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Bituminous Mix Design Using Plastic And Rubber Waste Materials For Dence Bound Mecadam

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ABSTRACT: The seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its visco-elastic nature. Several types of flexible pavement failure/distress occur due to this behavior of asphalt binder, among which rutting and fatigue cracks are very common. The waste plastic and rubber can be used to partially replace the conventional material to improve desired mechanical characteristics for particular road mix. Waste like plastic bottles, polymers, cups, waste tyre's can be re-used by powdering or blending it with crushers and can be coated over aggregate and bitumen by any heating process.

In this study, Low Density and High Density Polyethylene and Crumb rubber will be used as additions to base bitumen. In the present study, a comparison is carried out between use of different waste plastics like plastic bottles, polymers, cup and crumb rubber for different percentage by weight of bitumen in dense bituminous macadam (DBM) mix to analyze which has better ability to modify bitumen so as to use it for road construction particularly in base layer. The laboratory experiments for aggregates, bitumen with waste plastic and crumb rubber, Marshall stability test for mix design etc. will be carried out as per IRC guidelines. This type of application of waste plastics and waste rubber tyres in road construction activity will not only reduce the problem of environmental pollution, but also save the costly and scarce bitumen.

***Keywords*- Waste Plastic , Crumb Rubber , Bitumen , Marshal Stability Test**

I. INTRODUCTION

1.1 General

India has a road network of over 5,472,144 kilo-meters as on 31 March 2015, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of the total road network. India being a very vast country has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber modifier (CRM).

Crumb rubber is the term usually applied to recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles. From physical and chemical interaction of crumb rubber with conventional bitumen Crumb Rubber Modified Bitumen (CRMB) is made. Its advantages are: Lower susceptibility to daily & seasonal temperature variations, higher resistance to deformation at elevated pavement temperature, better age resistance properties, higher fatigue life of mixes, Better adhesion between aggregate & binder, Prevention of cracking & reflective cracking, and Overall improved performance in extreme climatic conditions & under heavy traffic condition.

1.2 Plastic

A plastic is a type of synthetic or man-made polymer; similar in many ways to natural resins found in trees and other plants. India's consumption of Plastics will grow 15 million tons by 2015 and is set to be the third largest consumer of plastics in the world. Various activities like packing consume almost 50-60% of the total plastics manufactured .Plastic offer advantages lightness, resilience, resistance to corrosion, color, fastness, transparency, ease of processing etc. The plastic constitutes two major category of plastics based on physical properties; (i) Thermoplastics and (ii) Thermo set plastics. The thermoplastics, constitutes 80% and thermo set constitutes approximately 20% of total postconsumer plastics waste generated .In a thermoplastic material the very long chain – like molecules are held together by relatively

weak Van der Waals forces. In thermosetting types of plastics the molecular are held together by strong chemical bonds making it quite rigid materials and their mechanical properties are not heat sensitive.

Table 1. Types of plastics

Thermoplastic	**Thermosetting**
Polyethylene Terephthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy
Polyvinyl Acetate (PVA)	Melamine
Polyvinyl Chloride (PVC)	Polyester
Polystyrene (PS)	Polyurethane
Low Density Polyethylene (LDPE)	Urea – Formaldehyde
High Density Polyethylene (HDPE)	Alkyd

Table 2. Waste plastic and its sources

HDPE	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
PET	Carry bags, bottle caps, house hold articles etc.
PP	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.,
PS	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc
PVC	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc

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 Fibers.

1.3 Crumb rubber

Crumb rubber is actually small pieces of waste tyre scrapped from light motor vehicles and whose disposal is a serious menace. The annual available capacity for procured tyres retreading is 4.8 million for bus and truck tyres and 4.5 million for car and jeep tyres .The crumb rubber is made by shredding scrap tire, which is a particular material free of fiber and steel. The rubber particle is graded and found in many sizes and shapes. The crumb rubber is described or measured by the mesh screen or sieve size through which it passes during the production process. To produce crumb rubber, generally, it is important to reduce the size of the tires.

1.4 Problem Statement.

The plastic wastes could be used in road construction and 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. The rapid rate of urbanization and development has led to increasing plastic waste generation. As plastic is non bio-degradable in nature, it remains in environment for several years and disposing plastic wastes at landfill are unsafe since toxic chemicals leach out into the soil, and under-ground water and pollute the water bodies.

1.5 Aim of the study

The aim of the study is to determine the feasibility of Bituminous Mix design in stabilization and cost optimization by locally available plastic & rubber waste using in sub-base dense bitumen macadam by conducting various laboratory tests.

1.6 Objective of the study

The main objectives of the study are:

- The purpose of this project is to utilize this plastic & rubber waste as useful binding material, save the bitumen in flexible pavement.
- Analysis of the properties of bituminous mix specimen.
- To study the Marshall properties of the dense bitumen macadam with PET bottles and crumb rubber so as to determine how they affect the properties of mixes and to compare it with each other and with the conventional mix.
- To find a suitable alternative over conventional materials with cost reduction and improvement in strength and other parameters in flexible pavements.

1.7 Scope of the study

This study is focused on to identify the Bituminous Mix design using plastic and rubber waste materials for Dence Bitumen Macadam. Also to determine the engineering characteristics of Bituminous Mix design with additives to find whether it is viable for use in terms of economically, suitability and environmentally. The main testing is carried out to compare the strength and characteristic of Bituminous Properties Without Waste material and with plastic & rubber waste in binder content and without waste material like all bituminous binder content. Marshall stability test (as per ASTM D 1559) can be applied to determine the binder content in bitumen mix design

II. Review of Literature

Miss Apurva J Chavan(2013) Disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as will help to improve the environment. 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. In my research work I have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen.

Abhaykumar & Mudassir(2013) Many roads agencies have been experiencing problem of premature failure of pavements like potholes, roughness, cracks and etc. which leads to poor performance of roads and its life. On the other hand, plastics, rubbers, etc. are increasing day by day. Waste like plastic bottles, polymers, cups, waste tyre's can be re-used by powdering or blending it with crusher's and can be coated over aggregate and bitumen by any heating process. In this study we have used polymer and crumbed rubber as a binder with respect to aggregate and bitumen. In bituminous roads, we use materials like aggregate (of various sizes), grit and bitumen. The various tests are conducted during this study on aggregates such as crushing value, impact value, abrasion value, and specific gravity and also on bitumen penetration value, ductility, softening point. The results are discussed in this paper.

V. Suganpriya (2016) The aim of the study was to utilize the waste materials i.e. crumb rubber waste for mass scale utilization such as in highway construction in an environmental safe manner. As a first part of this study, an attempt was made to assess the stabilization of the bitumen containing crumb rubber waste in shredded form by performing basic tests such as Penetration Test, Ductility Test, Softening Point Test, Viscosity Test and Flash & Fire Point Tests. On the basis of the performance of the modified bitumen, the range of optimum percentages of crumb rubber waste were selected for further investigations related to Bituminous Concrete Mixes such as Semi Dense Bituminous Concrete (SDBC). Marshall Values, namely Marshall Stability Value, Marshall Flow Value, Voids present in air, Voids in Aggregates and Voids in Bitumen, determined from Marshall Stability Test, serve as the benchmark values to assess the quality of Bituminous Concrete. The design and performance of Bituminous Concrete mainly depends upon the quality and percentage of binder used. Experimental investigations were undertaken to check the pavement worthiness of these mixes.

Kiran Kumar & J.Vikranth (2017) Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted. Now a days, the steady increment in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature put us in a demanding situation to think of some alternatives for the improvisation the pavement characteristics and quality by applying some necessary modifications which shall satisfy both the strength as well as economical aspects. Also considering the environmental approach, due to excessive use of plastics in the day to day business, the pollution to the environment is enormous. Since the plastic (polypropylene) are not biodegradable, the need of the current hour is to use the waste polypropylene in some beneficial purposes.

III. Methodology

3.1 Methodology Chart

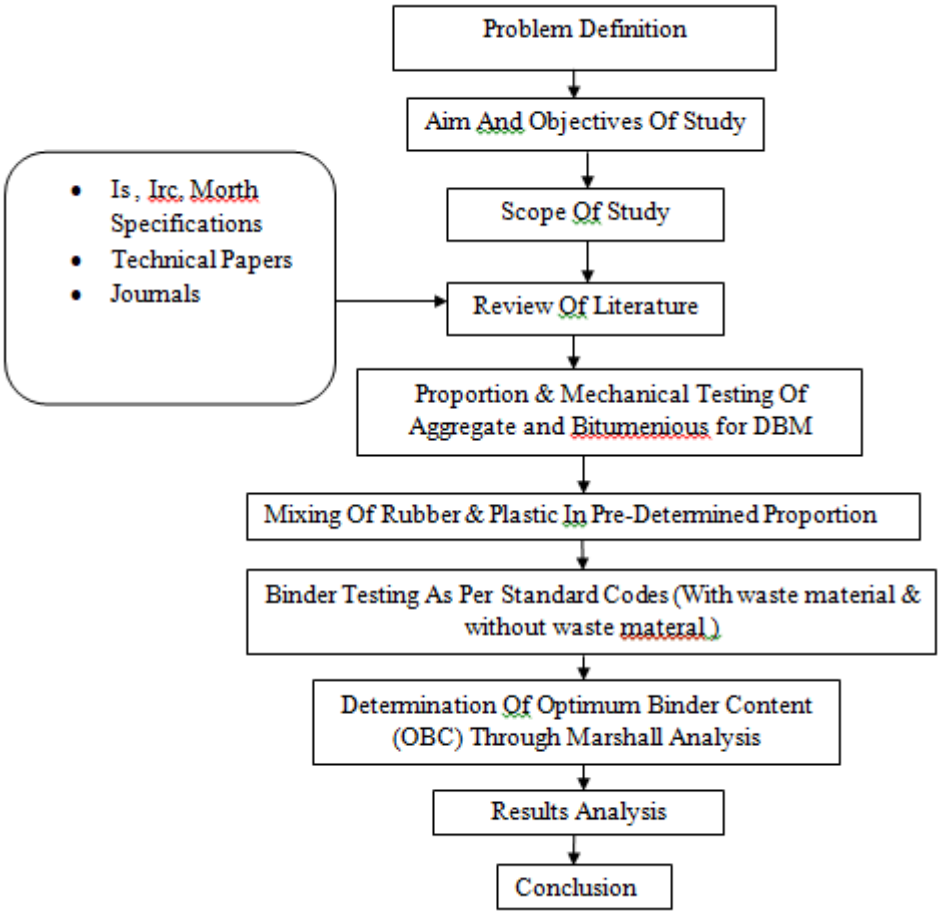

Figure 1 Methodology Chart

Iv Data Collection & Analysis

4.1 Sample Preparation

The sample preparation was done as per the following procedure.

a) Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan.

b) The aggregates and filler are mixed together and heated to a temperature of 175^0 C to 190^0 C. This is because the aggregate and bitumen are mixed in molten state so preheating is required.

c) The bitumen was also heated up to its melting point prior to the mixing.

d) The required amount of shredded CR waste (say, 5 % by weight of bitumen) was weighed and kept in a separate container.

e) The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above mentioned temperature.

f) The CR (crumb rubber) waste is being added to the aggregate and was mixed for 2 minutes.

g) Now, the required quantity of first trial percentage of bitumen (say, 5 % by weight of mineral aggregates) is added to the heated aggregates and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was clearly seen from the uniform colour throughout the mix.

h) The mixing temperature for 80/100 grade bitumen may be around 154^0 C

i) Then the mix was transferred to a casting mound so as to obtain a compacted bituminous mix specimen of thickness 63.5 ± 3 mm.

j) This mix was then compacted by the Marshall Hammer.

k) 75 No. of blows were given on each side of the sample so that total of 150 No. of blows was given per sample.

l) Then these samples with mounds were kept separately and marked.

m) Vary the bitumen content in the next trial by +0.5% and repeat the above procedure.

Table 3.Properties of Bitumen with Crumb Rubber Modified Bitumen

Sample	Penetration Value ($1/10^{th}$ of mm)	Ductility Value (cm)	Softening Point (c)	Viscosity (Second) At 60 c
Bitumen	51	75	51.7	405
Bitumen + 3.5 % CR	45	23	46.45	229
Bitumen + 5.5 % CR	53	19	49	300
Bitumen + 7.5 % CR	64	18	51.5	391

Table 4.Properties of Bitumen with Crumb Rubber Modified Bitumen

Sample	Penetration Value ($1/10^{th}$ of mm)	Ductility Value (cm)	Softening Point (c)
Bitumen	51	75	51.7
Bitumen + 1 % PET	68	67	61
Bitumen + 1.5 % PET	67	54	64
Bitumen + 2 % PET	64	35	65.2

Marshall Stability Test

The samples to be tested are then kept immersed under water in a thermostatically controlled water bath maintained at 60 ± 1^0 C for 30 to 40 minutes. Marshall mix design is the standard design procedure for determining the mix ratio for bituminous road pavements for a particular bituminous concrete. The test procedure is used in designing and evaluating bituminous paving mixes. The test procedure is extensively used in routine tests program for the paving jobs. There are two major features of the Marshall method of designing mixes namely, (i) density-voids analysis and (ii) Stability Flow tests. The Marshall stability of the mix is probably defined as a higher load carried by a compacted specimen at a standard temperature of 60 ^{0} C. The flow value is the deformation of Test specimen undergoes during the loading up to the maximum load, in 0.25 mm units. In this test it is necessary to obtain optimum binder content for the type of aggregate mix and traffic intensity. Therefore the following steps for the design of bituminous mix which are adopted are given below.

a) Select grading type which is to be used in the test.

b) Choose the aggregates to be employed in the mix.

c) Determine the proportion of each aggregate used are required to produce the design grading.

d) Determine the specific gravity of the aggregate combination and of the asphalt cement.

e) Make up trial specimens with varying asphalt contents.

f) Determine specific gravity of each compacted specimen.

g) Make stability test on the specimens.

h) Calculate the percentage of Air voids, Voids in Mineral Aggregates (VMA) and the Voids which are Filled with Bitumen (VFB) in each specimen.

i) Calculate the optimum bitumen content from the data obtained.

j) Check the values of Marshall Stability, Flow value, Voids in mix and maximum Voids which are filled with bitumen obtained at the optimum bitumen content, with the design requirements. The design may be repeated if necessary when altering of the gradation is done so as to fulfill the design requirements.

Fig 2. Mix with PET bbottle

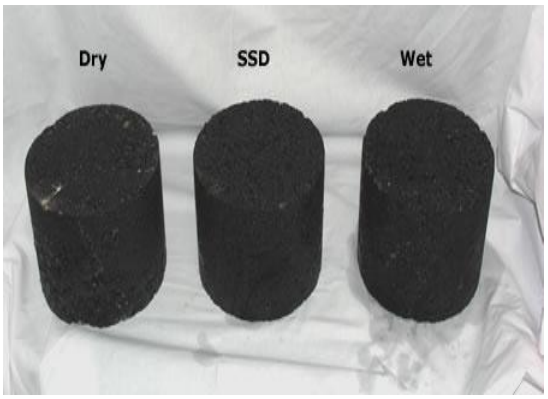

Fig 3. Mix with Crumb rubber

Marshall Stability and Flow Value

Table 5. Marshall Stability Flow Value for Crumb Rubber Modified DBM mix

CR %	Bitumen %	Flow Value (mm)	Stability (kn)
3.5 %	4 %	2.80	1055.60
5.5 %	4 %	3.10	1123.33
7.5 %	4 %	3.20	1176.70

Table 6.Marshall Stability Flow Value for PET Modified DBM mix

PET %	Bitumen %	Flow Value (mm)	Stability (kn)
1.0 %	4 %	1.60	18.16
1.5 %	4 %	1.85	19.76
2.0 %	4 %	2.22	21.80

Table 7.Density and Void Analysis for DBM Mix with Crumb Rubber

CR %	Bitumen %	V_v	V_b	VMA	VFB
3.5 %	4 %	4.2	12.10	17.64	78.62
5.5 %	4 %	3.9	12.60	20.66	73.85
7.5 %	4 %	3.7	13.60	15.62	72.62

Table 8 Density and Void Analysis for DBM Mix with Crumb Rubber

PET %	Bitumen %	V_v	V_b	VMA	VFB
1.0 %	4 %	4.82	10.20	12.62	72.66
1.5 %	4 %	4.5	12.20	13.10	77.80
2.0 %	4 %	4.35	14.20	14.80	81.72

Conclusion

1. By Carrying out Marshall test for control mix Samples Which was prepared by 3.9 % , 4 % , 4.1 % Bitumen By Weight of aggregate to from DBM mix , OBC Was Obtained as 4.0 %

2. Addition of Polyethine PET (1.0 %, 1.5 % , 2.0 %) Crumb Rubber in (3.5 % , 5.5 % , 7.5%) to DBM mix Samples Keeping Constants OBC it was found that in all Three Cases , the optimum content was obtained as 5.5 % in rubber and 2.0 % in Plastic waste
3. Since the Marshall stability is higher in case of PET Bottles Compared to rubber and polythene , They can be regarded as the best modified among three
4. The use of polythene , rubber and PET in roads can solve the problem of environmental damage which can be caused by their disposal

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