PERFORMANCE EVALUATION OF POLYMER MODIFIED BITUMEN IN FLEXIBLE PAVEMENT

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ABSTRACT

The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials world over creating a problem of its disposal in eco-friendly way. To deal with the problem, study on use of plastic waste as partial replacement to bitumen in flexible pavement is considered in the present work. The work consists of an experimental approach towards waste management and finding alternative to conventional materials in flexible pavements. To simulate with the field conditions Marshall stability method is considered to carryout experimental work. The objective of work is to investigate the effect of plastic waste in flexible pavement and to suggest the optimum percentage of bitumen that can be replaced by plastic waste for the improvement of roads. Number of laboratory tests has been carried out by replacing bitumen by plastic waste. The results obtained in laboratory investigation indicate major gain in strength with substantial saving in cost.

Key Words : Replacement, Plastic waste, Flexible pavement, Waste management, Ecofriendly waste disposal

INTRODUCTION

Plastic is a multipurpose material. Due to its large scale production plastic seemed to be a cheaper and valuable raw material for every fundamental sector of the economy starting from agriculture to packaging, building construction, electronics, electrical, automobile, communication sectors. Every sector is almost revolutionized by the applications of plastic. Due to the change in scenario of life style, the polymer demand is increasing everyday across the globe. Plastic is a non-biodegradable material and researchers have found that the material can remain for long duration on earth without degradation. 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.

Several studies have verified that plastic (LDPE/HDPE) can be used in experimental works related to flexible pavements Bitumen and bituminous mixes are modified in order to improve the performance of bituminous concrete mixtures. There are two different processes, the wet method involves the use of ready mixed modified bitumen, while the dry process involves adding waste polymers/rubbers (in powder, shredded or granular form) to the aggregate followed by bitumen during mixing process at the hot mix plant.[1] The effect of such modification varies with the percentage of the modifier used. In general, consumption of such waste materials in the highway sector is a valuable dumping alternative, which reduces the disposal cost and save the environmental pollution.[2] Consequently, with improved durability and resistance against deformation to conventional bituminous mixes the durability of the roads is increased.[3] In this work focus has been given on the strength of flexible pavement and disposal of plastic in eco-friendly way. To deal with the problem, attempt is made on use of plastic waste as partial replacement by wet mix process.

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AIMS AND OBJECTIVES

1. To study the use of waste plastic in bitumen roads by wet mix process,
2. To find an alternative method for disposal of plastic waste in eco-friendly way and
3. To find a suitable alternative over conventional materials with cost reduction and improvement in strength and other parameters in flexible pavements.

MATERIAL AND METHODS

Bitumen

Bitumen is a sticky, black and highly viscous liquid or semi-solid, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen. The bitumen used for the present work is of 60/70 penetration grade and has been widely used for paving application, it is used as binder in present work and the physical properties of bitumen in comparison to IS: 73, 1992[4] are given in **Table 1**. All tests conducted on bitumen were in accordance with procedure laid down in Indian Standards. The basic test properties on bitumen and modified bitumen indicates that the replacement of bitumen by waste plastic reduces the penetration and ductility values, whereas increases in softening point and specific gravity values, when about 7.5% by weight of bitumen having 5.5 percent optimum bitumen content, is replaced by waste plastic.

Table 1 : Physical properties of bitumen[5]

S/N	Properties tested	unit	Results obtained for		Specification limits as per IS: 73, 1992
			Bitumen	Modified bitumen	
1	Ductility (25 ^{o} C)	cm	78.87	78	≥ 75cm
2	Softening point	°C	49.55	51	46°C-54°C
3	Penetration (25 ^{o} C, 0.1mm)	mm	67.66	67	50-70
4	Specific gravity	g/c m^3	1.03	1.06	≥ 0.99

Aggregate

Aggregate forming the main skeleton of pavement should be tested against their suitability as a pavement construction material with reference to Morth. Number of tests were carried out on aggregate the results obtained are shown in **Table 2**.

Plastic

The plastic waste constitutes two major categories of plastics, thermoplastics and thermo set plastics. Thermoplastics, constitutes 80% approximately and thermo set constitutes approximately 20 % approximately of total post-consumer plastics waste generated in India.

Table 2 : Physical properties of aggregates used

S/N	Properties tested	Results	Permissible value as per MORTH
1.	Crushing strength	19.8 %	30 % Max
2.	Los Angeles abrasion value	16.96 %	30 % Max
3.	Impact value	14.36%	24 % Max
4.	Average specific gravity	2.68	2-3
5.	Water absorption	1.30 %	2 % Max
6.	Flakiness	12 %	30 % Max
7.	Elongation	14 %	30 % Max
8.	Coating and stripping of bitumen aggregate mixture	98 %	≥ 95%

The thermoplastics are recyclable plastics which include, polyethylene terephthalate (PET), low density poly ethylene (LDPE), poly vinyl chloride (PVC), high density poly ethylene (HDPE), polypropylene (PP), polystyrene (PS) etc. However, thermo set plastics contains alkyd, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, metalised and multilayer plastics etc. Most of thermoplastics on heating soften at temperature between 130-140°C. The analysis of thermoplastics has proven that there is no gas evolution in the temperature range of 130-180 °C and beyond 180 °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°C. **Table 3** gives the source of waste plastic generation.

Table 3 : Waste plastic and its source[5]

Waste plastic	Origin
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetics and detergent bottles.
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house articles etc
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottles caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps, Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl Chloride (PVC)	Mineral water bottles, Credit cards, toys, pipes and gutters: electrical fittings, furniture folder and pens, medical disposables:etc.

Low Density Poly Ethylene (LDPE) was used by Zoorob S.E.[6] in his work as a replacement to aggregates and High Density Poly Ethylene (HDPE) for example plastic carry bags were used by Vasudevan R., S.K.Nigam of Thiagarajar College of Engineering Madurai, they used plastic carry bags (HDPE) in two different ways i.e., wet method and dry method. It was found that both methods shown positive results related to use of plastic waste in flexible pavements.

Punith and Veeraragavan[7] used reclaimed PE as asphalt modifiers. They found that the basic test properties indicated that the addition of PE content to neat asphalt reduces the penetration and ductility values, whereas increases in softening point and specific gravity values were observed with the addition of PE modifier. A PE content of 5% by weight of asphalt is recommended for the improvement of the performance of asphalt cement.

Sinan and Emine[8] tried to investigate the possibility. The possibility of using various plastic

wastes containing High Density Polyethylene (HDPE) as polymer additives to asphalt concrete. From the work done it is observed that waste HDPE-modified bituminous binders provide better resistance against permanent deformations due to their high stability and high Marshall Quotient (MQ) and it contributes to recirculation of plastic wastes as well as to protection of the environment.

Ranadive and Tapase[9] investigated the benefits of use of plastic in bituminous mix in shredded form. Conventional (without plastic) and mix with variation in plastic waste (5%,10%, 15% and 20%) as replacement to bitumen mixtures were subjected to performance test including Marshall Stability. Based on the experimental study it is observed that the ten percent of bitumen can be replaced by plastic waste in

bituminous layer having 5.5 percent optimum bitumen content. Cost reduction in bitumen is nearly about 8.00 percent when the bitumen is replaced by 10 percent plastic waste. The sudden increase in stability is because of natural aggregates are coated with plastic waste before mixing with bitumen which do not allow water to enter inside and increases its stripping value. It is found that the recycled polyethylene bags may be useful in bituminous pavements resulting in reduced permanent deformation in the form of rutting and reduced low temperature cracking of pavement surfacing.

It have been decided to use High density polyethylene (HDPE) plastic waste carry bags in shredded as well as in powdered form in the present work, as a replacement to bitumen by following wet process and also to find the optimum bitumen that can be replaced by plastic waste. Here the scope is to investigate the effect of plastic waste in bituminous concrete layer of flexible pavement. The laboratory studies conducted by some research institutes regarding utilization of waste plastic bags in bituminous mixes have proved that these enhance the properties of mix.[10, 11] Also, the performance tests have proved that the fatigue life is doubled and resistance to rutting and water damages increased when plastic waste is used.

Wet mix process

Waste plastic is ground and made into powder plastic in trial percentage 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 for tar making the asphalt last long. By mixing plastic with bitumen the ability of the bitumen to withstand high temperature increases. 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.[12]

Experimental set up

Most asphalt technologist believes that fundamental changes must be made in the composition of hot mix asphalt and its testing methods. Though, there are many methods being followed, the basic principle behind them is to arrive at the optimum binder content, given the gradation selected and the mechanical properties desired. Here the specimen used is prepared as per standard Marshall stability test (ASTM D 1559), which is cylindrical 100mm diameter compacted with Marshall compacting hammer on either side with 75 number blows and loaded circumferentially. Overall, 60 specimens were prepared for different percentage of bitumen content. It was 4.5 %, 5%, 5.5% and 6% by weight of aggregates. Also the specimens were prepared by varying percentage of bitumen replaced by plastic waste in the range of 5 to 12.5 percent. For accuracy averaging from 3 tests was done.

Mix design

The gradations adopted for mix are taken as specified by Manual for Construction and Supervision of Bituminous works MoRTH India. Here blending percentage for aggregate are taken as 20mm size aggregate 25% of total aggregate mix, 12.5mm, 10mm, 6mm each 10% and grit as 45% as per mix design prepared for bituminous concrete layer of flexible pavement.

Steps for sample preparation for control mix with different bitumen content

(a) Oven dried aggregate for approximately 12 hours at around 105^{o}C to 110^{o}C was separated into the individual specified sizes by dry sieving.
(b) Individual aggregates were recombined to the correct proportions for approximately 1200gm specimens according to mix design.
(c) The aggregates were thoroughly mixed on mixing pan.
(d) Then after the hot bitumen as per trial percent (say 4.5% of total mix weight) is mixed with aggregate at temperature of 160 ^{o} C.
(e) After properly mixing aggregate with bitumen the mix was filled in a mould at a time and compaction plate was placed on which 75 number of blows were given on either sides of sample manual by Marshall hammer.

Sample preparation for different percent of bitumen replaced by plastic waste

All the steps up to (c) were carried out as mentioned earlier in than the steps from (d) were followed as mentioned below

(d) Before mixing hot bitumen at nearly about 170 ^{o} C with natural aggregates at 160 ^{o} C, the powdered plastic waste as trial percent (say 5 %, 7.5%, 10 %, and 12.5%) of replacement of bitumen was manually sprinkled into the hot bitumen. Plastic gets mixed with bitumen, modifying the properties of bitumen. (e) Required quantity of modified bitumen as per trial percent was added to the sample. Mix it thoroughly at temperature of 160 ^{o} C. (d) Same procedure was repeated for filling the sample in the mould as mentioned earlier.

RESULTS AND DISCUSSION

Experimental results from tests performed on bituminous concrete specimens to know the stability, flow value, bulk density, per cent air voids, and per cent V.M.A. are obtained.The use of modified bitumen prepared by partial replacement of bitumen with the processed waste plastic of about 7.5% by weight of bitumen having 5.5 percent optimum bitumen content, helps in improving the Marshall stability and other desirable properties of bituminous concrete mix, with marginal saving in bitumen usage, in comparison with the untreated or ordinary bitumen.

Considering stability as main parameter, it is observed **(Fig. 1)** that at 5.5 percent bitumen content with 7.5 percent bitumen replaced by plastic waste shows increased stability keeping all the other parameters within limits. From the experimental work it is clear that the properties of laboratorial designed bituminous mix for bituminous concrete are much more superior to those of the control mixes entirely composed of mineral aggregates and can be effectively used in practical applications.

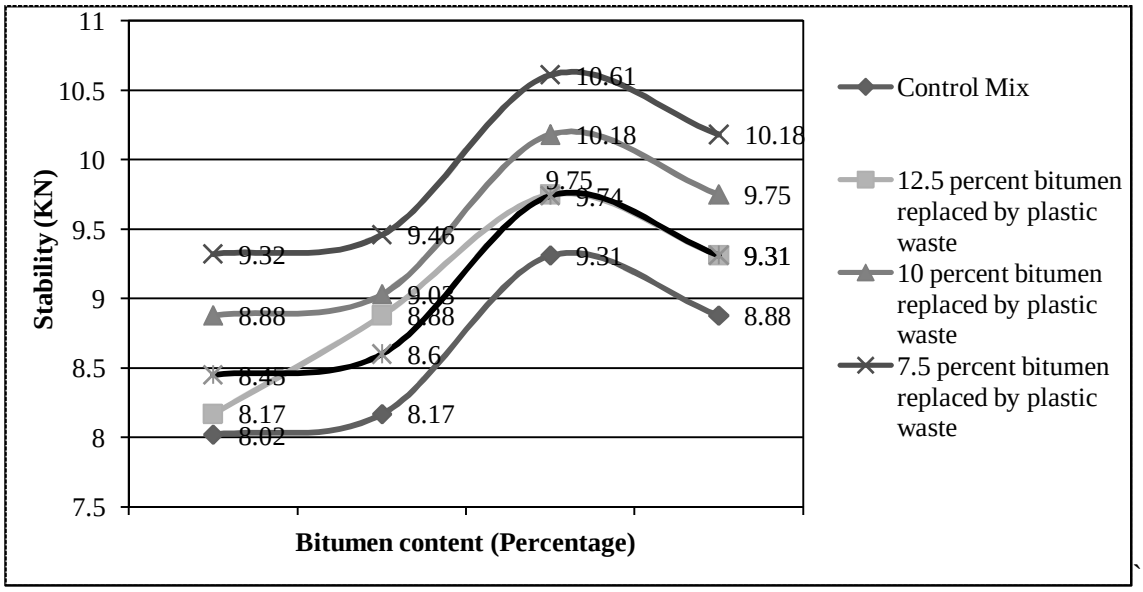

Fig. 1 : Stability (KN) Vs bitumen content (percentage) for all cases

CONCLUSION

Based on the experimental study following important conclusions are drawn. From the study, it is observed that the 7.5 percent of bitumen can be replaced by plastic waste in bituminous layer having 5.5 percent optimum bitumen content. The basic test properties indicate that the replacement of bitumen by waste plastic reduces the penetration and ductility values, whereas increases in softening point and specific gravity values, when about 7.5 percent by weight of bitumen having 5.5 percent optimum bitumen content, is replaced by waste plastic. Percent material cost reduction is approximately about 5% of total material cost and about 6.5% of total cost of project when there is 7.5 percent replacement of bitumen by plastic waste. It may vary from place to place due to difference in cost of materials.

It is concluded in general that it is a simple eco-friendly process, helps to save cost of bitumen, improves performance of roads, solves problem of plastic waste disposal and it is one time investment for shredding machine which can be reused. This process can prove practically more effective if segregation at the source is done, instead of going through the banning of plastics, it is important that needed education is to be given.

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