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Performance Evaluation of the Asphalt Mixture by using Polymeric Wastes

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Abstract: The asphalt pavements suffer from various failures such as rutting, fatigue cracking and low temperature cracking which may be due to poor asphalt mix design, low or high temperature or uncertainty in traffic and material properties. So, there is a need to modify conventional asphalt in order to cope with these failures. Therefore, in this research, the conventional asphalt was modified with different polymeric wastes not only to improve the performance of asphalt pavement but also to reduce the abundance of wasted plastic stockpiles in order to reduce environmental pollution. The modified asphalt samples were prepared using a variety of polymeric wastes ranging from 5% to 20% respectively by Marshall Method of mix design with Marshall Stability and rutting resistance as target parameters. The asphalt containing polymeric waste from 5% to 15% showed tremendous effect on the performance of asphalt mixture in terms of rut resistance but beyond 20% modification showed a decreasing trend in rut resistance.

Keywords: Polymeric Wastes, Hot Mix Asphalt, Marshal Mix Design, Rutting evaluation.

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Abbreviations
HMA----------Hot Mix Asphalt
OBC-----------Optimim Binder Content
Va--------------Air voids
VMA----------Voids in mineral aggregates
VFA-----------Voids filled with aggregates
Gmb----------Bulk Specific gravity
Gmm---------Theoratical maximum Specific gravity

I. INTRODUCTION

A. General

In any transportation system, the maintenance and rehabilitation basically depends on the resources and the finance system that includes the construction cost, maintenance and the technologies to be utilized in planning. While considering problems that are being faced by the state in case of transportation system includes the issue related to transportation facilities and the increased cost of the material that include aggregates and binders. As it has been observed that most the polymeric wastes that include HDPE,LDPE are thrown in the earth crust which causes the environment polluted as we don't have any proper place to dispose them off. Many people are suffering from fatal disease due to toxicity of polymeric wastes. In transportation system, one the prime failure that has been observed is rutting although pavement structure undergoes many distresses. In order to counteract the problem and to make the pavement structure more sustainable to the environmental impact, it has been observed that by using polymeric waste in the flexible pavements to increase the lifespan of pavement and to reduce distresses in the pavement including rutting resistance. As it is also known that the roads prepared from the virgin bitumen are very expensive. One of the solution for flexible pavements failure is outlined to use the polymeric waste in the construction of asphalt pavements in order to reduce pavement failures as well as to dispose off the polymeric waste.

B. Bitumen

Bitumen can be defined as a black sticky cement like material whose compounds can be classified into two generic groups, maltenes and asphaltenes. Maltenes are basically the oily, resinous component of asphalt that remains when asphaltenes are removed. Asphaltenes are molecular substances that are found in crude oil, along with resins, saturates and aromatic hydrocarbons. The word "Asphaltene" was invented by Boussingault in 1837. Asphaltenes in the form of asphalt or bitumen products from oil refineries are used as paving materials on shingles for roofs, roads and water proof coating on building foundations. Most of the roads are generally made up with the hydrocarbon.

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The production of bitumen mixture was first used in United States for the sidewalks, crosswalks. The concept of the road was first started in the late 1860's. The first asphalt pavement was laid by a Belgian Chemist in the City hall in Newark, new jersey. Hot mix asphalt concrete (HMAC) is composed:

1) Aggregate
2) Asphalt binder
3) Mineral Filler

a) *Asphalt Pavement Structure:* Asphalt pavement is basically composed of three layers that includes the subbase, base coarse and Ashpalt coarses that is asphalt binder coarse and asphalt wearing coarse. The pavement structure that is placed above the subgrade with all coarses consist of a combination of asphalt coarse and untreated aggregate coarses. The subgrade is the existing soil on which the the pavement structure sits. It is the existing soil that bear up the load from the top layer and transfer it to the ground. In highway engineering, the layer of aggregate material that is laid on the subgrade is that of subbase, on which the base course is layed. It has been considered that subbase is the main load bearing layer of the pavements. The role of this layer is to spread the load evenly over the subgrade. The materials specified are the either the unbound granular or cement bound. The surface course is seldom ever more than two inches in thickness and is chiefly responsible for pavement friction and smoothness. Often this layer uses smaller aggregates than the two layers of asphalt beneath it. Most importantly, this layer can be replaced at the onset of distress to protect the underlying support layers from being damaged The binder coarse serves as the intermediate layer in order to transfer loads between surface coarse and base coarse. To ensure surface coarse of uniform thickness, this layer is layed. A typical binder coarse is between 2-4 inches thick. The thickness of the base coarse varies from 4-12 inches and is considered as the thickest pavement layer as it uses less asphalt binder between the top layers on it.

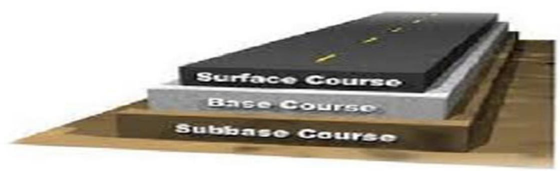

Fig 1: Different layers of Road

b) *Aggregate:* Aggregate is a structure or material formed from the fragmentations of mass or particles loosely compacted together. For building homes, bridges, highways, schools and sidewalks, aggregates are used. It is one of the most mined material in the world. On the basis of grain size, aggregates are mainly classified into two types that are fine and coarse aggregates. The most common size of aggregates used for the concrete mix in case of fine aggregate is 4.75mm and 20mm for coarse aggregate. On the basis of shape, aggregates are classified into rounded, irregular, angular, flaky, elongated.

Table 1: Fine Aggregates Size Variation

Fine Aggregates	Size Variation
Coarse Sand	2.0mm-0.5mm
Medium Sand	0.5mm-0.25mm
Fine Sand	0.25mm-0.06mm
Silt	0.06mm-0.002mm
Clay	<0.002

Table 2: Coarse Aggregates Size Variation

Coarse aggregates	Size
Fine gravel	4mm-8mm
Medium gravel	8mm-16mm
Coarse gravel	16mm-64mm
Cobbles	64mm-256mm
Boulders	>256mm

c) *Polymers:* It is a large molecule or macromolecule formed by the composition of many repeated subunits. Polymers are broadly divided in to two categories which include synthetic polymers and natural polymers. The polymers obtained from the polymerization of petroleum based raw materials while the polymers obtained from the renewable sources comes in the category of the natural polymers
d) *Problem Statement:* In recent years, it has been noticed in Pakistan that waste materials from the industries and households experienced drastic increase that causes insufficient capacity of landfills. The construction cost of highways in Pakistan has also showed an increase in recent years. On the other hand in order to utilize the polymeric wastes and dispose them in attractive way by using them in the asphalt pavement as an additive to increase the performance of asphalt pavement. By using of polymeric wastes with the modified asphalt, it can enhance in reducing the rutting and fatigue cracking respectively (Yetkin et al...2007).

One of the most problematic plastic produced now days is polyvinylchloride (PVC) and polythene Bags. Survey has been taken in consideration on the production of polyvinylchloride and it is shown in the report that the production of PVC is more than 10 million tons per year. For many years the throw-away products that are made up of PVC has leading to the main cause of pollution in environment. As it is noticed as well that there is no proper disposal stage for these wastes that definitely causing fatal diseases

C. Historical Background

Research has been carried out that rutting is due to the repeated loading on the flexible pavement structures. It is the permanent deformation under the wheel path. It has been reported by many agencies in the world that the failure of asphalt pavements is due to the heavy loads, truck traffic and pressure that is exerted by the tires. The wheel path depression is due to the the excessive bitumen and due to poor mix design. In most of the cases, it has been observed that due to heavy loading exceeding the limits when brake applied so it causes rut resistance. In the world, flexible pavement undergoes many failures that include alligator cracking, rutting and many other distresses. The permanent deformation that is rutting has been considered on top priority. This results to the permanent deformation, cracking and surface wear are being reported by the concerned agencies [1]. On polymer modified binders, research has been conducted from the last few decades. In United States, Canada, Europe and Australia, the polymer modification of asphalt binder has been using in increasing the performance of the pavement. Some of the polymers that have been used which include Elvaloy, SBS, SBR and Rubber [2]. The Polymeric wastes which can be recycled like Polypropylene (PP), Polyvinylchloride and polyethylene has been shown a remarkable result in helping to increase the performance of the flexible pavement [3]. The Performance of flexible pavements of the road network can be improved by using polymeric wastes[4]. The failure of pavements occurs due to external excessive load of vehicles and the environmental impact on flexible pavement, By utilization of polymeric wastes it can help to improve the pavement performance [5]. Studies have been conducted previously that by the application of different type of polymeric wastes it helps to enhance the life time of flexible pavements as the polymers increases the interaction between aggregates and binder[6].The blacktop is made up of elastic materials when load is applied on the surface of flexible pavement so it bends and it come back to its original position when the applied load is removed but due to Periodic loading and accumulation of millions of strains on the flexible pavement and due to repeated axle loadings it results in surface rutting[7]. The growing traffic volume has been observed from the last few decades in transportation system which includes the airports and road networks due to heavy traffic it has been brought in consideration that to produce materials having high remarkable quality for rehabilitation and maintenance purpose in the field of flexible pavements. As in the blacktop roads one of the most important component is bitumen mixture which has remarkable importance in terms of performance. The study for replacement of bitumen with the polymeric wastes have been conducted in the flexible pavements for reducing distresses [8]. For economic reasons it is taken in to the consideration that one of the most important issue is the pavement lifetime as due to distress it reduces the lifetime of flexible pavement. The most common distress observed is rutting which commonly happens in the form of permanent deformation. The effect of rutting can be reduced by adding polymeric wastes [9]. By using polymeric wastes in the flexible pavements, it greatly helps to produce better performance with longer life as in the flexible pavements which are purely made up of bitumen the most common failure is seen to be rutting that is the wheel path depression [10]. Rutting assessment has been done on two types of polymer modified asphalt mixture which contain (1) Amorphous Polyolefin Polymer (2) Polymer obtained by the combination of low density polyethylene (LDPE) and ethyl-vinyl-acetate (EVA). For the confirmation of performance of the asphalt mixtures, Stiffness and fatigue tests were carried out. For Rutting, tests were performed by a wheel tracking device. After the results of performed tests, the improvement has been showed in rut resistance behavior [11]. For High Performance of asphalt pavements, strong absorption, Most of the researchers in the recent studies concluded that Polymers with excellent beneficial properties have paid an extensively great results in flexible pavements as additive[12]. In Saudi Arabia, the amount of solid plastic wastes which are generated from the industries of plastic bottles and similar

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utilities has been increased very rapidly. As a result of rapid increase of wastes and by managing these solid wastes has also difficult task. By considering the effect of polymeric wastes like Polypropylene, High and low density Polyethylene (HDPE and LDPE) and recycled plastic wastes (RPW) on the performance of the asphalt binder has been conducted[13]. A study has been conducted in china that for the improvement of the performance of the asphalt pavements, Polymer modified asphalts are used, this helps in improving the aging performance. Assessment of characteristics of polymers like Polyurethane (PU), Styrene-butadiene-styrene (SBS) has been taken in modified asphalt and its mixtures [14]. For improving the the rutting resistance, it is understood that by using rubberized asphalt pavement that has shown a remarkable and also is environmentally sound. The main theme is to investigate the rutting resistance by characterization of the rubberized asphalt mixtures through a laboratory testing program. By using the experimental design, it included two types of rubber that showed a brilliant result. The results concluded by using the use of waste crumb rubber have shown that HMA can effectively improve the rut resistance of the mixes [15]. The waste fibers that are produced from the manufacturing process of scrap tire etc are usually disposed of in landfills. In many states, it has been noted that the wastes are thrown in the earth crust and there is no proper arrangement to dispose it, but these waste fibers can further be used in the flexible pavements in order to increase its life span and also reduce the environmental impact on it that include temperature, wearing and tearing etc. research was carried out to utilize these wastes in Stone mastic asphalt. Many agencies utilize them such as in the flexible pavements on heavily travelled highways specifically the load carrying trucks as these heavy vehicles are one of the main cause of failures develops in the flexible pavement that is rutting. these waste fibers are properly utilized in order to ensure the environmental benefit and to protect the state from being polluted. Based on this study, utilization of waste fibers that include tire carpet fibers in asphalt pavement. Findings were made that include that by using these wastes, it has shown very effective preventing of rut resistance in flexible pavements and the tensile strength ratios for the mixes containing the wastes used in this research were greater and showed a better improvement in flexible pavements [16].

The objectives of this study are

a) To evaluate the rutting ability of modified pavement cement with plastic waste and to compare it with standard asphalt cement reliability.
b) To minimize air and water pollution because we don’t have decent waste management in Pakistan.

II. METHODOLOGY

The methodology adopted to achieve the objective of this research includes collection of materials, testing of materials, specimen’s preparation and different tests on specimen. In this chapter, the first step taken was the determination of the optimum binder content with different percentages starting from 3%,3.5%,4%,4.5% and 5%. The main tests of this research was the preparation of samples that is the marshal mix design at different percentages in order to find out the optimum binder content. The techniques used in order to achieve the main objective of this research was done accordingly in this chapter of the research. The first step was the collection of the material from different resources that is to collect virgin aggregates from the quarry and then to find out the bitumen of 60/70 grade, the polymeric wastes that are being thrown outside the hospitals and homes including surgical wastes and polythene bags in order to dipose them off in a proper way and to use them in asphalt binder to check the change in the behavior of the flexible pavement whether it is positive or negative

A. Materials Collection

In order to achieve my objective in this reseach, the first step was to collect the virgin aggregates that are from Margalla Hills crush plant which is considered to be the largest quarry of virgin aggregates in Pakistan and asphalt binder of grade 60/70 which is mostly used in highways from Attock Refinery Limited. As in this research, the main objective is to utilize the polymeric wastes which includes surgical wastes that are thrown outside the hospitals causing fatal diseases and it is also non digestible. The second polymeric waste was the polythene bags and polypropylene.

The polymeric wastes are usually obtained from the hospitals are not properly dumped in Peshawar as it is seen outside of the every hospital. In order to utilize them and to make the flexible pavements to sustain against the environmental impact and also helpful in reducing rutting resistance in pavements. As it is also known that constructing asphalt pavement consist of an expensive expenditure. After collection of materials, the first step was the characterization of the Margalla aggregates that includes the physical properties of the aggregate.

B. Gradation Selection

Proper gradation of coarse aggregates is one of the most important factors in producing workable concrete. Proper gradation ensures that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. The size distribution of aggregate is an important characteristic because it determines the paste requirement for workable concrete. ... The more these voids are filled, the less workable the concrete becomes, therefore, a compromise between workability and economy is necessary.

Table 3: Sieve Analysis According to Percentage Passed and Percentage Retained

Sizes mm	Sieve No	Percentage passing	Percentage retained
25	1	100	0
19	¾	95	5
9.5	3/8	63	37
4.75	No.4	42.5	57.5
2.36	No.8	29	71
0.3	No.50	8.5	91.5
0.075	200	5	95
Pan	-	0	100

Table 4 :Physical Properties of Bitumen

Characteristics	80/100	60/70	30/40	10/20
Specific Gravity at 27°C min	0.98	0.99	0.99	1.00-1.05
Flash point,°C	175	175	175	225
Softening point,°C	35-50	40-55	50-65	65-80
Penetration at 25°C	80-100	60-70	30-40	10-20
Ductility at 27°C	75	75	50	2.5
Penetration of residue	60	60	60	-
Percentage by weight soluble in carbon di-sulphide	99	99	99	99

1) *Flash Point:* The flash point of a material is the lowest temperature at which the vapour of the substance momentarily takes fire in the form of flash under the specified condition of the test.
2) *Fire Point:* The fire point is the lowest point at which the materials gets ignited and burns under the specified condition of the test. In order to determine the fire and flash point of bitumen, the apparatus used in pensky-martens closed tester. Pensky-Martens closed tester consist of cup, lid,stirres, device, shutter, flame exposure device Thermometer (0-350°C).
3) *Penetration Test:* The penetration of bituminous material is its consistency expressed as the distance in tenths of a millimeter that a standard needle penetrates vertically into a specimen of the material under specified conditions of temperature, load and duration of loading. Grades of straight-run bitumen are designated by two penetration values, for example, 40/50, 60/80, 80/100 etc.; the penetration of an actual sample.
4) Softening Point of Bitumen**:** Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test that is it indicates the maximum expected temperature that the asphalt mixture can support on the road without having natural ability to behave in particular way in order to quickly increase the rutting deformation.

5) Characterization of Polymeric wastes: In order to dispose the surgical waste that is the main objective of this research, there are mainly four major types of medical wastes.
6) General Medical Waste: General medical waste is the lion's share of medical waste in a facility and is not typically considered hazardous. This includes paper, plastic, and office waste. These can disposed of regularly and don't require any special handling.
7) Infectious Medical Waste Infectious waste is just what the name suggests: it is waste materials that can pose a risk of infection to humans, animals, and the overall environment. This includes blood-soaked bandages, sharps waste, surgical waste, human or body parts, cultures, and swabs. Each state has comprehensive rules for the management of infectious waste, including requirements for storage, transport, disposal, licensing, and processing.
8) Hazardous Medical Waste: Hazardous waste is dangerous waste but is not considered infectious to humans. Believe it or not, sharps falls into this category as well, at least sharps that have not been used, because they have the ability to puncture or harm the user. Chemotherapy agents fall into this category, as well as chemicals, such as solvents, mercury in thermometers, and lead in paint.

C. Calculations

To calculate the bulk specific gravity, use the following formula:
Bulk Specific Gravity (Gmb) = [A/(B - C)]
A = Weight in grams of the specimen in air
B = Weight in grams, surface dry
C = Weight in grams, in water

D. Marshall Stability and Flow Test

1) The specimens to be tested are kept immersed in water in a thermostat.tically controlled water bath at 60±1°C for 30 to 40 minutes
2) Take out the specimen from the waterbath and place it in the breaking head
3) Place the breaking head in the marshal testing machine.
4) Load is applied on the breaking head by the loading machine at the rate of 5cm per minute
5) Stability value is the load taken by the specimen at failure
6) Flow value is the deformation of the specimen at failure

III. RESULTS AND DISCUSSIONS

Table 5: Marshal Parameters Determined For Conventional Mix

Bitumen %	Va (%)	VMA (%)	VFA (%)	Gmb	Gmm	Stability (KN)	Flow (0.25mm (0.01in))
3.5	3.5	5.49	14.09	53.56	2.332	2.49	10.09
4	4	4.19	13.45	63.78	2.352	2.468	11.48
4.5	4.5	3.29	13.39	72.78	2.365	2.465	12.76
5	5	2.96	13.98	78.09	2.374	2.44	11.87
5.5	5.5	2.78	14.35	80.15	2.368	2.439	10.44

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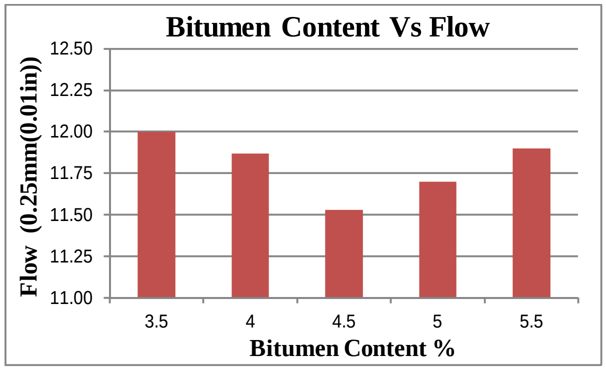
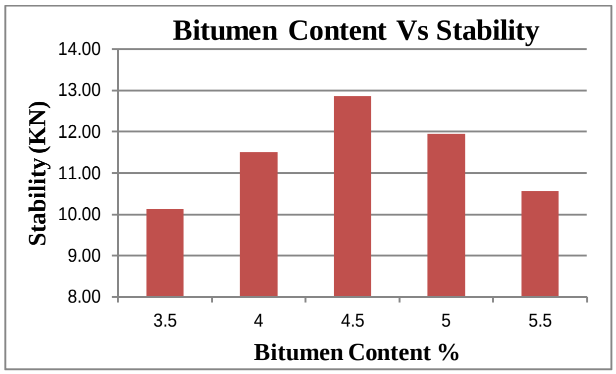
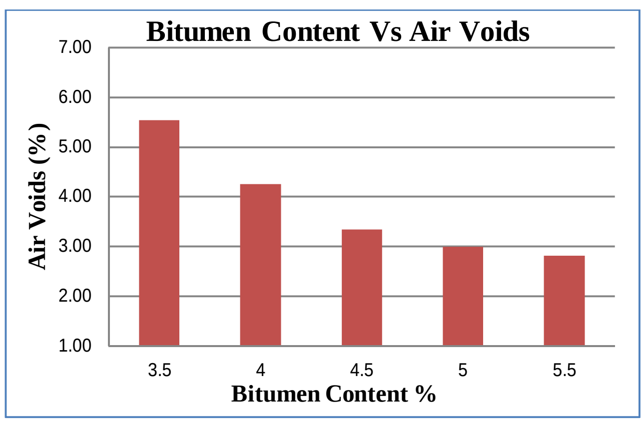


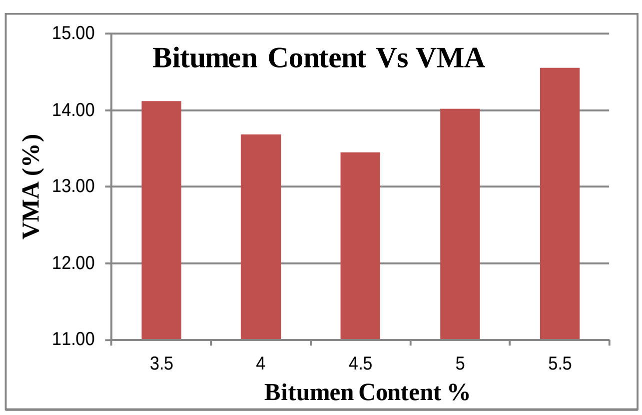
Graph 1-a BC Vs Flow



Graph 1-b BC Vs Stability



Graph 1-c BC Vs Air Voids



Graph 1-d BC Vs VMA

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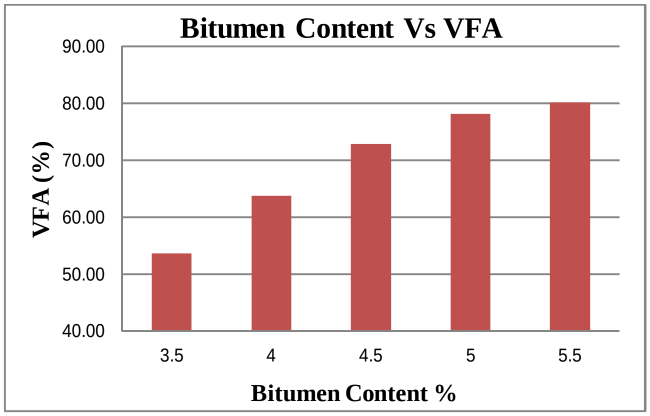
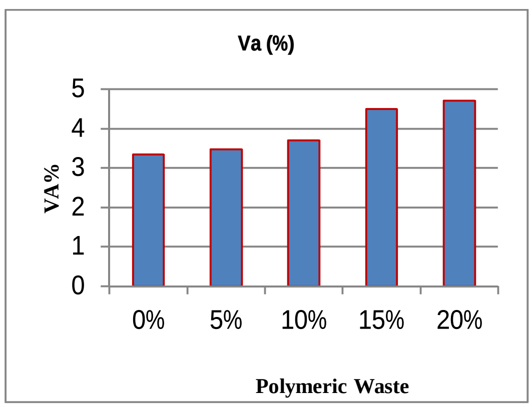


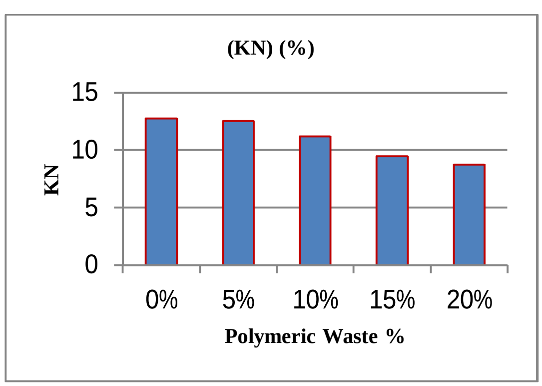
Graph 1-e BC Vs VFA

Table 6: Marshal Parameters Determined for HMA Mix

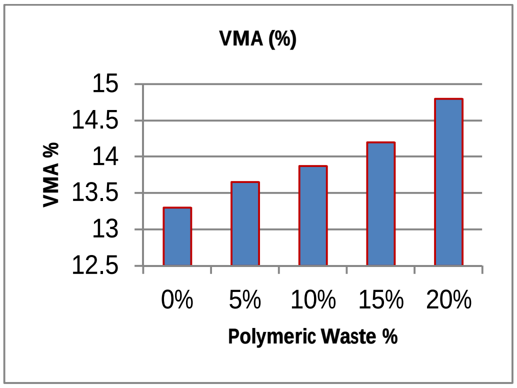
Waste %	Va (%)	VMA (%)	VFA (%)	Gmb	Gmm	(KN)	Flow (0.25mm (0.01in))
5%	3.47	13.65	73.5	2.45	2.49	12.55	3.25
10%	3.70	13.87	75.9	2.47	2.51	11.20	3.75
15%	4.5	14.20	80.2	2.49	2.53	9.45	4.21
20%	4.71	14.80	81.4	2.51	2.57	8.72	4.45
5%	3.47	13.65	73.5	2.45	2.49	12.55	3.25



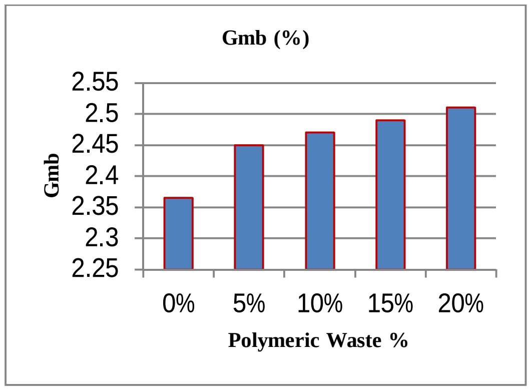
Graph 2-a PW Vs Va



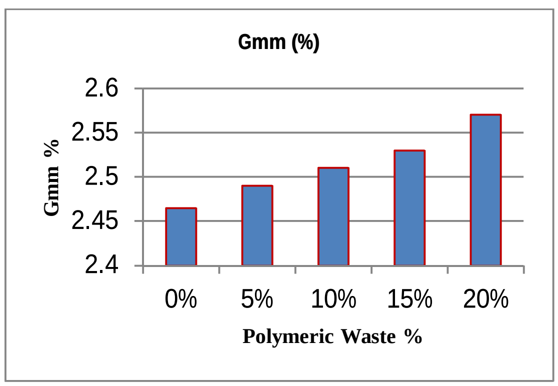
Graph 2-b PW Vs KN



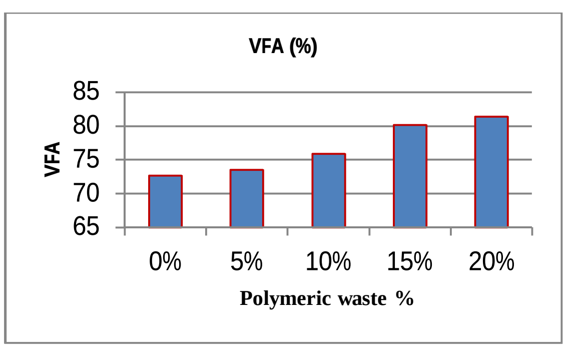
Graph 2-c PW Vs VMA



Graph 2-d PW Vs Gmb



Graph 2-e PW Vs Gmm

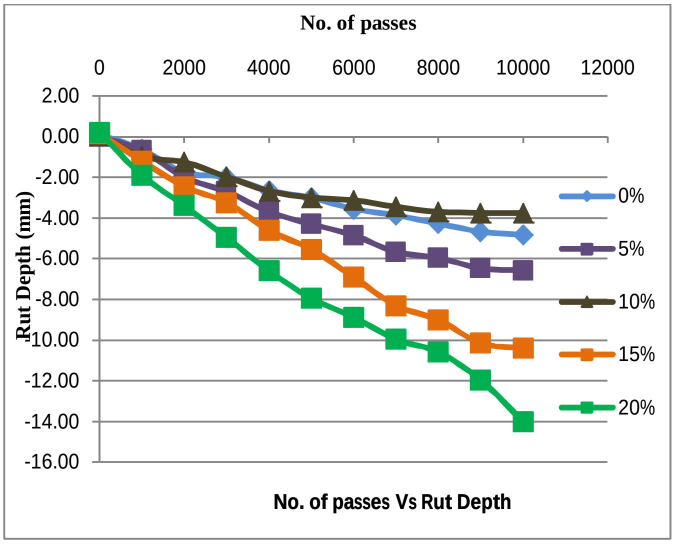


Graph 2-f PW Vs VFA

Table 7: Criteria For Passing: Maximum 12mm Rutting depth at 10000 Passes

Polymeric Waste %	Rut Depth (mm)
5%	8.21
10%	7.34
15%	4.26
20%	11.78

Table8: Comparison of Results



A. Conflict Of Interest

The contents of this study are free from plagiarism and therefore the study is original and is not copied from anywhere. Previous work of original authors has also been referenced.

IV. CONCLUSION

This study concludes that

Based on the laboratory study of different mixtures containing polymeric waste as additive, the following outcomes are concluded:

A. The Marshall Stability of the modified asphalt mixtures is much better than conventional asphalt mixture.
B. The marshal stability showed linearly increasing trend up to 15% plastic modification but beyond 15%, a decreasing trend in stability was observed.
C. The rut resistance of modified asphalt mixtures showed an increasing trend up to 15% plastic modification but beyond 15%, a decreasing trend was observed recommendations

Based on the conclusions of the research the following recommendations are to be considered appropriate.

V. RECOMMENDATIONS

A. On the basis of the above results, it is recommended that by using 15% of the polymeric wastes in the asphalt pavement has shown remarkable results in reducing rutting.
B. Road pavement will get more strengthen by using 15% of the polymeric waste.
C. It also helps in reducing the environmental pollution and to dispose them off in a proper way.

VI. ACKNOWLEDGEMENT

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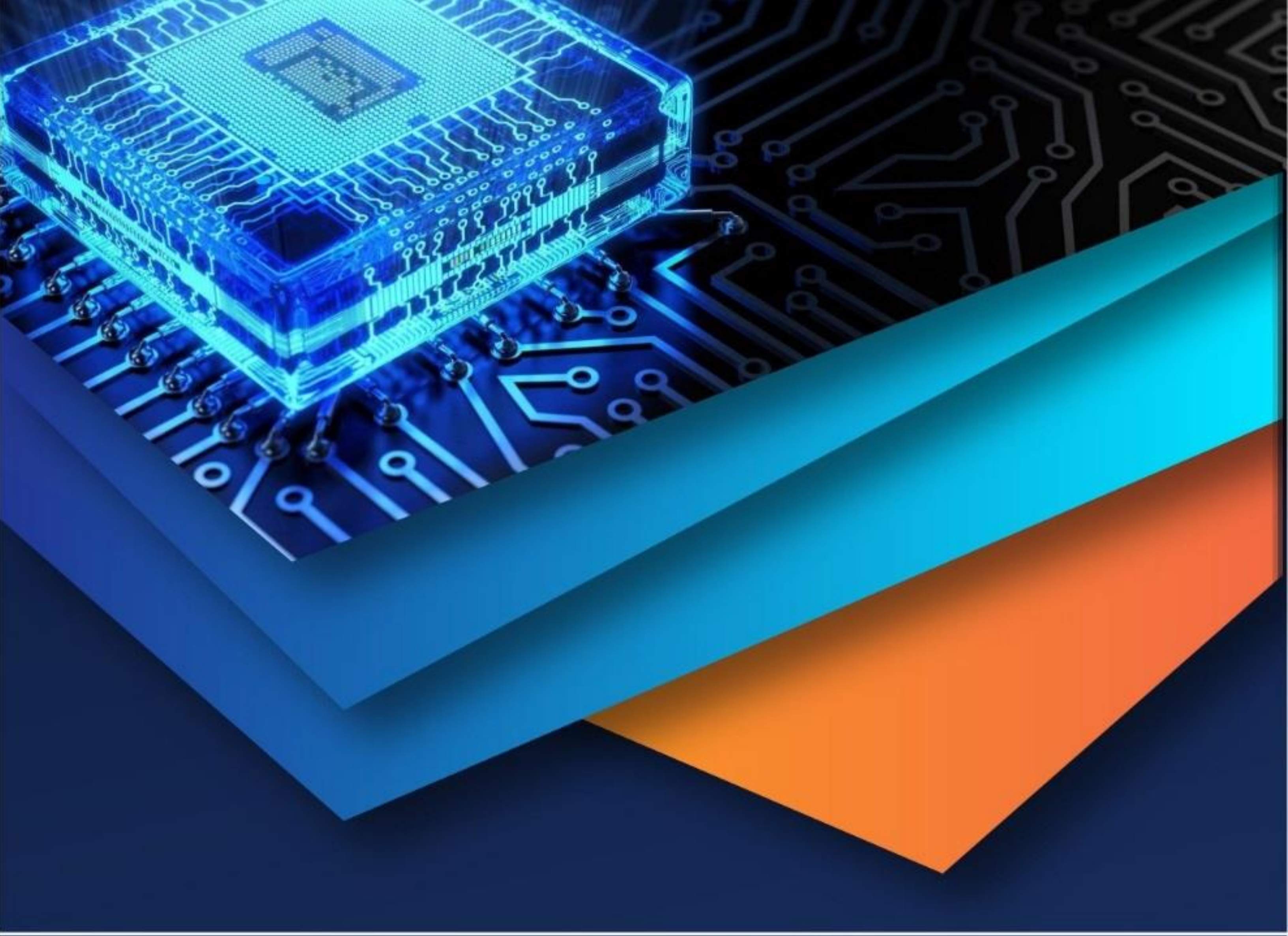

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