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Application of Waste Plastic as an Effective Construction Material in Flexible Pavements

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ABSTRACT

Many roads are constructed with bitumen, in this process modified the bitumen with adding of waste plastic. Now a days plastic was generated very huge. In this point of view, present project work makes a change to environment to reduce waste plastic, in this point I used waste plastic as coating agent to aggregates with specific percentages. In this project work I conducted the material tests for what I used in this work. 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, and we used waste plastic as coating agent to aggregates. In this process I noticed that the use of waste plastic was to increase strength and void ration of bitumen mix. And slightly used in flexible pavements not effected to strength properties. In this project work I used 3.5,4,4.5,5 percentages of bitumen mix, and I added the waste plastic also. Finally, present project work conclude in this work was to use waste plastic as coating agent to aggregates was not affecting strength.

Keywords— Waste Plastic, Aggregate, Bitumen.

1.INTRODUCTION

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

Requirements of a pavement:

An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

TYPES OF PAVEMENTS:

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

FLEXIBLE PAVEMENTS

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure (see Figure 1).

Deflection on flexible pavement:

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Types of Flexible Pavements

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,
- Full - depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

Typical layers of a flexible pavement

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder

course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade

a) Seal Coat

Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.

b) Tack Coat

Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.

c) Prime Coat

Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface.

2) Surface course

Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete(AC). The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course

This layer provides the bulk of the asphalt concrete structure. It's chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course

The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course

The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade

The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

Failure of flexible pavements

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable number of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue test on asphaltic concrete specimens. Rutting occurs only on flexible pavements as indicated by permanent deformation or rut depth along wheel load path. Two design methods have been used to control rutting: one to limit the vertical compressive strain on the top of subgrade and other to limit rutting to a tolerable amount (12 mm normally). Thermal cracking includes both low-temperature cracking and thermal fatigue cracking. Pavement design deals with the structural design of roads, both (bituminous and concrete), commonly known as (flexible pavements and rigid pavements) respectively. It deals with the design of paving materials, determination of the layer thickness, and construction and maintenance procedures. The design mainly covers structural aspects, functional aspects, drainage. Structural design ensures the pavement has enough strength to withstand the impact

of loads, functional design emphasizes on the riding quality, and the drainage design protects the pavement from damage due to water infiltration. Traffic engineering covers a broad range of engineering applications with a focus on the safety of the public, the efficient use of transportation resources, and the mobility of people and goods. Traffic engineering involves a variety of engineering and management skills, including design, operation, and system optimization. In order to address the above requirement, the traffic engineer must first understand the traffic flow behaviour and characteristics by extensive collection of traffic flow data and analysis. Based on this analysis, traffic flow is controlled so that the transport infrastructure is used optimally as well as with good service quality. In short, the role of traffic engineer is to protect the environment while providing mobility, to preserve scarce resources while assuring economic activity, and to assure safety and security to people and vehicles, through both acceptable practices and high-tech communications. Flexible pavement by CBR Method is consists of processed materials of super imposed layers, which are above the soil sub-grade. The main objective of this road is to transfer the vehicular load to the lower layers. The purpose of pavement to provide adequate skid resistance, require surface riding quality, lessnoise pollution and more reflecting character. The ultimate function of the pavement structure to reduce the transmitted stresses due to wheel, different layers, their structure functions loads, by this process bearing capacity of the subgrade will not be exceed. There are two general types of pavement, one is Flexible Pavement other one is Rigid Pavement. In this project we found an overview of types of pavement sand failure of pavements. Improper pavement design leads to pavement failure, which affects the riding quality.

CHARACTERISTICS OF PLASTIC-COATED AGGREGATE

Moisture Absorption and Void Measurement Hot stone aggregate (150 0 c) is mixed with hot bitumen (170 0 c). 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 viscos-elastic property. The aggregate, when coated with plastics and rubber improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic and rubber decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement.

PURPOSE OF APPLYING TACK COAT IN BITUMINOUS ROAD CONSTRUCTION

Teak coat is a single initial application of bituminous material on the surfaces which has previously been treated or prepared such as existing bituminous, Portland cement concrete, brick or block surfaces. Teak coat is simply applied to insure adhesion between the existing surface and the new bituminous surface. Since in this case the base is comparatively impervious, the quantity of binder required may be less than the primer.

Flakiness index.

The flakiness index of aggregates is the percentage by weight of particles in it whose least dimension (thickness) is less than three fifths (0.60 of their mean dimension. Techniques for protecting the subgrade from moisture due to capillary rise. If the water reaching the subgrade due to capillary rise is likely to be determintal.it is possible to solve the problem by arresting the capillary rise instead of lowering the water table. The capillary rise may be arrested either by a capillary cut off of any one of the following two types:

By providing a granular material of suitable thickness between the subgrade and the highest level of subsurface water table. By inserting an impermeable or a bituminous layer instead of a granular material. Softening point of bitumen. Softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test.

2. LITERATURE REVIEW

P. Vijaya Lakshmi kanthi et,al., Plastics are non-biodegradable materials and their omnipresence degrades our environment. The waste plastic and its disposal cause environmental pollution and global warming. Plastic waste can be used in flexible pavements by enhancing the bitumen properties and strength. Various defects in Road Pavements i.e., pot holes, corrugation, ruts, etc. can be remedied using waste plastic in the form polyethylene and poly-propylene. A series of tests were performed on the bitumen with conventional and plastic mix with 4%, 5% and 6% of

Binder content. The Marshall method of mix design is used for the determination of optimum bitumen content. It is further used for the design of flexible bituminous pavement using VG-30 grade of bitumen. The Results of plastic mix has shown an increase in its stability value when compared with conventional mix. From the results, 5% binder content has the maximum stability value. Hence, it is considered as the optimum bitumen content for the design of flexible pavements.

Dr. Abhaykumar S Wayal , Mudassir. D. Wagle 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.

Prashant Singh et al., Today, plastic waste and its disposal Such as wrappers of chocolate, chips, carry bags, cold drink bottles and all other forms of plastic create significant environmental and economic problems. These forms of plastic consume massive energy-depleting in the environment in various ways. So manufacturing firms and construction industries, the use of plastic is a priority to handle and pack things comfortable due to its lightweight, effectiveness cost, and strength. The plastic waste used is poly-ethylene, poly-styrene, poly-propylene, the temperature varying between 120ºc - 160ºc gives the softening point of these plastics. The plastic waste is shredded & coated over the aggregate and mixed with hot bitumen and the resulted mix is used for pavement construction this mix will not only strengthen the pavement and also increases its durability. The main objective of this paper is to discuss the importance of plastic in terms of cost reduction, increases the strength and durability when these plastics are heated and coated upon the aggregates to reduce the air voids with plastic and binds with aggregate to provide stability. It's economical and eco-friendly.

S. VenkatCharyulu and G.K.Viswanadh In nowadays it is very important to have a proper road network for the purpose of good transportation. Few places road network is not available while the traffic is higher and enough. Pavement is generally being constructed and used for the purpose of smooth and comfort moment of the traffic. Flexible pavements will be subjected to load by wheel develop stress particles-to-particles transmit to the lower grades of layers through the granular structure. The pavement is subjected to the wheel loading action on it and the load is to be distributed to a larger area, such that the decrease in stress will occur with respect to the depth. The patch considered in this project is of KKY District Road. [KKY-Karimnagar Kamareddy Yellareddy]. The current condition of the KKY road is very much disturbed with the presence of uneven undulations as heavy loaded vehicles like moment of trucks took part. Hence, for the purpose of the fulfilment of all the above requirement factors and for the comfort moment of traffic. Adopted the effective design of flexible pavement. In this paper, we are enclosing the design report KKY road which includes all the which comes under the project of the pavement construction.

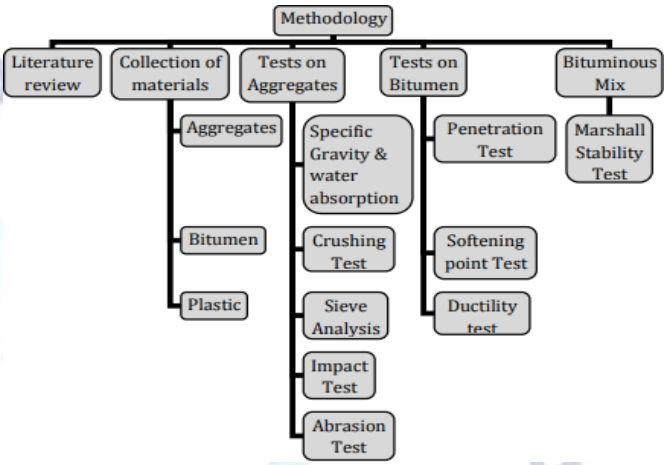
P. Vijaya Lakshmi kanthi et al., Plastics are non-biodegradable materials and their omnipresence degrades our environment. The waste plastic and its disposal cause environmental pollution and global warming. Plastic waste can be used in flexible pavements by enhancing the bitumen properties and strength. Various defects in Road Pavements i.e., pot holes, corrugation, ruts, etc. can be remedied using waste plastic in the form polyethylene and poly-propylene. A series of tests were performed on the bitumen with conventional and plastic mix with 4%, 5% and 6% of Binder content. The Marshall method of mix design is used for the determination of optimum bitumen content. It is further used for the design of flexible bituminous pavement using VG-30 grade of bitumen. The Results of plastic mix has shown an increase in its stability value when compared with conventional mix. From the results, 5% binder content has the maximum stability

value. Hence, it is considered as the optimum bitumen content for the design of flexible pavements.

U. SATHISH et all., The main objective of this project is use of waste plastic material in the flexible pavement construction and analyse the Marshall Stability value for the bituminous mix in the laboratory. Since the traffic intensity is increasing every year, because of which there will be more repetition of loaded vehicles. There is a need for better quality of pavement in terms of strength, durability and resistance to the deformation for avoiding deterioration of pavement and obtain better raiding quality. This study will take care of aspects like better pavement characteristics and eco-friendly nature in terms of reusing the waste materials. In the present study twenty mm down aggregates is replaced for about five percent with plastic waste and BC grade-II mix is prepared. This can be used for surface course of flexible pavement in road construction. The Marshall Stability values are checked for the above samples and is compared with the conventional BC grade-II mix. By using above plastic waste materials there will be increase the strength, durability, resistance to the deformation and water resistance as well as providing a mean to dispose of wastes. At the end, it concludes that the modified bituminous mix is cheaper than conventional bituminous mix. The test result of modified bituminous mix is found to be better than conventional bituminous mix.

Prashant Singh et al., Today, plastic waste and its disposal Such as wrappers of chocolate, chips, carry bags, cold drink bottles and all other forms of plastic create significant environmental and economic problems. These forms of plastic consume massive energy-depleting in the environment in various ways. So manufacturing firms and construction industries, the use of plastic is a priority to handle and pack things comfortable due to its lightweight, effectiveness cost, and strength. The plastic waste used is poly-ethylene, poly-styrene, poly-propylene, the temperature varying between 120ºc - 160ºc gives the softening point of these plastics. The plastic waste is shredded & coated over the aggregate and mixed with hot bitumen and the resulted mix is used for pavement construction this mix will not only strengthen the pavement and also increases its durability. The main objective of this paper is to discuss the importance of plastic in terms of cost reduction, increases the strength and durability when these plastics are heated and coated upon the aggregates to reduce the air voids with plastic and binds with aggregate to provide stability. It's economical and eco-friendly.

3. METHODOLOGY



Observations for specific gravity of coarse aggregate

Description	20mm	10mm
Weight of the sample (g)	1000	1000
Wt. of the Vessel + Sample + Water (A) (g)	1989	1976
Weight of the Vessel filled with water (B)	1350	1350
Weight of Saturated Surface Dry Sample (C) (g)	1000	1002
Weight of oven dry Sample (D) (g)	997	994
Water absorption = 100 (C-D) / D	0.3	0.502
Specific gravity = D / C - (A-B)	**2.76**	**2.65**

Observations for bulk density of coarse & fine aggregate

Description of measure	Coarse Aggregate	
	10mm	20mm
Volume of measure (V) (l)	5.29	5.29
Weight of measure (W_1)	10.437	11.093
Wt. with compacted aggregate (W_2) Kg	18.932	19.118
Loose Bulk Density = (W_2 - W_1)/V (kg/m^3)	**1.603**	**1.51**

Observations for Fineness Modulus of Natural C.A

IS SieveNo.	Weight Retained (gm)	Percentage weight retained	Cumulative %of wt. retained	Percentage Passing	Permissible Limits IS:383-1970
80mm	0	0	0	100	
40mm	0	0	0	100	100
20mm	617	30.85	30.85	69.15	
16mm	812	40.6	71.45	28.55	-

10mm	561	28.05	99.53	0.47	0-5
4.75mm	10	0.47	100	0	0-20
2.36mm	0	0	100	0	-
1.18mm	0	0	100	0	-
600 µ	0	0	100	0	-
300 µ	0	0	100	0	-
Total			701.83		
Fineness modulus of CA= 701.83 / 100 = 7.02 According to IS 383-1970, Sample confirms to Single-Sized Aggregate					

4.EXPERIMENTAL INVESTIGATION TESTS ON WASTE PLASTIC

Waste bottles are in shredded form and they can be used as a binder and/or they can be mixed with a binder like bitumen to enhance their binding property. this may be an honest modifier for the bitumen, used for road construction. Plastic used in the project was in the form of clinkers having diameter less than 5 mm. The test conducted at the source and properties noted are presented in table below.

Properties of Plastic

S.No	Property	Value
1	Density	0.93 gm/cc
2	Surface Hardness	SD48
3	Tensile Strength	11MPa
4	Flexural Modulus	0.27 GPa
5	Max. Operating Temperature	48
6	Water Absorption	0.01%
7	Melting Temperature	221C-250C

Correction Factor for Marshall Stability Test

Average Thickness of Specimen, Mm	Correction Factor
57.5	1.20
58.9	1.15
60.1	1.10
62.0	1.07
64.2	1.05
65.2	0.98
67.1	0.93
69.1	0.91
69.6	0.85

5.RESULTS AND DISCUSSIONS

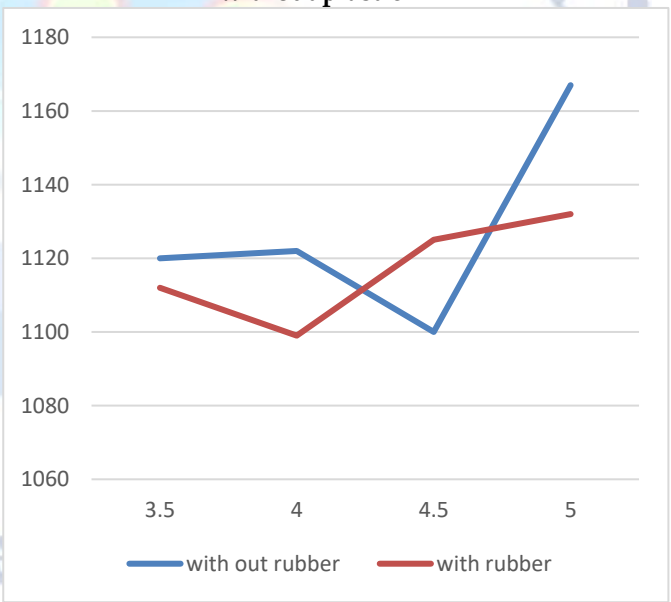
Values of conventional bituminous mix

% of Bitumen	Sample wt. gm	Marshall stability (kg)	Flow (mm)	Gmb (gm/cm³)	Gt (gm/cm³)	Vb (%)	AV (%)	VMA (%)	VFB (%)
3.5	1120	871.12	3.1	2.10	2.31	7.3	9.24	16.59	44.30
4.0	1122	940.75	3.0	2.11	2.30	8.4	8.12	16.58	50.99
4.5	1100	892.70	2.9	2.15	2.25	9.4	6.49	15.94	60.26
5.0	1167	882.90	3.0	2.25	2.23	9.6	5.35	14.97	68.94

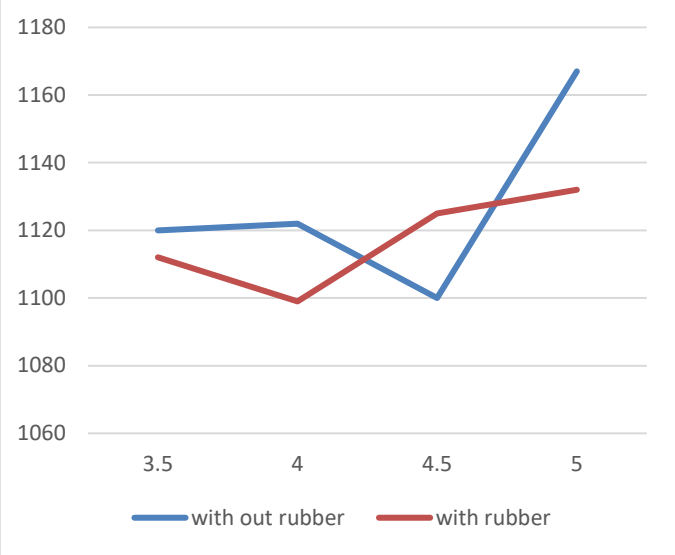
Values of conventional bituminous with plastic mix

% of Bitumen/ plastic	Sample wt. gm	Marshall stability (kg)	Flow (mm)	Gmb (gm/cm³)	Gt (gm/cm³)	Vb (%)	AV (%)	VMA (%)	VFB (%)
3.5	1112	670.50	3.2	2.30	2.51	5.3	17.24	22.32	24.21
4.0	1099	725.80	3.6	2.25	2.32	6.2	15.12	21.20	35.02
4.5	1125	950.80	3.4	2.42	2.35	8.2	13.20	20.15	48.27
5.0	1132	1045.50	3.5	2.50	2.40	9.5	8.30	18.24	54.45

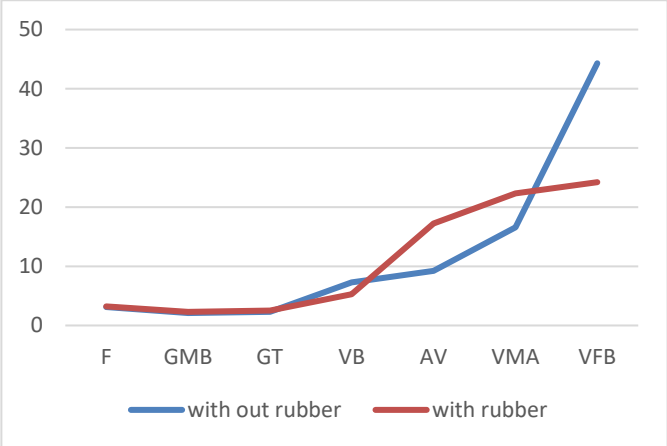
Results for weight of samples with plastic and without plastic mix



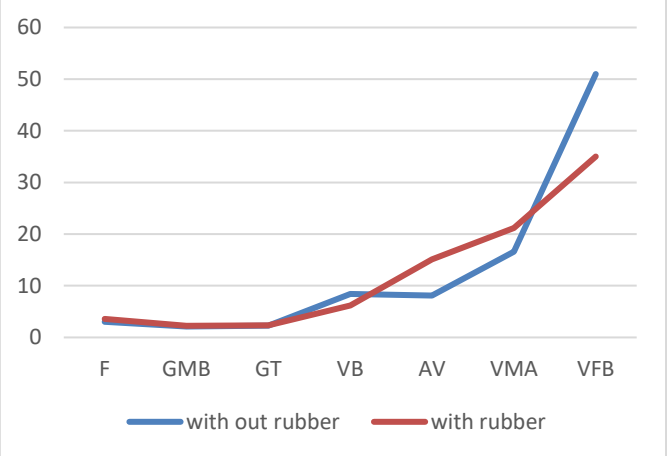
Results for Marshall Stability test for with plastic and without plastic mix



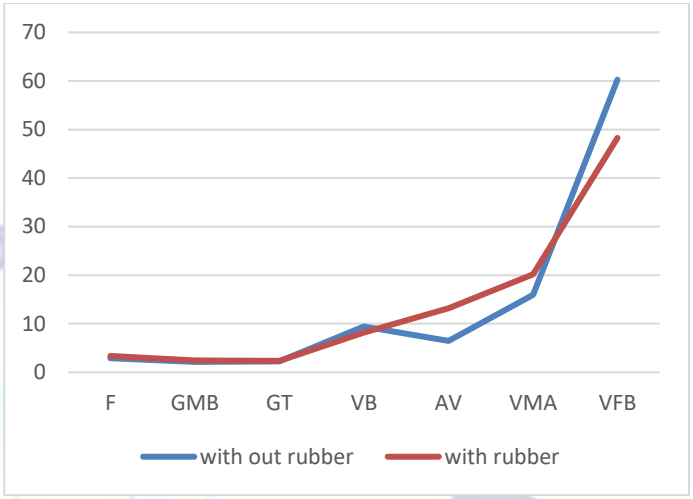
Results for different tests with plastic and without plastic mix for 3.5%



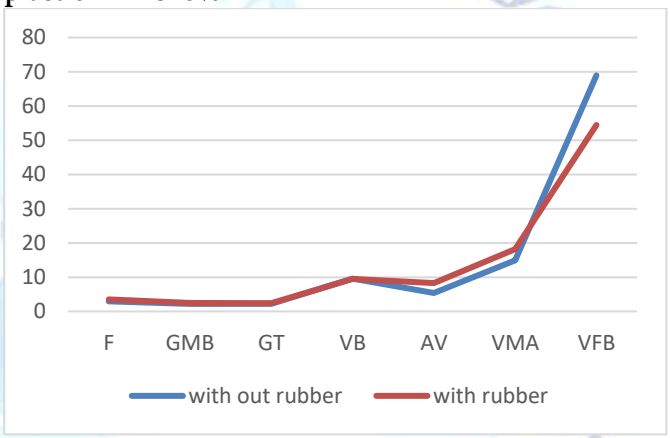
Results for different tests with plastic and without plastic mix for 4%



Results for different tests with plastic and without plastic mix for 4.5%



Results for different tests with plastic and without plastic mix for 5%



Where,

Gmb = Density of the bitumen,

Gt = Maximum theoretical density of bitumen,

Vb = Volume of bitumen, cm3

Av = air Voids, %

VMA = voids of mineral aggregates,

% VFB = voids filled by bitumen, %.

6. CONCLUSIONS

In this chapter we can conclude the project work of waste plastic usage in bitumen mix for flexible pavements.

- As per the above results finally we conclude that the we can use the waste plastic mix in with bitumen mix.
- If we use waste plastic mix in bitumen mix we can reduce the voids ratio.
- And remaining test values like Density of the bitumen, Maximum theoretical density of bitumen,

Volume of bitumen, cm3, air Voids, %voids of mineral aggregates, % voids filled by bitumen were lightly increased while using waste plastic.

- It shows that the increase in strength while using waste plastic up to certain percentage and we can reduce the plastic waste formation on the earth.
- By using of plastic waste in road construction we can reduce the pores.

Future Work:

We can improve the percentage of waste plastic in bitumen mix and we can test for different tests.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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