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Utilization of Waste Polymer (Rubber, Plastic) To Enhance the Strength of Asphalt Aggregate in Flexible Pavement

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ABSTRACT- Globally, sustainability is indeed an urgent necessity in the construction sector, and the use of waste products in road building is becoming more common recommended in order to lessen the environmental effect. A great variety of novel materials and techniques have been developed in the highway infrastructure to establish their feasibility for pavement design, construction, and maintenance. Plastics and rubbers being two examples. The amount of plastic garbage in landfill is growing as the population grows and lifestyles change. Similarly, most tire's, particularly those used in automobiles, are made of synthetic rubber. The management of either is a severe issue. At the same time, the growing number of cars stresses the need for roads of higher quality and engineering design. This plastic & rubber can be utilized to partially replace conventional materials in order to improve desirable mechanical properties for a certain road mix.

In this study a comparison is made between polythene and crumb rubber used to modify bituminous mixes. The percentage of bitumen is varied from 3,3.25,3.5,3.75,4 and 4.25 percent and the quantity of polythene and crumb rubber is varied in the percentages of 7.5,10,12.5 and 15 percent. The marshall stability procedure was used to prepare the specimens and stability values flow value, air void and VMA was found for the specimens. The optimum value of marshall stability was obtained at 4.25% bitumen content and 10% polythene or crumb rubber percentages.The value of Marshall stability was more for polythene modified bituminous mix. However, the flow values were grater for crumb bituminous mix. From the results it was concluded that polythene is a better modifier compared with crumb rubber.

KEYWORDS- Waste Polymer, Asphalt, Flexible Pavement, Rubber, Plastic

I. INTRODUCTION

After its use, polyethylene, a versatile material and a friend to the ordinary man, becomes a concern for the environment. The focus of today's research is on the environmentally appropriate disposal of a variety of polymer wastes [1]. The authors' novel approaches to using the polymer waste and tyre trash for the building of flexible pavement making walkway stones and laminated roofing sheets is a suitable solution for the disposal of both municipal solid trash and plastic waste. The severity of rutting, cracks, raveling, and edge drops on roads has increased in recent years as a result of strong wheel loads, tyre pressure, and heavy traffic [2]. Various efforts are being undertaken to strengthen the structures of flexible pavement, thereby boosting the road's strength and durability. Many additives are being added to increase the bitumen's binding property. Polymers have also been used in the building of flexible pavements for the past two decades. Polymers of various sorts are combined with bitumen, and polymer modified bitumen is employed [3].

The polymer is coated over the heated aggregates in this process, and the coated aggregate is mixed with hot bitumen. The mixture is used to create a flexible pavement. This is an environmentally beneficial method. Polymers used are solely waste polymer materials such as Polyethylene, plastic bags, plastic bottles, toys, and so on [4]. Because this procedure just includes coating over aggregate, a larger percentage of polymer, such as 10-15%, is easily adopted. This procedure also contributes to a 10-15% reduction in bitumen usage, which is replaced by waste polymers [5]. Polymer coating of aggregate also helps to improve aggregate properties. All hard surfaced pavements are classified into two types: flexible and rigid.

Rigid Pavement: Rigid pavements have the beam strength to span across localised subgrade failures and areas of inadequate support. When the subgrade deflects beneath a rigid pavement, the concrete slab's structural characteristics allow it to bridge over isolated failures and areas of inadequate support [6]. As a result, as long as the subgrade meets certain minimum requirements, its thickness is largely unaffected by its quality.

Flexible Pavement: A bitumen-surfaced pavement is referred to as "flexible" because the entire pavement structure can bend or deform in response to traffic pressures. Flexible pavement is made up of a bituminous material surface course, as well as underlying base and sub base courses. The bituminous substance is often asphalt, which allows for considerable plastic deformation due to its viscous nature. Although some 'full depth' asphalt surfaces are laid directly on the subgrade, the majority of asphalt surfaces are built on a gravel foundation [7]. Depending on the temperature at which it is poured, asphalt is categorised as hot mix asphalt (HMA), warm mix asphalt, or cold mix asphalt. The term "Flexible Pavement" refers to the fact that the pavement surface reflects the complete deflection of all subsequent layers generated by traffic stress. A layered system's load distributing properties serve as the foundation for flexible pavement design [8].

Figure 1: Flexible Pavement

Figure 1 is showing how a flexible pavement looks like and Figure 2 is showing how a Rigid pavement looks like.

Figure 2: Rigid Pavement

A. Polythene

Polyethylene, often known as polythene or polythene, is one of the most commonly used plastics on the earth. Polyethylene is known to be expansion polymers and typically have a direct structure [9]. Bundling is a critical use for these designed polymers. Polythelne is frequently used in the production of plastic bags, bottles, plastic films, compartments, and geomembranes. It is possible that more than 100 million tons of polyethene are produced each year for commercial and industrial purposes. Plastic refers to a broad range of synthetic or semi-synthetic organic solid materials derived from oil and natural gas. Plastics have become an incredibly crucial element of our daily living, according research, and we now consider it to be one of the necessary elements of daily life [10]. Plastics have progressed from the use of naturally occurring plastic materials like chewing gum and shellac to the use of chemically altered natural materials like rubber, nitrocellulose, gilalite, which is a strong, flexible, fiber-like protein, and finally to completely produced by people but not by naturally occurring molecules like Bakelite, epoxy, polyvinylchloride, and polyethylene. Plastic-made roadways are more durable and cost-effective, as well as environmentally sustainable. Plastic and bitumen bond well since they are both petroleum components. This combination increases the road's weight capacity as well as its durability. The roads are also more resistant to damage from heavy rain [11].

Polyethylene has long been utilized in the construction of roads. Some aggregates are extremely hydrophilic (water loving). Like bitumen, polyethylene is hydrophobic (hates water). As a result, including hydrophobic polymers into asphalt mixes via dry or wet mixing improves the mix's strength and water repellency. Polyethylene is added to a hot bitumen mixture, which is then laid down on the road surface in the same manner as a traditional tar road [12]. Plastic roads are mostly constructed from garbage-collected plastic carry-bags, disposable cups, polyethylene packages, and PET bottles. Polymer treatment is one approach for increasing pavement fatigue life, minimizing rutting, and lowering thermal cracking.

1) Crumb Rubber

Polymers are known to absorb liquids and swell, with the amount absorbed depending on the nature, temperature, and viscosity of the liquid/solvent, as well as the type of polymer [13]. Polymers are classified into two types: those that swell in water and those that swell in organic solvents. The first class comprises of polymers such as cellulose (cotton, wood, etc.) and protein (gelatine, wool, etc.), whereas rubber, both synthetic and natural, is the major category in the second class. Rubber swelling in organic liquids is a diffusion process [14]. The solvent diffuses into the bulk of the rubber, expanding its dimensions until the liquid concentration is homogeneous and equilibrium swelling is attained. The amount of solvent that will permeate into the rubber is determined by the number of cross-links in the rubber and the molecular compatibility of the solvent and rubber. The more cross-links there are in the rubber, the shorter the average length of the rubber chains between cross-links and the slower the rate of diffusion. Furthermore, the smaller the solvent's molecular weight, the more easily it will diffuse into the rubber [15].

II. OBJECTIVES

- To coat the aggregates with waste polymer materials such as plastic, polyethylene, rubber.
- Check the properties of various bitumen mixes.
- Check the properties of bitumen mix after the coating the waste polymer materials.
- Compare the bituminous mixes with waste polymer coating and conventional ones.

III. MATERIAL & METHODOLOGY

A. Material

The materials used in this study some were sourced locally and some had to be ordered.

1) Aggregates

The CA (coarse aggregate) was 12-20 mm in size and was brought from a local crusher facility in Lasgan, Srinagar, while the FA river sand was purchased from the same location from a local seller with a fineness modulus of 2.389, according to Zone II as shown in figure 3.

Figure 3: Coarse aggregate

2) Polythene

Polythene was collected from local stores and shredded into small bits no larger than 50mm x 5mm as shown in fig 4/

Figure 4: Polyethene waste

3) Crumb Rubber

Crumb Rubber was collected from the local garage in the Karan Nagar, Srinagar as shown in figure 5.

Figure. 5: crumb rubber

4) Bitumen

The binder 60/70 was used and was purchased from NIT Petrochem Private Limited, Srinagar as shown in figure 6.

Figure 6: Bitumen

B. Experimental Procedures

- Collection of all the raw materials which include the bitumen, aggregates, polythene and crumb rubber.
- Tests carried out on raw materials.
- Gradation of all the aggregate for the bituminous mix.
- Preparation of Marshall mixes with bitumen content varying in the percentages of 3,3.25,3.5,3.75.4 and 4.25.
- Modifying the bitumen mix with polythene and crumb rubber added in different specimens in the percentages of 7.5, 10, 12.5 and 15.
- Performing tests on specimens to calculate Marshall stability, flow value, air voids, voids in mineral aggregate and density.
- Comparing the values of these tests.

IV. RESULTS AND DISCUSSION

A. Sieve Analysis

Table 1: Gradation of aggregates

Sieve mm	% Passing		Cumulative % retained	Individual retain %	% Of CA, FA and filler	weight
	specification	blend				
19	100	100	0	0	CA 40%	0
13.2	79-100	85.3	14.7	14.7		130
9.5	70-88	75	25	14.7		130
4.75	53-71	64	36	15		207
2.36	42-58	53	47	11		142
1.18	34-48	46	54	8		106
0.6	26-38	33	67	8	FA 55%	107
0.3	18-28	24	76	8		107
0.15	12-20	17	83	6		95
0.075	4-10	8	92	8		118
					Filler 5%	58
Total weight of aggregate						1200gm

Table 1 shows values of gradation of aggregates, the aggregates were sieved through different sieve sizes and the weight retained on each sieve was calculated. Then the aggregates were divided in to coarse aggregates, fine aggregates and filler material. The amount of coarse aggregate in the total aggregates taken was 40 %, fine aggregates were 55 % and 5 % was filler material.

B. Polythene Modified Mix

1) Air Voids, Volume In Air Voids, Marshall Stability, Flow Value And Density

The air voids in the bituminous mix decreases as the percentage of bitumen is incraesed. However, when the plastic content is increased there is an increases in air void upto 10 % after which there is again a decraese in the airvoid percentage.

Table 2: Air void values for polythene mix for polythene mix

Polythene Percentage	Bitumen percentage	Air void
0	3	7.63
	3.25	7.14
	3.5	6.76
	3.75	6.33
	4	5.92
	4.25	5.58
7.5	3	7.83
	3.25	7.52
	3.5	7.16
	3.75	6.95
	4	6.62
	4.25	6.24
10	3	8.17
	3.25	7.82
	3.5	7.58
	3.75	7.23
	4	6.96
	4.25	6.54
12.5	3	7.55
	3.25	7.36
	3.5	6.97

	3.75	6.74
	4	6.48
	4.25	6.18
15	3	8.19
	3.25	7.83
	3.5	7.57
	3.75	7.24
	4	6.98
	4.25	6.55

The air void decreased as the perentage of the bitumen was increased as can be seen in table 2 and figure 7. The grapgh also shows the change as polythene was added.

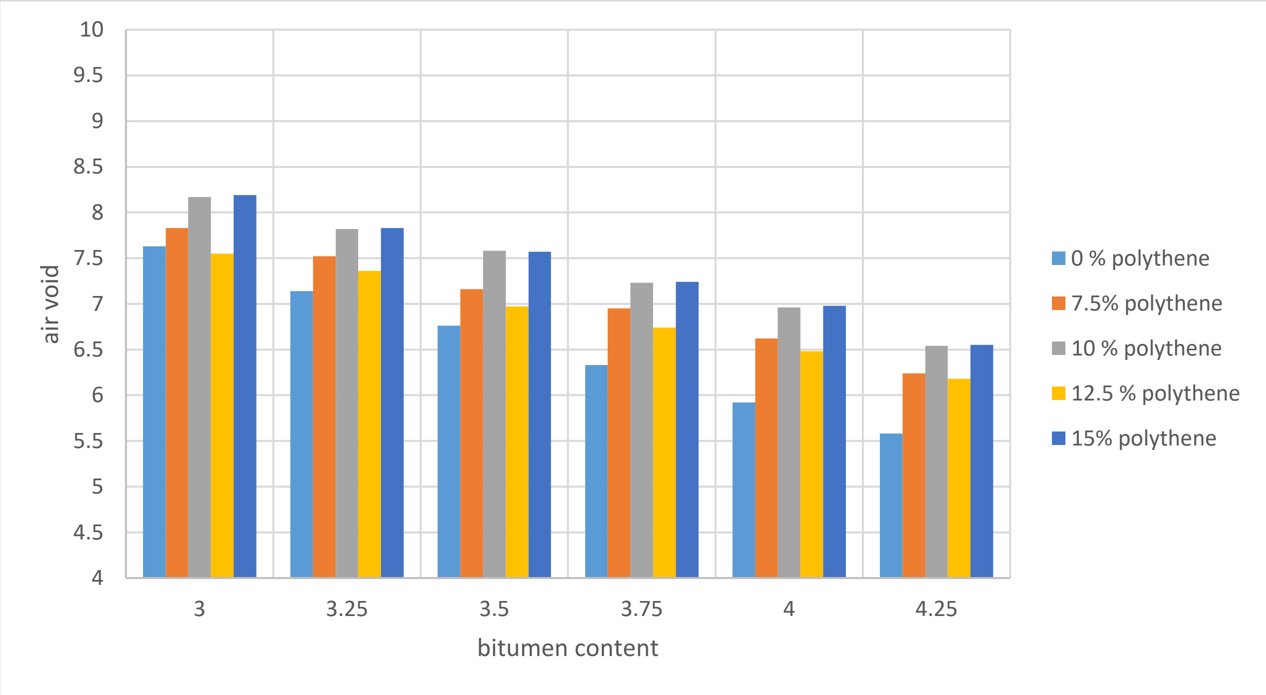

Figure 7: Air void vs bitumen content for polythene mix

The Figure 7 above shows the variation in the values of air voids. The values decrease as the percentage of bitumen is increased however there is an increase and then a decrease in the values as the polythene content is increased in the mix.

Table 3: VMA values for polythene mix

Polythene Percentage	Bitumen Percentage	VMA
0	3	15.3
	3.25	15.6
	3.5	15.8
	3.75	16.1
	4	16.3
	4.25	16.5
7.5	3	13.8
	3.25	14.2
	3.5	14.7
	3.75	15.4
	4	16.0
	4.25	16.2
10	3	14.1
	3.25	14.3

	3.5	14.6
	3.75	14.8
	4	15.3
	4.25	15.8
12.5	3	13.2
	3.25	13.8
	3.5	14.3
	3.75	14.8
	4	15.1
	4.25	15.5
15	3	13.1
	3.25	13.7
	3.5	14.2
	3.75	14.7
	4	15.0
	4.25	15.4

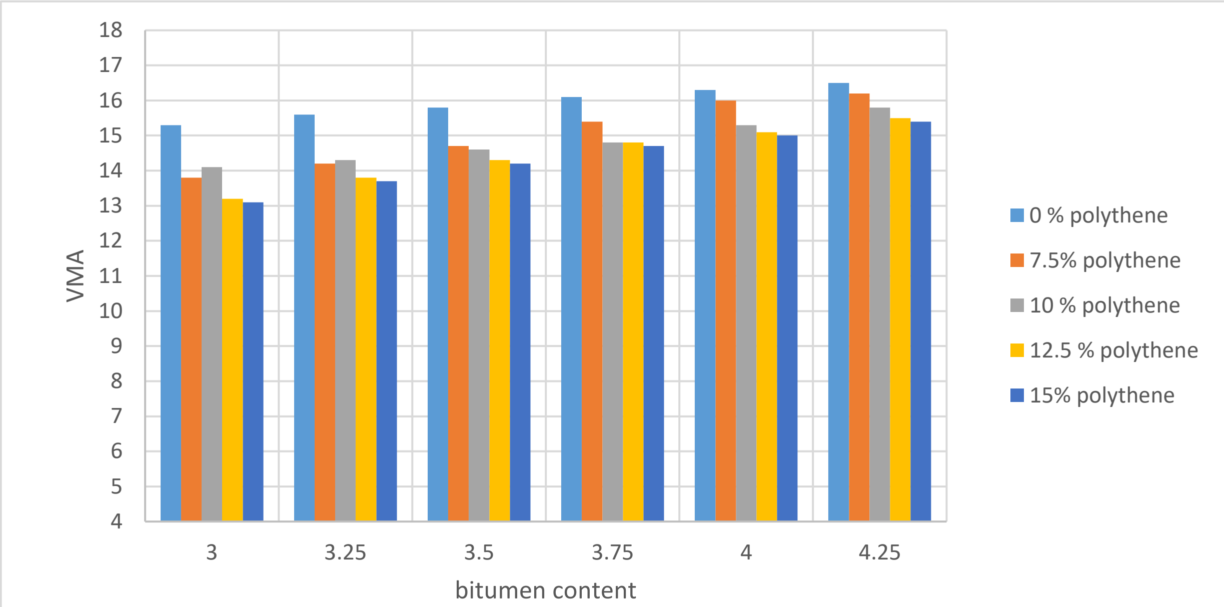

Figure 8: Void in mineral aggregate vs bitumen content

The table 3 and Figure 8 represent the values of voids in mineral aggregate for various mixes. The value of VMA can be seen to decrease as the percentage of bitumen is increased however as we increase the value of polythene, we saw an increase in the VMA.

Table 4: Marshall Stabilities for polythene mix

Polythene Percentage	Bitumen Percentage	Marshall Stability
0	3	859
	3.25	877
	3.5	885
	3.75	892
	4	900
	4.25	911
7.5	3	861
	3.25	879
	3.5	889
	3.75	895
	4	904
	4.25	919
10	3	886
	3.25	891
	3.5	904
	3.75	912
	4	923
	4.25	940
12.5	3	872

	3.25	885
	3.5	893
	3.75	906
	4	917
	4.25	924
15	3	861
	3.25	872
	3.5	886
	3.75	893
	4	907
	4.25	918

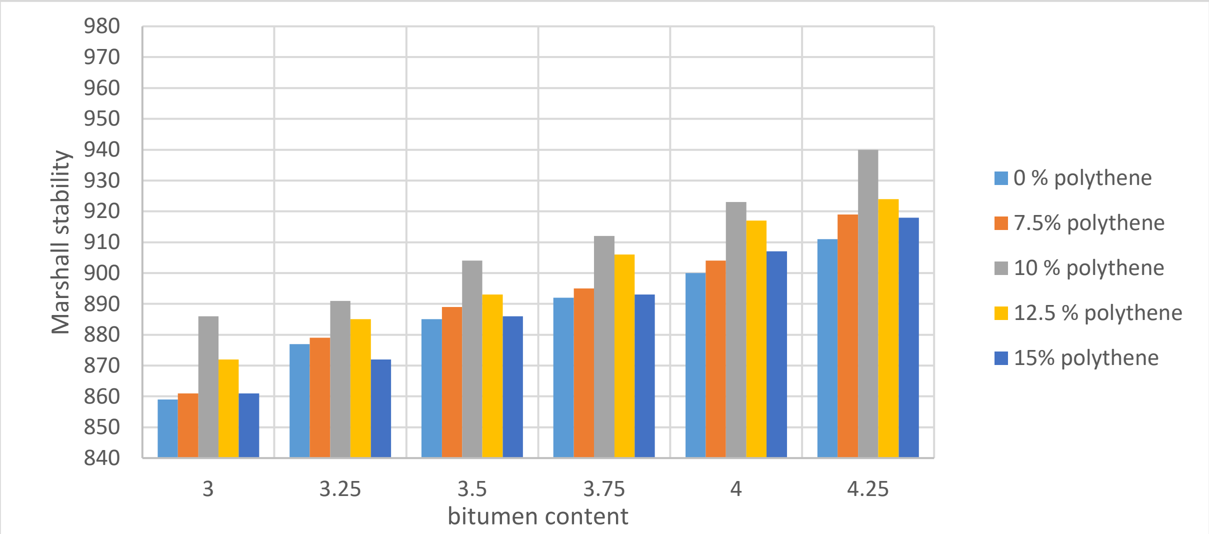

Figure 9: Marshall Stabilities vs bitumen content for polythene mix

The table 4 and Figure 9 shows the values of marshall stabilities. The values of stability can be seen to increase as the percentage of bitumen is increased. The values increase till 10 % polythene is added and after that any increase causes a decrease in the values.

Table 5: Flow values for polythene mix

Polythene Percentage	Bitumen Percentage	Flow Values(mm)
0	3	6.52
	3.25	6.84
	3.5	7.17
	3.75	7.63
	4	7.93
	4.25	8.12
7.5	3	6.41
	3.25	6.68
	3.5	7.03
	3.75	7.54
	4	7.88
	4.25	8.06
10	3	6.61
	3.25	6.93
	3.5	7.22
	3.75	7.71
	4	7.97
	4.25	8.27
12.5	3	6.53
	3.25	6.85
	3.5	7.18
	3.75	7.64
	4	7.94
	4.25	8.13
15	3	7.15
	3.25	7.83

	3.5	8.12
	3.75	8.27
	4	8.43
	4.25	8.64

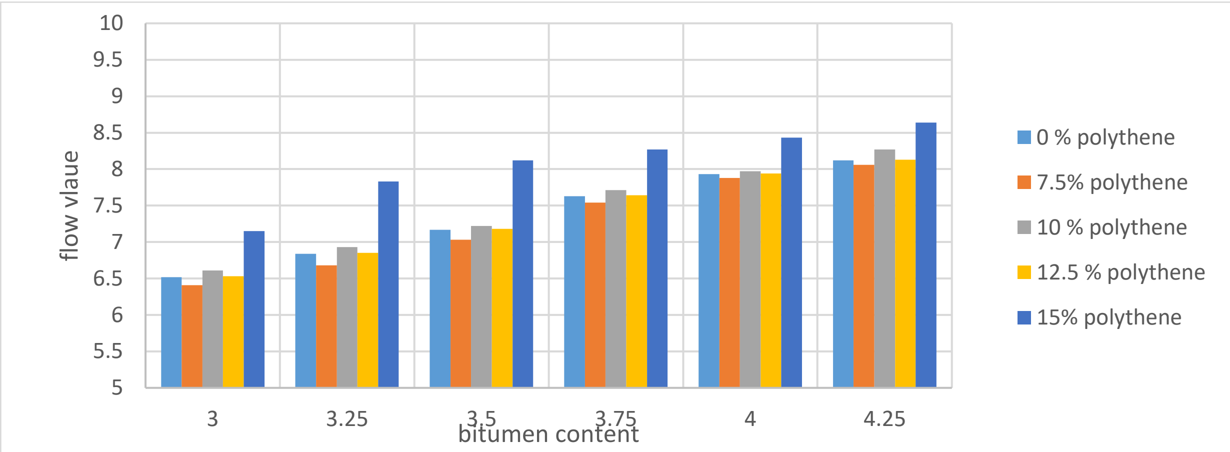

Figure 10: Flow values vs bitumen content for polythene mix

The table 5 and Figure 6 shows the values of flow as the percentage of bitumen and polythene are added to the mix.

Table 6: Density values for polythene mix

Polythene Percentage	**Bitumen Percentage**	**Density**
0	3	2.29
	3.25	2.29
	3.5	2.30
	3.75	2.30
	4	2.31
	4.25	2.31
7.5	3	2.28
	3.25	2.28
	3.5	2.29
	3.75	2.29
	4	2.30
	4.25	2.30
10	3	2.27
	3.25	2.27
	3.5	2.28
	3.75	2.28
	4	2.29
	4.25	2.29
12.5	3	2.30
	3.25	2.30
	3.5	2.31
	3.75	2.31
	4	2.32
	4.25	2.32
15	3	2.28
	3.25	2.28
	3.5	2.29
	3.75	2.29
	4	2.30
	4.25	2.30

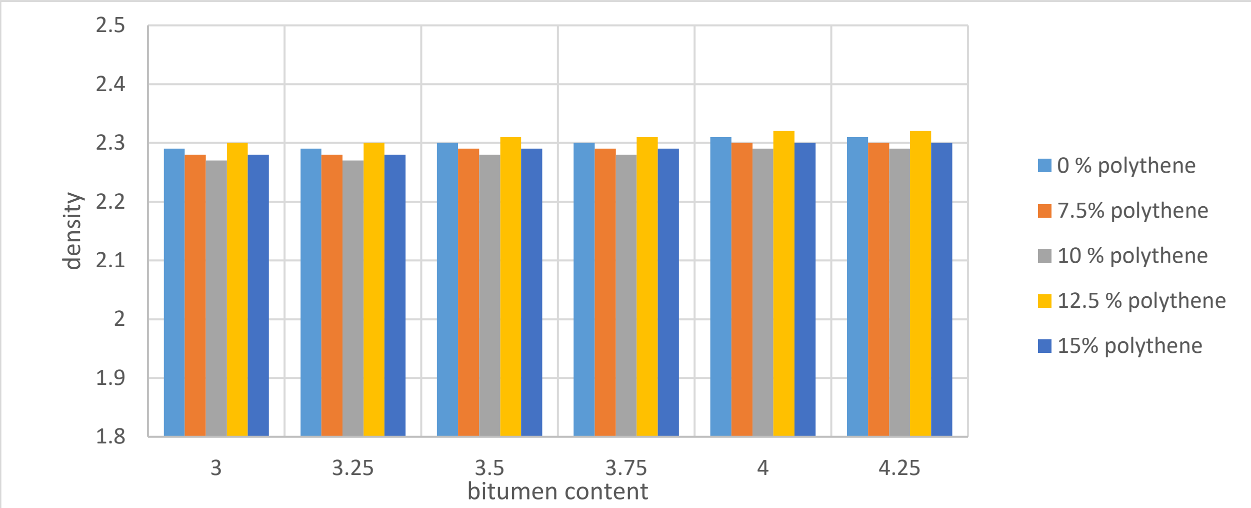

Figure 11: Density vs bitumen content

The density values are represented in table 6 and figure 11. The variation in the density values can be seen in the graph above.

The value of Bitumen percentage addition at which the optimum value of marshall stability was obtained was 4.25%. Thus for 0% addition of polyethene 4.25% is the optimum value of bitumen. With the addition of polythene, the value of stability increased will 10% however after that there was a decrease in the stability values. The percentage increase in stability was 3.18% for 4.25 % bitumen content and 10% polythene. The flow values increased with increase with the bitumen content however the value decreased as the percentage of polythene was increased. The VMA values also saw an increase with bitumen content and a decrease as the polythene content was increased. The effect on density was not much. The variations in it were small.

C. Crum Rubber Modified Mix

2) Air Voids, Volume in Air Voids, Marshall Stability, Flow Value and Density

Table 7: Air void values for crumb rubber mix

Rubber Percentage	Bitumen Percentage	Air void
0	3	7.63
	3.25	7.14
	3.5	6.76
	3.75	6.33
	4	5.92
	4.25	5.58
7.5	3	7.79
	3.25	7.48
	3.5	7.07
	3.75	6.86
	4	6.56
	4.25	6.09
10	3	8.05
	3.25	7.78
	3.5	7.49
	3.75	7.16
	4	6.88
	4.25	6.47
12.5	3	7.49
	3.25	7.28
	3.5	6.85
	3.75	6.66
	4	6.38
	4.25	6.08
15	3	8.07
	3.25	7.74
	3.5	7.46
	3.75	7.13
	4	6.87
	4.25	6.44

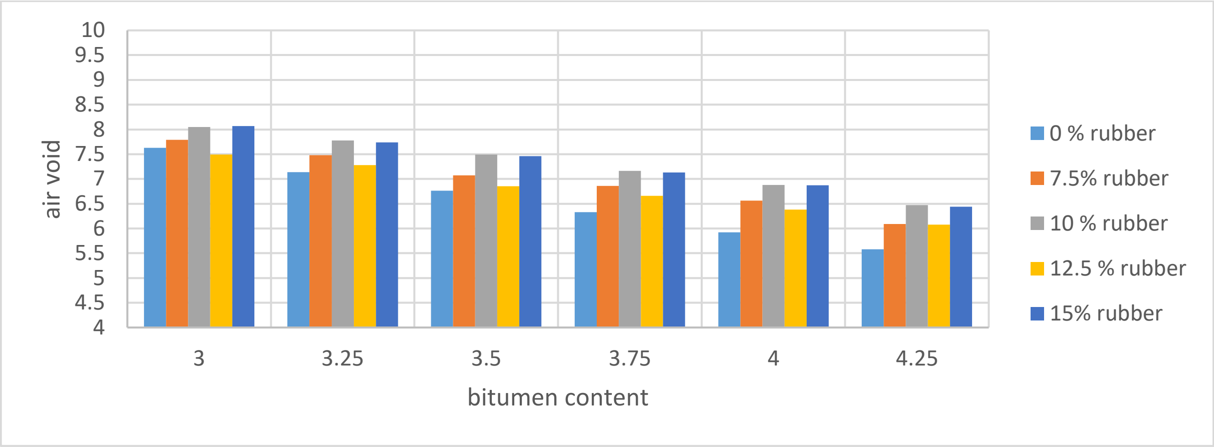

Figure 12: Air void vs bitumen content for crumb rubber mix

The values of air void are shown in the table 7 and figure 12. The values of air voids decrease as the percentage of bitumen is increased and the values of increases as the percentage of crumbed rubber is increased in the mix.

Table 8: VMA values for crumb rubber mix

Rubber Percentage	Bitumen Percentage	VMA
0	3	15.3
	3.25	15.6
	3.5	15.8
	3.75	16.1
	4	16.3
	4.25	16.5
7.5	3	13.5
	3.25	13.9
	3.5	14.5
	3.75	15.1
	4	15.7
	4.25	15.9
10	3	13.8
	3.25	14.0
	3.5	14.3
	3.75	14.5
	4	15.0
	4.25	15.5
12.5	3	12.9
	3.25	13.5
	3.5	14.0
	3.75	14.5
	4	14.8
	4.25	15.2
15	3	12.8
	3.25	13.4
	3.5	13.9
	3.75	14.4
	4	14.7
	4.25	15.1

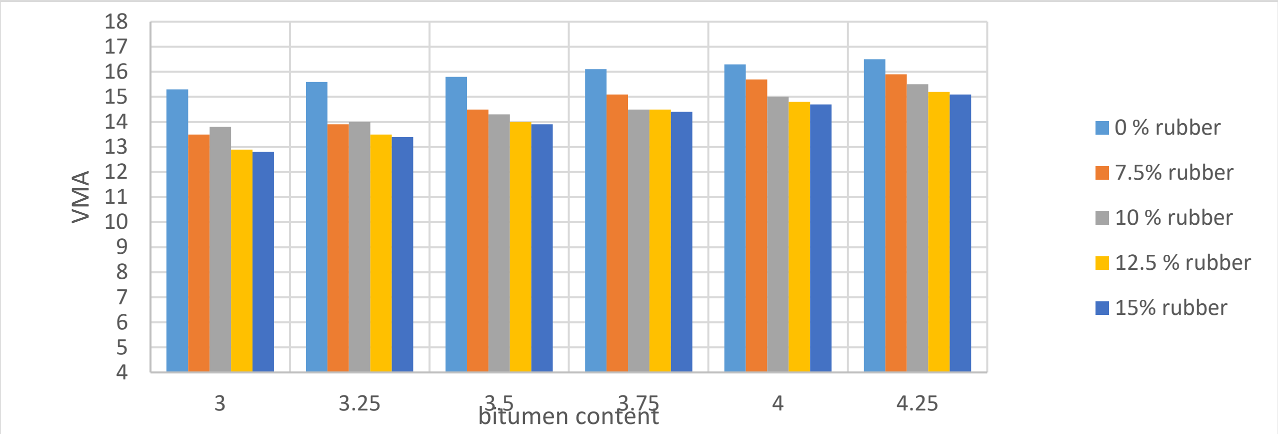

Figure 13: Void in mineral aggregate vs bitumen content for crumb rubber mix

Table 10 and Figure 13 show values of VMA when the percentages of bitumen and crumbed rubber is increased in the mix. The increase in bitumen percentage saw an increase in the VMA however the increase in the crumbed rubber saw a decrease in VMA.

Table 9: Marshall Stabilities for crumb rubber mix

Rubber Percentage	**Bitumen Percentage**	**Marshall Stability**
0	3	859
	3.25	877
	3.5	885
	3.75	892
	4	900
	4.25	911
7.5	3	858
	3.25	876
	3.5	885
	3.75	893
	4	901
	4.25	916
10	3	881
	3.25	887
	3.5	897
	3.75	906
	4	919
	4.25	935
12.5	3	868
	3.25	878
	3.5	887
	3.75	896
	4	909
	4.25	919
15	3	857
	3.25	865
	3.5	879
	3.75	887
	4	896
	4.25	911

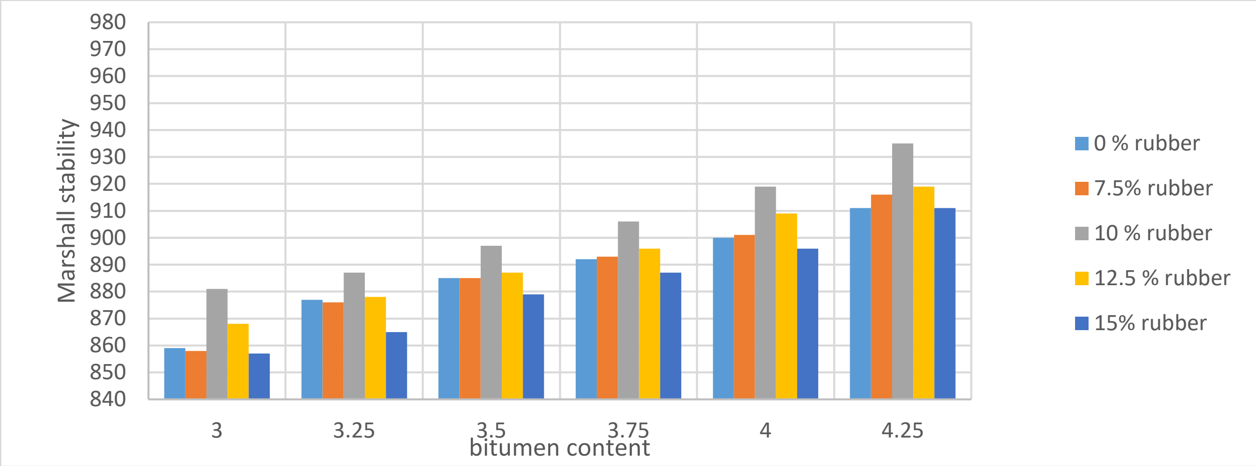

Figure 14: Marshall Stabilities vs bitumen content for crumb rubber mix

The values in table 9 shows the values of marshall stabilities. The figure 14 shows that the increase in bitumen content increases the value and the optimum value for crumbed rubber addition is 10 %. Any increase beyond this value causes a decrease in the marshall stability value.

Table 10: Flow values for crumb rubber mix

Rubber Percentage	Bitumen Percentage	Flow Values(mm)
0	3	6.52
	3.25	6.84
	3.5	7.17
	3.75	7.63
	4	7.93
	4.25	8.12
7.5	3	6.49
	3.25	6.72
	3.5	7.09
	3.75	7.60
	4	7.91
	4.25	8.10
10	3	6.71
	3.25	7.08
	3.5	7.31
	3.75	7.82
	4	8.13
	4.25	8.38
12.5	3	6.61
	3.25	6.93
	3.5	7.29
	3.75	7.73
	4	8.18
	4.25	8.28
15	3	7.16
	3.25	7.84
	3.5	8.13
	3.75	8.28
	4	8.44
	4.25	8.65

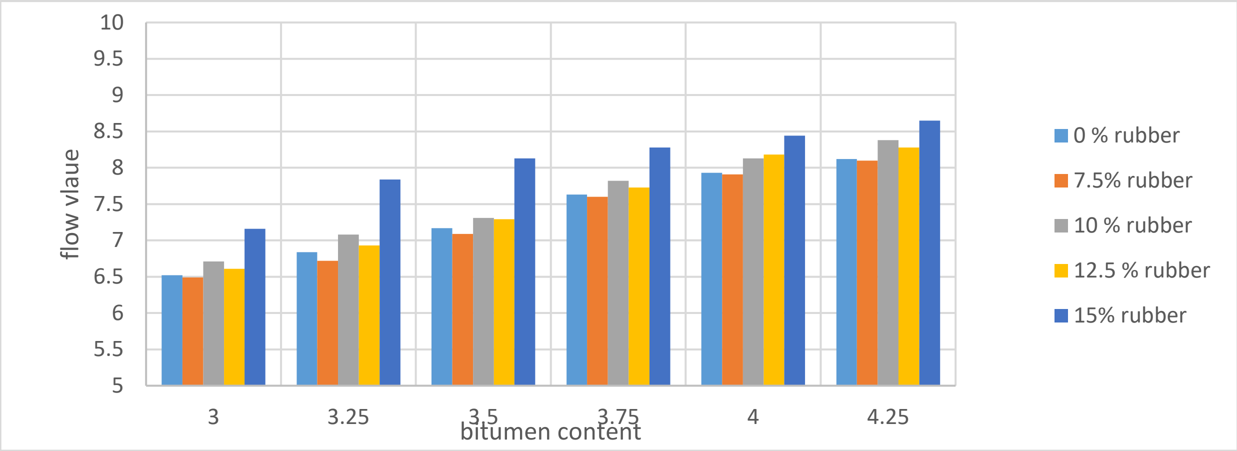

Figure. 15: Flow values vs bitumen content for crumb rubber mix

The flow values of the mix are noted in the table 10 and these values are represented in figure 15. The values of flow increase as the percentage of bitumen is increased. It can be observed that the increase in crumbed rubber percentage in the mix causes an increase in the flow value.

Table 11: density values for crumb rubber mix

rubber Percentage	Bitumen Percentage	Density
0	3	2.29
	3.25	2.29
	3.5	2.30
	3.75	2.30
	4	2.31
	4.25	2.31
7.5	3	2.29
	3.25	2.29
	3.5	2.30
	3.75	2.30
	4	2.31
	4.25	2.31
10	3	2.28
	3.25	2.28
	3.5	2.29
	3.75	2.29
	4	2.30
	4.25	2.30
12.5	3	2.31
	3.25	2.31
	3.5	2.32
	3.75	2.32
	4	2.33
	4.25	2.33
15	3	2.29
	3.25	2.29
	3.5	2.30
	3.75	2.30
	4	2.31
	4.25	2.31

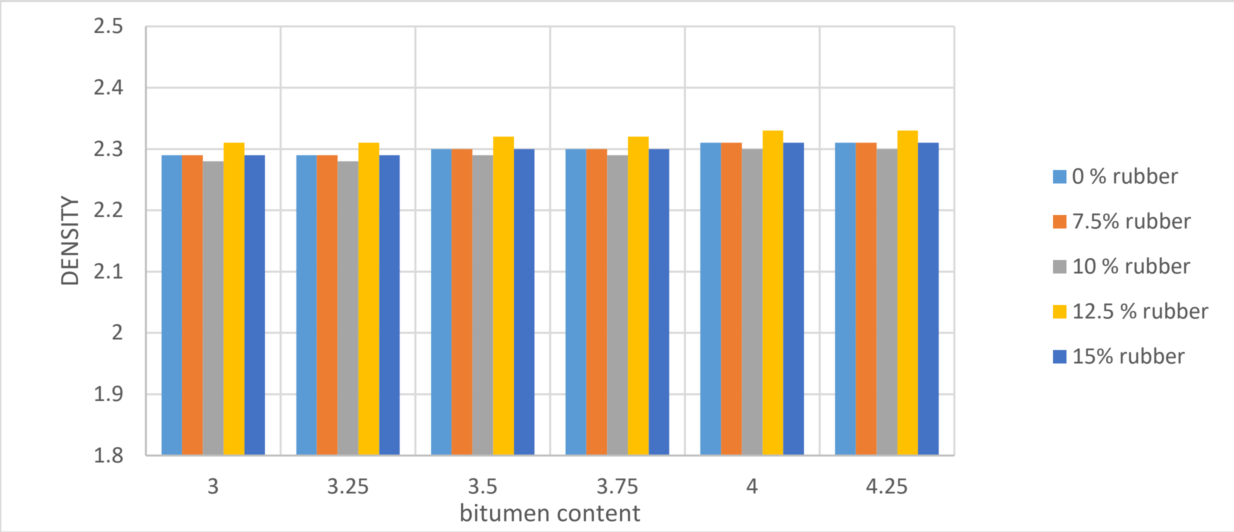

Figure 16: Density vs bitumen content for crumb rubber mix

The bituminous mix modified with crumb rubber the values of Marshall stability increased with the increase in bitumen however the values decreased as the percentage of crumb rubber was increased. The values of stability were lesser than that of polythene modified bitumen. The flow values increased with increase of bitumen content and but decreased after the percentage of crumb rubber was increased. The values of flow were more for crumb rubber modified bituminous mix compared with polythene modified bituminous mix.

V. CONCLUSIONS

- The optimum binder content for the bituminous mix was 4.25% when 10% polythene was added with the mix. The maximum value of marshall stability obtained was 940 kg.
- The optimum binder content for the bituminous mix was 4.25% when 10% crumb rubber was added with the mix. The maximum value of marshall stability obtained was 935 kg.
- 3. The flow values for both modified mixes increased with increase in bitumen content but decreased when polythene or crumb rubber were added. However, the values were more for crumb rubber modified bituminous mix.
- 3. The VMA values also saw an increase with bitumen content and a decrease as the polythene content was increased. The values of crumb modified bituminous mix were more compared with polythene compared mix.

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