Use of Modified Bitumen in Highway Construction

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Abstract

In India, flexible pavements with bituminous surfaces are widely used. Due to increased traffic intensity of roads, overloading of commercial vehicles and temperature variation of pavements due to climatic changes leads to formation of various distresses like rutting, shoving, bleeding, cracking and potholing of bituminous surfacing. Due to high temperature, bitumen becomes very soft in summer and brittle in winter. Also, in a developing country like India, roadway construction is taking place at a very high pace which require large demand of construction material that too eco-friendly and economical. Several Studies have revealed that properties of bitumen and bituminous mixes can be improved/ modified with addition of certain additives and the bitumen premixed with these additives/modifiers is known as "modified bitumen". The present study aims for use of modified bitumen by using plastic waste for road construction. The paper includes details of literature and methodology of using modifiers in bitumen and aims to provide highway construction in a eco-friendly and economical way. The modified bitumen mix shows better binding property, stability, density and more resistant to water.

Keywords: Modified Bitumen, Marshall Stability Test, SDBC, CRMB

I. INTRODUCTION

1.0 Introduction

India is having second largest road network of over 4.6 lakh KM in the world. Due to extreme climatic conditions, growth of traffic and increasing maintenance expenditure on roads in India there is a necessity to develop sustainable technologies and economical road construction. In recent years cost of bitumen in India has raised very rapidly due to hike in the crude oil price. As highway construction involves huge sum of money, appropriate engineering design and use of waste material in construction of highways may save considerable cost. It should be noted that major portion of highway in India is flexible. Several studies have shown that permanent deformation within flexible pavement is usually confined to the top 100 to 150 mm of the pavement also known as surface course.

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. But its resistance towards water is poor. Anti-stripping agents are being used. Road surface with neat bitumen can cause bleeding in hot climate, may develop cracks in cold climate, possess fewer loads bearing capacity and can cause serious damages because of higher axle load in present conditions due to rapid infrastructure development. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic synthetic polymers like rubber and plastics. Plastics are user friendly but not eco-friendly as they are non-biodegradable generally, it is disposed by way of land filling or incineration of materials which are hazardous. Also, Use of plastic bags in road help in many ways like Easy disposal of waste, better road and prevention of pollution and so on. The better binding property of plastics in its molten state has helped in finding out a method of safe disposal of waste plastics. Polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased Softening point and decreased Penetration value with a suitable ductility. When it used for road construction it can withstand higher temperature and load. The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Studies on this subject are going on both at national and international level. This Concept of Utilization of Waste Plastic in Bituminous Mixes for Road Construction has been done since 2000 in India. India has to raise transportation system to a higher level both in terms of length and quality. This study presents the use of waste in hot bituminous mixes to enhance pavement performance, protect environment and provide low cost roads.

II. LITERATURE REVIEW

Centre for Transportation Engineering, Bangalore University used processed plastic bags as an additive in asphalt concrete mixes. The properties of this modified bitumen were compared to that of ordinary bitumen. It was noted that penetration and ductility values of modified bitumen was decreasing with the increase in proportion of the plastic additive, up to 12 % by weight.

Dr. P. K. Jain, (2012) carried out use of plastic waste in bituminous road construction. It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. The optimum dose is 0.4-0.5 % by weight of bituminous mix and 6-8% by weight of bitumen. Plastic waste may also be used for up gradations of fly ash for its use as fine aggregate and filler in bituminous road construction.

Rokade S (2012) prepared SDBC (Semi Dense Bituminous Concrete) mix using Marshall Method of bituminous mix Design. The SDBC mix was prepared with 4.5to6%incrementof 0.5% bitumen. This study used LDPE Low Density Polyethylene and CRMB Crumb rubber modified bitumen3% increment of of the (LDPE) for 3%, 6%, 9% and CRMB used for 8%, 10% ,12% respectively by weight of bitumen.

The study on the use of LDPE and CRMB reveals that the Marshal Stability value, which is the strength parameter of SDBC has shown increasing trend and the maximum values have increased by about 25 % by addition of LDPE and CRMB. The density of the mix has also increased in both the cases of LDPE and CRMB when compared with 60/70 grade bitumen.

Sangita, Tabrez Alam Khan, Sabina, D.K. Sharma (2011) carried out study of the effect of waste polymer (nitrile rubber and polyethylene in 1:4 ratio) modifier (WPM) on various mechanical properties such as Marshall stability, flow, Marshall quotient (stability to flow ratio), resilient modulus and permanent deformation potential of bituminous concrete overlays has been evaluated.

P Sreejith (2010) carried out Polymer modified bitumen is emerging as one of the important construction of flexible pavements. The polymer modified bitumen show better properties for road construction and plastics waste can find its use in this process and this can help solving problem of pollution. The studies on the thermal behaviour and binding property of molten plastics promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction.

Pada Sabtu, (2010) compared properties of the modified bitumen were compared with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight. The softening point of the modified bitumen increased with the addition of plastic additive, up to 8.0 %by weight. Studies were carried out on Bituminous mixes using 60/70 grade bitumen having average Marshall Stability Value (MSV) of 1300 kg at optimum bitumen content of 5.0 % by weight of the mix.

Mohammad T. Awwad and Sheeb Lina. (2007) worked out polyethylene as one sort of polymers used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat the aggregate High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate.

Dr. R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, B. Sundarakannan (2006) The authors' applied innovative techniques to use the waste plastics and the tyre waste for the construction of flexible pavement, for making pathway blocks, and for making laminated roofing sheets. The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state.

III. MATERIALS

Materials required for construction of surface course in flexible pavement are as follows:

- Aggregates
- Plastic Waste as modifier
- Bitumen

A. Aggregates

Aggregates are the materials which are used in surface course and can be divided into two types according to their size: coarse aggregates and fine aggregates. Coarse aggregates are generally defined as those aggregates which are retained on the sieve size of 2.36 mm. Whereas Fine aggregates are those that pass through sieve size of 2.36 mm and are retained on the 0.075 mm sieve. Aggregates which are required for the research work can be obtained from the local market.

B. Plastic Waste as modifier

Modifiers or additives are hereby used to reduce the air void present between aggregates which will enhance the properties of bituminous concrete mixes and also modifiers bind the aggregates together so that no bleeding of bitumen will occur. For the present study, plastic waste such as carry bags, water bottles, milk packets, glasses, cups, etc, will be used as a modifier.

C. Bitumen

Bitumen is a black, highly viscous and very sticky liquid or semi-solid, found in some natural deposits. It is also the by-product of fractional distillation of crude petroleum. Basically, Bitumen is composed of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also bitumen is Mixture of about 400 - 2000 chemical components, with an average of around 600 - 800. It is the heaviest fraction of crude oil, the one with highest boiling point (525° C). Bitumen acts as binding agent for aggregates in bituminous mixes. Generally in India bitumen used in road construction of flexible pavement is of grades 60/70 or 80/100 penetration grade.

D. 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: Primers are obtained by mixing of penetration bitumen with petroleum distillate.
Modified Bitumen: Blend of bitumen with modifiers such as waste plastics or crumb rubber or fly ash is called Modified Bitumen.

E. Various Grades of Bitumen used for pavement purpose

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

F. The desirable property of bitumen for pavement

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

G. Drawbacks of Bitumen

- Temperature Effect: At high temperature bleeding of road occurs, reducing performance of road.
- Oxidation Effect: Due to oxidation bitumen may led to cracking phenomenon.
- Water Effect: Due to water, bitumen strips off from the aggregate forming potholes on roads as it is water repellent material.
- Reduction in life of roads.
- High Cost - Being petroleum product it costs much higher.

IV. MODIFIED BITUMEN

IS 15462:2004 classifies the polymer and rubber modified bitumen into the following four types:
1) PMB(P) Plastomeric thermoplastic based
2) PMB(E) Elastomenc thermoplastic based
3) NRMB Natural rubber and SBR latex based
4) CRMB Crumb rubber/ treated crumb rubber based.

A. Advantages of Modified Bitumen

Properties of modified bitumen depend upon type and quantity of modifier used and process adopted for their manufacture. The advantages of modified bitumen can include following for road works:

- Better adhesion between aggregates and binder
- Lower susceptibility to temperature variations
- Higher fatigue life of mixes
- Better age resistance properties
- Higher resistance to deformation at high pavement temperature
- Delay of cracking and reflective cracking
- Overall improved performance

B. General Requirements of Modifiers:

Modified Bitumen is obtained with the incorporation of selected thermoplastic polymers (Plastomeric or Elastomeric), crumb rubber or natural rubber in bitumen. When used as bitumen modifier, selected polymers/rubbers or a blend of these should have the following properties:

1) Compatible with bitumen.
2) Resist degradation at mixing temperature.
3) Capable of being processed by conventional mixing and laying machinery.

4) Produce coating viscosity at application temperature.
5) Maintain premium properties during storage, application and in service.
6) Capable of providing homogeneous blend with bitumen.

C. Type of Bitumen Modifiers:

Over the years, different types of materials have been investigated as modifiers for bitumen modifications. The commonly used modifiers are given in Table 1. The modifier should be compatible with bitumen to achieve the required properties. Proprietary products may contain a blend of different polymer additives to achieve improvement in properties of bitumen for road works.

Table – 1
Classification of Rubber and Polymer Based Bitumen Modifiers

Types of Modifiers	*Examples*
Plastomeric Thermoplastics	*Polyethylene (PE), Ethylene Vinyl Acetate (EVA), Ethylene Butyl Acrylate (EBA), Ethylene-Methyl-Acrylate copolymers (EMA) etc.*
Elastomeric Thermoplastics	*Styrene Isoprene Styrene (SIS), Styrene-Butadiene-Styrene (SBS) block copolymer, Styrene-Butadiene Rubber , and Ethylene Tar Polymer (ETP) etc.*
Natural Rubber Latex or Rubber Powder	*Synthetic Rubber Latex Styrene Butadiene Rubber (SBR) latex and any other suitable synthetic rubber*
Crumb Rubber or Treated Crumb Rubber	*Crumb Rubber, Treated Crumb Rubber*

D. Applications of Modified Bitumen:

Since a bituminous mix prepared with modified bitumen has a higher stiffness modulus, enhanced fatigue life, better resistance to creep and higher indirect tensile strength, it is suitable as a wearing course, a binder course and overlay material on surfaces which are cracked and subjected to heavy traffic. Modified binders are also used for application like Stress Absorbing Membrane (SAM) for sealing of cracks, Stress Absorbing Membrane Interlayer (SAMI) for delaying reflection cracking, Porous Asphalt and Stone Matrix Asphalt (SMA).

Modified bitumen performs better than conventional bitumen in situations, where the aggregates are prone to stripping. Due to their better creep resistance properties, they can also be used at busy intersections, bridge decks and roundabouts for increased life of the surfacing.

E. Methodology

In order to achieve the objectives of the study, a thorough review is done to have knowledge of the works available in literature. First of all collection of plastic waste can be done. After that shredding or cutting of plastic into small pieces can be done. After that ordinary tests can be performed on aggregate and bitumen. After that using plastic waste coating of aggregate can be done and tests will performed. After that plastic is mixed with bitumen and laboratory tests can be performed. At last comparison of both test results with and without plastic waste can be done.

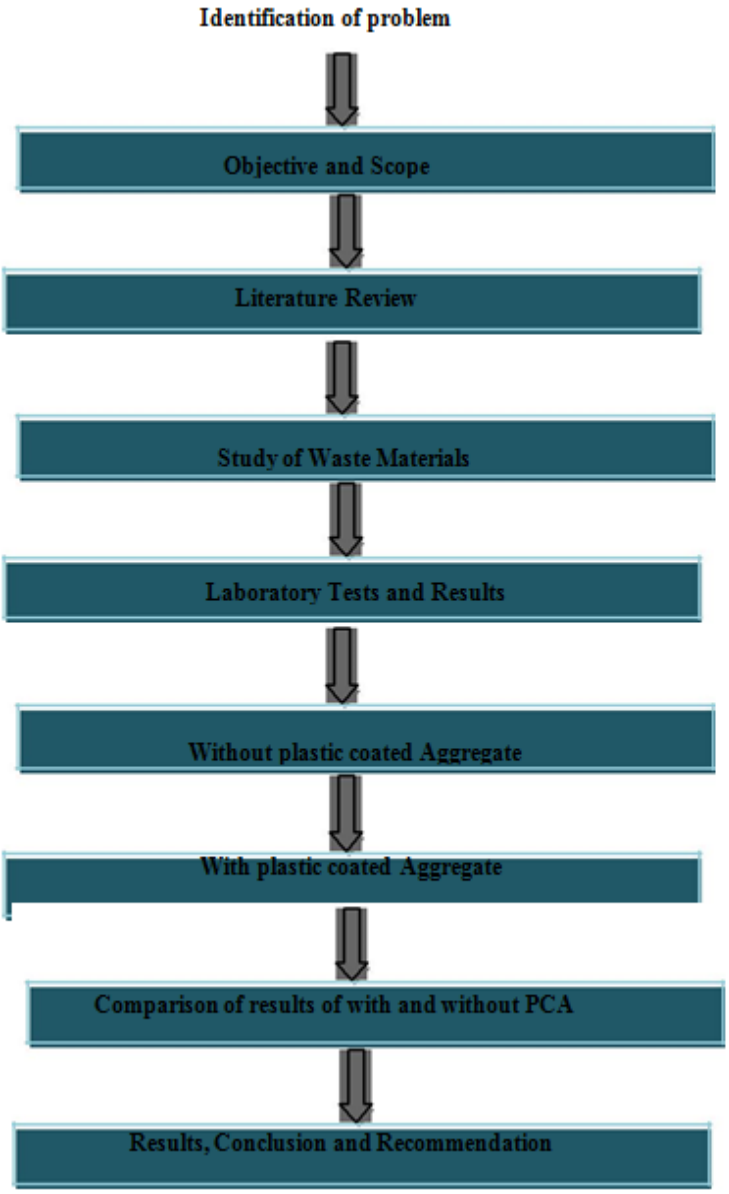

Fig. 1: Proposed Methodology

F. Characteristics of Polymer Modified Bitumen

An alternate use of plastic waste is also under study where plastics is mixed with bitumen and used for preparing the mix. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. The penetration value was decreased to a very low value and similarly the ductility. More than 4% addition of waste plastics to the bitumen results in a hard polymer modified bitumen with very poor visco-elastic property (The minimum values for a suitable bitumen P.V = 85; Ductility ≈ 49).

Table – 2
Properties of Polymer Modified Bitumen

% of Plastics	*Ductility (cm)*	*Penetration (mm)*	*Softening Point (°C)*
1%	*66*	*93*	*56*
2%	*56*	*89*	*51*
3%	*23*	*80*	*50*
5%	*16*	*60*	*78*
10%	*5*	*5*	*82*

On comparison it may be inferred that the use of higher percentage of plastics in polymer modified bitumen is not favourable (Table 2)

1) Binding Property

The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc. were coated with plastics and then moulded into a stable product. On cooling, it was tested for compression and bending strengths.

Table – 3

Binding Property

Percentage of plastics coating over aggregate	*Compression Strength (Tonnes)*	*Bending Strength (Kg)*
10	*265*	*320*
20	*280*	*332*
25	*290*	*345*
30	*330*	*370*

The increase in the values of the compression strength and bending strength shows that the plastics can be used as a binder

Table – 4

Comparison of Test results

S.no	*Tests conducted*	*Test results*			
		Plain Bitumen		*Modified bitumen (10% plastic replaced)*	
1.	*Penetration test*	*72mm*		*66mm*	
2.	*Ductility*	*80mm*		*45mm*	
3.	*Flash point*	*225°c*		*249°c*	
4.	*Fire point*	*246°c*		*287°c*	
5.	*Stripping value*	*0.5%*		*0.05%*	
6.	*Softening point*	*Temp.in°c*	*Time in sec*	*Temp.in°c*	*Time in sec*
		55	*362*	*67*	*248*

V. Economy of the Process and the Plastic Waste Available

This dry process helps to use good quantity of plastic waste in road construction. A model calculation is given in Table 5.

Table – 5

Economics of the process

Size of the road	*Bitumen needed*	*Plastics needed*	*Bitumen saved*	*Cost reduced*
1kmX 3.75 m	*9 tonnes*	*1 tonnes*	*1 tonnes*	*Rs.18,000*

A model is being worked using Tirunelveli, a town in Tamil Nadu. The plastics waste collected is around 750 tonnes/ annum. The roads available are approximately 400km and their annual requirement of plastic waste to lay plastic road is more than 600 tons. So the total waste generated could be used for road laying. The life of the road is increased and hence the maintenance expenditure is reduced.

VI. Summary of Marshall Stability Test

A. Mix design for bitumen:

The Marshall Quotient is also within the range of tolerance, thus showing that the plastic waste (polyethylene) blended bitumen mix is better and more suitable for flexible pavement construction.

Table – 6

Marshall Stability test within 6 % plastic waste

Bitumen usage in A.C. Mix (%)	*Identification Mark*	*Weight of Asphaltic concrete mould in air (gm)*	*Weight of Asphaltic concrete Mould in water (gm)*	*Volume of mould (cc)*	*Asphaltic mould C.D.M. (g/cc)*	*Dial Gauge reading*					
						Flow Value	*Division*	*Load Factor*	*Co-relation*	*Ratio*	*Marshall Stability (Kgs)*
4.5	*I*	*1187*	*647*	*539*	*2.22*	*2.55*	*125*	*6.74*		*0.96*	*772.12*
	II	*1181*	*643*	*537*	*2.2*	*2.4*	*116*	*6.74*		*0.96*	*765.31*
	III	*1178*	*641*	*538*	*2.15*	*2.54*	*128*	*6.74*		*0.93*	*781.54*
	Average				*2.19*	*2.496*					*772.99*
5.0	*I*	*1191*	*652*	*536*	*2.12*	*2.62*	*152*	*6.74*		*0.96*	*951.15*
	II	*1189*	*657*	*538*	*2.2*	*2.60*	*156*	*6.74*		*0.96*	*961.04*
	III	*1193*	*653*	*539*	*2.22*	*2.64*	*153*	*6.74*		*0.96*	*949.59*
	Average				*2.176*	*2.626*					*953.926*
5.5	*I*	*1192*	*651*	*541*	*2.2*	*2.84*	*181*	*6.74*		*0.93*	*1131.27*
	II	*1189*	*656*	*538*	*2.21*	*2.78*	*180*	*6.74*		*0.96*	*1161.12*
	III	*1190*	*654*	*536*	*2.12*	*2.77*	*182*	*6.74*		*0.96*	*1149.89*

Based on above results (Table 6) the graph is placed between plastic contents and stability:-

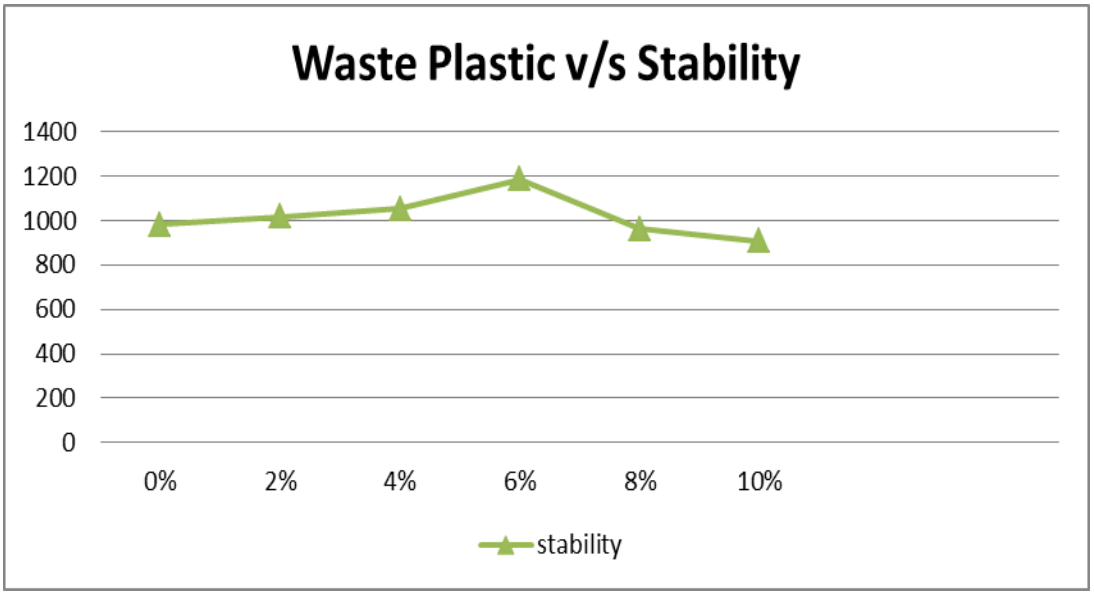

Fig. 2: plastic content on X axis and stability on Y axis.

VII. SIGNIFICANCES

The polymer bitumen blend is a better binder compared to plain bitumen. The blend has increased Softening Point and decreased Penetration Value with a suitable ductility. When used for road construction it can withstand higher temperature. Hence it is suitable for tropical regions. It has decreased Penetration Value. Hence its load carrying capacity is increased. The blend with aggregate has no Stripping Value. So it can resist the effect of water. The Marshall Stability Value is high. The bitumen required can be reduced depending upon the % of polymer added. It is a good saving too. No toxic gas is produced. Disposal of waste plastic will no longer be a problem. The binding properties of polymer also improve the strength of mastic flooring. The use of waste plastics on the road has helps to provide better place for burying the plastic waste without causing disposal problem. At the same time, a better road is also constructed. It also helps to avoid the general disposal technique of waste plastics namely land-filling and the incineration, which have certain burden on ecology.

VIII. CONCLUSION

The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. So, the use of waste plastics and crumb rubber for flexible pavement is one of the best methods for easy disposal of waste plastics. These processes are ecofriendly and socially highly relevant, giving better infrastructure .The addition of waste plastic modifies the properties of bitumen. When compared to standard results the modified bitumen shows good result. The optimum content of waste plastic to be used is between the ranges of 5% to 10%. The problems like bleeding are reduced in hot temperature region. Plastic has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic. The waste plastics thus can be put to use and it ultimately improves the quality and performance of road. Total material cost of the project is reduced by 7.99%

REFERENCES

[1] Bindu, C.S. Beena, K.S. (2010). "Waste plastics as stabilizing additive in Stone Matrix Asphalt", International Journal of Engineering and Technology, Vol.2(6), 379-387
[2] IRC SP-53:2010, "Guidelines on use of modified bitumen in road construction"
[3] IRC SP: 53-2002, 2004, 2010 "Guidelines on use of Polymer and Crumb Rubber Modified binders
[4] Ministry of Road Transport and High Ways, Manual for construction and supervision of Bituminous works, New Delhi, November 2001.
[5] Ministry of Road Transport and Highways Specification (2010)
[6] R. Vasudevan, S. K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar and B. Sundarakannan, Utilization of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymers, Proceedings of the International Conference on Sustainable Solid Waste Management, 5-7, Chennai, India, September (2007) pp. 105-111
[7] Rokade S "Use of Waste Plastic and Waste Rubber Tyres in Flexible Highway Pavements" (2012)International Conference on Future Environment and Energy IPCBEE vol.28, IACSIT Press, Singapore (2012)
[8] Sabina,Khan Tabrez A, Sangita, Sharma D.K., Sharma B.M, Performance Evalution. of Waste Plastic/ Polymers Modified Bituminious Concrete Mixes,Journal of Scientific and Industrial Research Vol.68,2009.
[9] S.K. Khanna and C.E.G. Justo, (2000) "Highway material testing manual", Nemschand and brothers publications,
[10] Vasudevan, R., Utilization of waste plastics for flexible pavement, Indian High Ways (Indian Road Congress), Vol. 34, No.7. (July 2006).