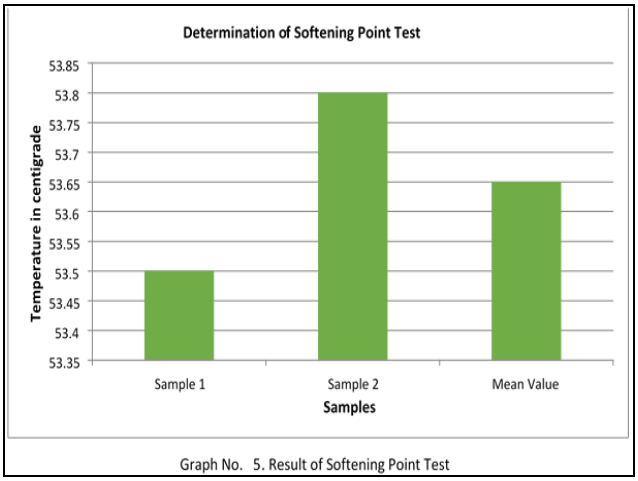
4.1.5. Soundness Test

Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic-coated aggregate, did not show any weight loss, thus conforming the improvement in the improvement in the quality of the aggregate.

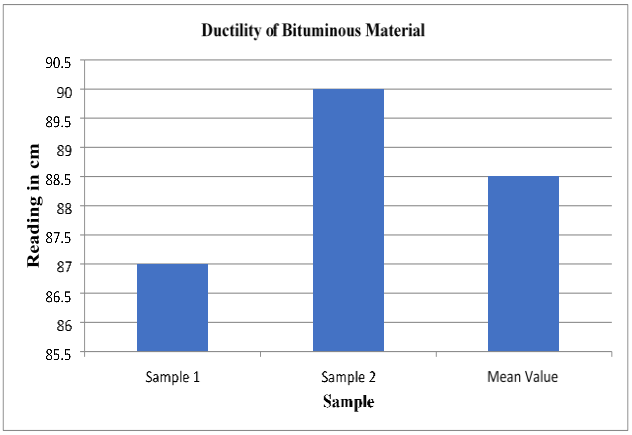
4.2. Important test carried out of bitumen

4.2.1. Softening point test

This test is conducted using ring and ball apparatus. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.



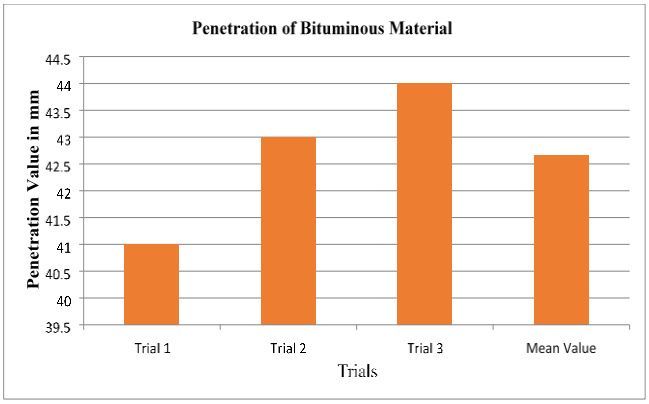
Graph No. 5. Result of Softening Point Test



Graph No. 7. Result of Ductility Test

4.2.2. Penetration Index Test

Lengths of a millimeter, which a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time.



Graph No. 6 Result of Standard Penetration Test of Bitumen

4.2.3. 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.

V. CONCLUSIONS

1. It was found from study of behavior of polymeric packaging material with improvement of modified mix possesses Marshall Characteristics as mentioned It is found that increase of Marshall Stability Value with polymeric polyethylene content up to 4% and after that it decreases. If the addition of polymeric material increases then the Marshall Value decreases.
2. Using polymeric packaging material in road construction will help reduction in need of bitumen by around 10%, increases the strength and performance of road as well as its durability.
3. Polymeric material also improves the strength of bitumen mixes with their binding properties.
4. This technique also helps to avoid general disposal technique of waste plastics like land filling and incineration, which are certainly burden on environment or ecology.
5. In Impact value test of aggregate, it is found that the plastic coated aggregate shows less impact than non-plastic coated aggregate. But excessive coating of plastic to aggregate also leads to rise in impact value of aggregate.
6. In Abrasion value test, the value gets reduced as coating percentage increases but at specific point the increase in coating may leads to high abrasion value. Thus, to obtain good results coating of aggregate should be in proper proportion.
7. In Moisture absorption test, it is found that the increase in percentage of coating of plastic to aggregate may leads to minimum percentage of moisture absorption by aggregate as compared to normal aggregate or non-coated aggregate. Due to polymeric material coating of aggregates the voids present in aggregate are completely filled by plastic so there is less number of voids and thus

as coating percentage increases the moisture absorption of aggregate gets decreases.

8. For Marshall Stability test, the value of load also increases with increase in coating percentage but higher coating percentage may lead to failure of sample. Therefore, to minimize this failure plastic coating should be in proper parameters.
9. Hence from all test results we conclude that the 20% plastic coated aggregate will perform the excellent role as construction material in bituminous road construction.

V. FUTURE SCOPE

Day by day increase in traffic conditions will and reducing the life span of roads. The plastic roads are means of prevention and ultimately will be the cure. It will save millions of rupees in future as well as reduce amount of plastic present in environment with reduction resources used for construction.

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