Vol. 3 No. 1 (2025)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN

3007-3138

Print ISSN

3007-312X

A Novel Structural and Environmental Approach: Incorporating Biohazard Litter with Hot Mix Asphalt Modifier

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Abstract

The quantity of plastic in solid trash is escalating owing to population growth, urbanization, and lifestyle changes, resulting in extensive littering across landscapes. Consequently, the disposal of biomedical plastic waste has emerged as a significant global issue because of its non-biodegradability. Hospitals in Pakistan generate around 250,000 tons of garbage annually. This garbage is typically

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

incinerated in hospitals. The incineration procedure produces smoke that is highly detrimental to health. This study indicates that the accumulation of biomedical plastic waste poses significant health risks. Biomedical plastic trash includes needles, gloves, glucose containers, blood bags, and plastic trays. Various proportions of biomedical plastic waste, including Polypropylene, High-Density Polyethylene (HDPE), and Polyvinyl Chloride, were combined by weight with 80/100 pavement-grade asphalt. The Marshall Stability performance test was conducted, and its physical and volumetric features, including air spaces, voids in mineral aggregate, and voids filled with binder, were assessed in hot mix asphalt concrete (HMA). The findings indicated superior values for polymer-modified asphalt concrete. This is a sustainable procedure. The implementation of novel technologies will enhance road construction, extend road longevity, and contribute to environmental improvement. This research involves a comprehensive examination of the process for incorporating plastic debris into bituminous mixtures and conducting numerous tests. Following the literature assessment, it has been determined to use 4%, 6%, 8%, and 10% of plastic polymer (polypropylene, HDPE, and PVC) by weight of the bitumen content for our investigation. The investigation into polypropylene, HDPE, and PVC indicates that the Marshal Stability value, a strength parameter of Bituminous Concrete, has exhibited an upward trend, with maximum values rising around 16% due to the incorporation of HDPE. Additional polymers likewise exhibit a rising trend in Marshall Mix stability values.

Keywords: HMA, Bitumen, Plastic waste, medical waste, biohazard material, PVC

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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3007-3138
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Introduction

The primary means of getting from one location to another is by road. Road networks, particularly those with flexible pavements, are very important in Pakistan simply because of the country's excellent network. Subgrade, sub base, base coarse, and wearing surface make up flexible pavements. One of the most detrimental impacts on the bituminous surface of flexible pavements is dampness. The asphaltic layer is negatively impacted if moisture seeps through the bitumen [1-2]. Asphalt binders and aggregates are the two main components of hot-mix asphalt (HMA). The primary goal of bitumen modification is to create a structure that is both cost-effective and highly resistant to moisture [3–4]. According to the findings of many studies, moisture damage is the primary cause of pavement collapse, particularly in Pakistan. It makes sense to suggest a way to recycle waste materials in engineering and industrial building projects like road pavement to enhance the qualities of the asphalt mixture and lessen the detrimental effects of the waste materials on the environment and nature [5–9]. Because so many everyday items are made of plastic, plastic products have become an essential part of our lives.

The usage of plastic is expanding rapidly worldwide, and as the population grows, so does the amount of plastic waste in our society. The production of different kinds of waste materials has increased dramatically worldwide as a result of the expansion of several industries and population growth [10]. Through bitumen alteration, the wearing surface of hot mix asphalt is the primary target for moisture susceptibility. The enhanced functionality and long-term advantages of flexible pavements. To modify bitumen, certain additives must be added. Hot mix asphalt (HMA) polymers

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
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3007-312X

are shown to be highly successful since they enhance bitumen's internal and exterior qualities, making them the ideal modifier. After crude oil is refined, a thick, heavy substance known as asphalt binder is produced. Asphalt behaves like soft rubber and has a consistency comparable to any soft rubber when left at room temperature. When the temperature is high asphalt gets greasy.

But on the sub-zero temperature, the property of the bitumen mimics that of brittle material. Modified hot mix asphalt is created when asphalt is combined with polymers to improve its physical characteristics. The kinds of polymers added to the mixture have a significant impact on its consistency and variance in melting and boiling temperatures [11–12]. According to gradation curve requirements, the maximum volume or weight of hot mix asphalt (HMA) depends on the kind of aggregate. These aggregates come in a variety of sieve diameters. The aggregates are classified as coarse aggregates, fine aggregates, and mineral fillers based on their size. Because hot mix asphalt makes up a large portion of the total volume, it is essential to choose and use aggregates of various sizes carefully whenever possible. From the perspective of placement and compaction, workability is crucial. At a certain density, the mixed asphalt should be workable in every way.

When melted, the biomedical plastic waste exhibits good binding qualities. It has aided in the discovery of a secure biomedical plastic waste disposal technique [13]. The polymers can be employed as a modifier in bitumen to increase its strength because they are often significantly non-biodegradable [14]. To enhance road performance, new pavement design techniques are being developed. Older materials are being replaced with new

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3007-3138
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ones to increase economy, strength, durability, and beauty. The use of plastics in the bituminous road-building sector is one of the most promising approaches. Biomedical plastic debris is utilized on public roadways to prevent moisture damage. If properly crushed by environmental regulations, biomedical plastic waste from various sources may be utilized as a modifier material in certain pavements [15]. Biomedical wastes pose a serious threat to the environment, particularly when they end up in bodies of water, such as rivers, canals, channels, and seas, where they can affect aquatic life, including fish. Thus, its use might lessen pollution in the earth, ocean, and atmosphere. However, plastic's excellent ductility and long-lasting load-bearing capability may greatly extend the lifespan and durability of different pavement systems. Since it would provide the best green pollution-controlled infrastructure compared to the current pavements and infrastructure, it is thus extremely beneficial if it is optimized and deployed on a wide scale, i.e., projects sponsored by the government and other responsible authorities.

The overall objectives of this study are the following.

- To investigate the different types of biomedical plastic waste materials and their suitable range for our study.
- To select the optimum percentages of selected polymers through the Marshall Mix design of HMA.
- To select the most suitable type of polymer using Marshall Mix results by comparing Marshall Mix stability values.

The following conclusions are made in light of the test data acquired throughout this study project: The final results have improved by 44% with the addition of 3% LDPE. Stability has improved by 43% with 3.5% HDPE. The stability has improved by

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Online ISSN
3007-3138
Print ISSN
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44% with 4% CR use. The stability value of 17.26 KN was obtained by adding 3% LDPE. The stability rating of 19.2 KN has been provided by the 3.5% HDPE. When 4% crumb rubber is added, 19.18KN of stability is achieved. According to the aforementioned findings, the optimal modifier is 3.5% HDPE, which has demonstrated superior resistance to moisture susceptibility. The present study's recommendations consist of: High-density polyethene (HDPE) can be used to lessen bitumen's stability and moisture properties. Using plastic bottles (HDPE) as a bitumen modifier can lower the overall budget's maintenance costs [16].

Tina Maria Sunny (2018) looked at bituminous road buildings using waste plastic. The current study examines the application of autoclaved medical plastic waste—such as needles and glucose bottles—in road building. In contrast to the standard bituminous mix, the study examines the performance of the bituminous mix enhanced with biomedical plastic waste. Marshall The mixed design method is used. According to their findings, a polymer bitumen blend works better as a binder than regular bitumen. The combination had suitable ductility, a higher softening point, and a lower penetration value [17]. The use of waste plastic as a strength modifier in the surface course of rigid and flexible pavements was examined by Sultana and Prasad (2012). They concluded that waste plastic might be used as a modifier for cement and asphalt concrete pavement. The stability values were raised and the necessary amounts of binder components were lowered by increasing the percentages of plastic [18]. Rawid Khan and Syed Shahan Ali Shah (2016) looked at the recycling of medical plastic waste in hot mix asphalt. Zainab Z. Ismail et al. substituted shredded plastic waste for sand in concrete. In the investigation, 30

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3007-3138
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kg of waste plastic was recycled. Concrete was tested for slump, toughness indices, fresh and dry densities, compressive and flexural strengths, and more. The ages at which they cured were 3, 7, 14, and 28 days. The findings showed that concrete mixes produced micro cracks, but they also suggested that utilizing plastic instead of sand in cement concrete is a good way to address some of the problems with solid waste that plastics generate [19].

R. K. Yadav and Pratiksha Singh Rajput (2016) looked at the use of plastic waste in bituminous road construction. One potential answer to the problems associated with plastic waste disposal is the use of plastic waste on flexible pavements. The use of plastic debris in bituminous road buildings has been the subject of several studies [20]. The application of biomedical plastic waste in bituminous road construction was examined by Bhageerathy et al. (2014). They concluded that the plastic-modified mix had a 51% higher Marshall Stability value than the standard mix, indicating a greater capacity to support loads. Waste plastics are burned for apparent disposal, which pollutes the environment. The disposal of waste materials, particularly waste plastic bags, has become a major issue. It has been demonstrated that using waste plastic in bituminous mixtures improves the mix's qualities and partially resolves disposal issues. The cleaned Using a shredding machine, plastic waste is reduced into pieces small enough to fit through a 2.36 mm sieve. After heating the aggregate mixture, the plastic is successfully applied on top of the aggregates. To create the job mix recipe, heated bitumen is combined with these aggregates covered in plastic trash. In addition to strengthening road construction, the application of cutting-edge technologies will

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extend road life and contribute to a reduction in environmental pollution. The use of waste plastic as a modifier for semi-dense bituminous concrete is being examined in this study. In this study, heated aggregate is combined with shredded plastic waste to create a plastic-modified mix that contains 6%, 8%, 10%, 12%, and 14% plastic by weight of bitumen. It has been discovered that adding 12% plastic trash to the mixture maximizes the Marshall stability value. The addition of plastic trash to the bituminous mix also improves the other Marshall characteristics. According to the test results above, the ideal ratio of plastic waste is 12% [21].

Materials and Methodology

Sarwar & Company Private Limited, a facility on the Sahiwal bypass along the Lahore-Multan route, provides the testing and analysis of building materials, specifically aggregates and bitumen, as described in the paragraph. Among the materials provided is "Sargodha Crush," a crushed stone kind that is popular in the area. Several standardized tests are used to evaluate the aggregate's appropriateness and quality, including the aggregate's particle size distribution is established using sieve analysis, tests of specific gravity measure the aggregate's density about water, the aggregate's resilience to unexpected shocks or impacts is gauged by the Aggregate Impact Value Test, the aggregate's resistance to crushing under a progressively applied compressive load is assessed using the Aggregate Crushing Value Test and the aggregate's hardness and abrasion resistance is assessed using the Los Angeles Abrasion Test. Bitumen, the binder material, is further subjected to the following assessments in addition to these aggregate tests:

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The penetration test gauges bitumen's consistency or hardness. Determines the temperatures at which bitumen emits flammable vapours that catch fire using the Flash and Fire Point Test. The ductility test evaluates bitumen's ability to stretch under stress. The test for the softening point determines the temperature at which bitumen softens.

The Marshall Mix Design Test is used to find the ideal mix ratio for modified hot mix asphalt (HMA). For every polymer ratio, a minimum of three samples are created to guarantee precise and trustworthy findings. To determine the ideal or most efficient composition for enhanced asphalt performance, these samples are evaluated with different polymer contents. The materials and combinations are guaranteed to fulfil the required technical and performance criteria thanks to this thorough approach.

Results and Discussions

These results include the physical and mechanical properties of aggregates.

General

The final results were obtained from tests performed on materials and Marshall Mix design. Different topics have been written below to discuss the results, while the results obtained from the Marshall Mix design have been summarized in tables below.

Properties of Material

Before going through the test, it is necessary to find out the properties of the material that has been used in the mix. The physical properties of the material have a great impact on the final testing and the results to be determined.

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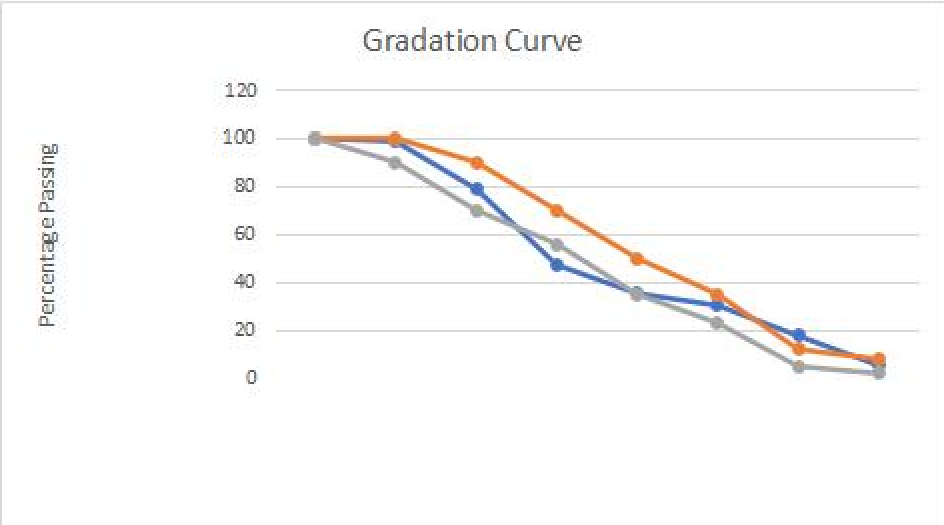
Online ISSN
3007-3138
Print ISSN
3007-312X



	1	2	3	4	5	6	7	8
Passing Percentage	100	98.65	78.91	47.2	35.28	30.23	17.63	5.27
Upper	100	100	90	70	50	35	12	8
Lower	100	90	70	56	35	23	5	2

Figure 1: Gradation Curve Based on the Material Used

The properties of the aggregates and the bitumen were determined by carrying out the following tests and the results of the tests have been summarized in the following tables.

Table 1: Properties of Bitumen

Sr. No.	Property	Result
1	Bitumen grade	80/100
2	Penetration at 25°C	92
3	Softening point	51°C
4	Flash Point	243°C
5	Fire Point	261°C

Table 2: Properties of Aggregate

Sr. No.	Property	Results
1	Abrasion value	18.67%
2	Impact value	11.56%

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3007-3138
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3	Soundness	17.42%
4	Specific gravity	2.66
5	Ductility	105cm

Highlighting the Gradation

The Asphalt that was used to determine the optimum binder content (OBC) and optimum polymer content (OPC) has a penetration grade of AC 80/100. The addition of binder content was from 3.5 % to 5.5 % with a positive increment of 0.5% for fulfilling the criterion of the Marshall Mix Design. For the determination of optimum polymer content, 4.20% binder content was used after finalizing the optimum binder content.

Mixes Prepare for Determining The (OBC)

For achieving the optimum binder content (OBC), 15 specimens were prepared by the addition of 3.5%, 4%, 4.5%, 5% and 5.5% binder content. The results of the flow and stability, Gmb and Gmm along with the graphical presentation have been discussed in this section.

Mix With 3.5% Binder Content

With the addition of 3.5% binder content, the average values of three specimens have shown a flow value of 2.7 mm and a maximum corrected value of stability, 19.24 KN. The stability value fulfils the desired targets as it is greater than 1000 Kg, while the average value of Gmb is 2.20 and the average value of Gmm is 2.52 which is within the specified range of standard values. The value of the air voids is 5.9 % which was out of range. The Voids Mineral Aggregate (VMA) was found to be 19.9 and the Voids Filler Aggregate (VFA) value was 70.0 which falls in the range “between 65 to 85”, which was observed in the recommendation. So, all the

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results obtained by the addition of 3.5% binder content were found to be satisfactory.

Mix With 4% Binder Content

After preparing the mix of 3.5% binder content an increment of 0.5% was made. The 4% binder content has the average values of three specimens showing the flow value of 3.02 mm and the corrected value of the stability, 18.34 KN. The stability value fulfils the desired target as it is greater than 1000 Kg, while the average value of Gmb is 2.21 and the average value of Gmm is 2.51, which is within the specified range of standard values. The value of air voids is 4.6 %, which is within the range. The Voids Mineral Aggregate (VMA) was found to be 19.8 and the Voids Filler Aggregate (VFA) value was 76.8 which falls in the range "between 65 to 85" which was observed in the recommendation. So, all the results obtained by the addition of 4% binder content showed a little bit better results than 3.5% binder content.

Mix With 4.5% Binder Content

An increment of 0.5% is used while going further. The 4.5% binder content has the average values of three specimens, which showed a flow value of 3.38 mm and the corrected value of stability, 19.55 KN. The stability value fulfils the desired target as it is greater than 1000 Kg, while the average value of Gmb is 2.20 and the average value of Gmm is 2.47 which are within the specified range of standard values. The value of the air voids is 3.5 % which is within the range. The Voids Mineral Aggregate (VMA) was found to be 20.0 and the Voids Filler Aggregate (VFA) value was 82.6, which falls in the range "between 65 to 85", which was observed in the recommendation. So, all the results obtained by the addition of

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4.5% binder content are better as compared to 3.5% and 4.0% binder content.

Mix With 5% Binder Content

5% binder content has the average values of three specimens, the flow value of 4.30 mm and the corrected value of the stability, 24.98 KN. The stability value fulfils the desired target as it is greater than 1000 Kg, while the average value of Gmb is 2.20 and the average value of Gmm is 2.24 which are within the specified range of standard values. The value of the air voids is 1.8 % which is within the range. The Voids Mineral Aggregate (VMA) was found to be 19.8 and the Voids Filler Aggregate (VFA) value was 90.8 which does not fall in the range "between 65 to 85" as observed in the recommendation. So, all the results obtained by the addition of 5% binder content are better than previous experiences.

Mix With 5.5% Binder Content

The 5.5% binder content has the average values of three specimens, a flow value of 4.38 mm and the minimum corrected value of the stability, 15.04 KN. The stability value fulfils the desired target as it is greater than 1000 Kg, while the average value of Gmb is 2.31 and the average value of Gmm is 2.34 which is within the specified range of standard values. The value of the air voids is 0.7% which is within the range. The Voids Mineral Aggregate (VMA) was found to be 19.4 and Voids Filler Aggregate (VFA) value was 96.6 which does not fall in the range "between 65 to 85" as observed in the recommendation. All the results were obtained by the addition of 5.5% binder content.

Determination of OBC

For the determination of optimum binder content, the following results have been tabulated

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Table 3: OBC Results

BC (%)	Gmb	Gmm	Air Voids (%)	VMA (%)	VFA
3.5	2.20	2.34	5.9	11.9	70.0
4	2.21	2.32	4.6	12.8	76.8
4.5	2.22	2.30	3.5	13.0	82.6
5	2.24	2.28	1.8	15.8	90.8
5.5	2.26	2.28	1.3	17.4	93.3

Stability

It indicates the maximum load that the compacted asphalt can carry at standard test temperature. The value of stability against OBC is 18.92kN.

Table 4: Flow of Conventional Stability Mix

BC %	Stability (KN)	Flow (mm)
3.5	16.84	2.77
4.0	18.92	3.02
4.5	19.55	3.38
5.0	21.23	4.30
5.5	21.34	4.38

This graph is plotted between optimum bitumen content and air voids and in this graph, Air voids value is 4%.

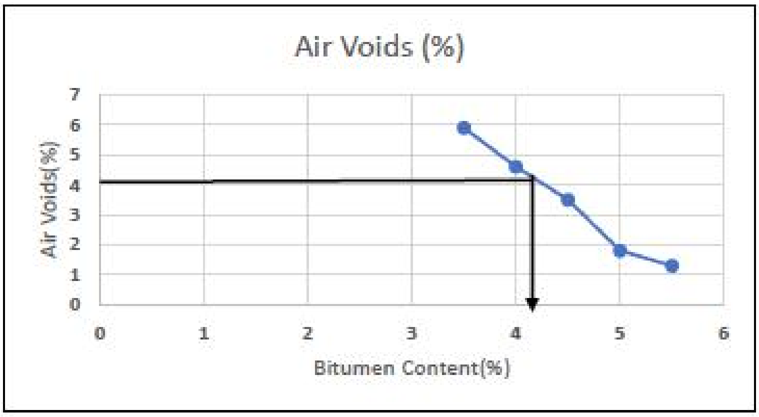

Figure 2: Bitumen content vs. Air Voids

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This graph is plotted between optimum bitumen content and Stability. The stability value is 18.92KN.

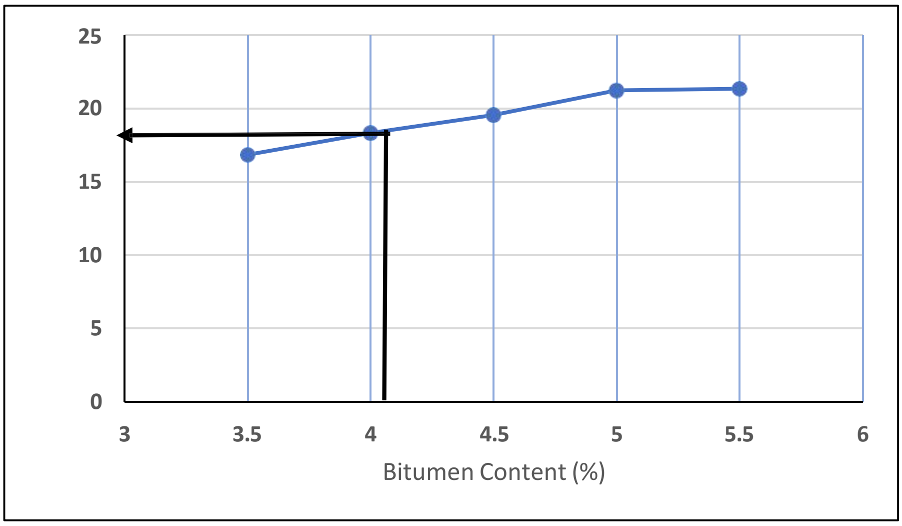

Figure 3: Bitumen Content vs. Stability

This graph is plotted between optimum bitumen content and Flow. The value of flow is 3.1mm.

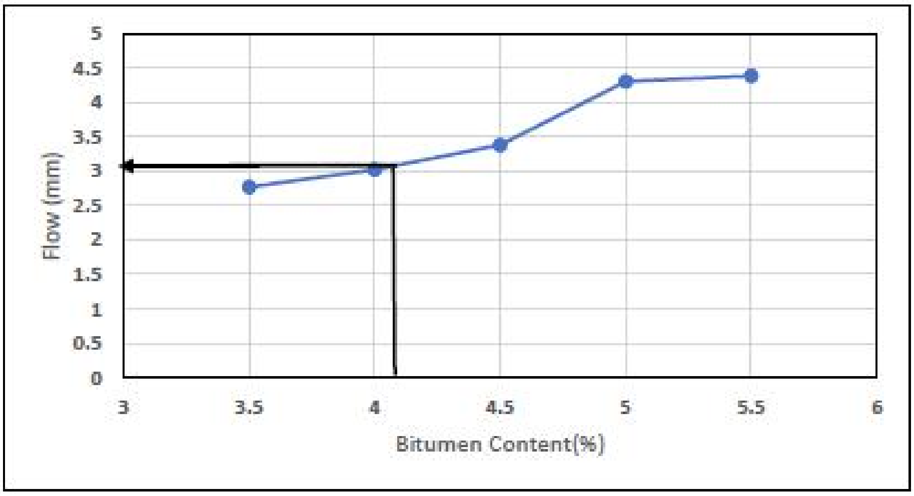

Figure 4: Bitumen Content vs. Flow

This graph is plotted between optimum bitumen content and Voids in mineral aggregate. The value of VMA is 13%.

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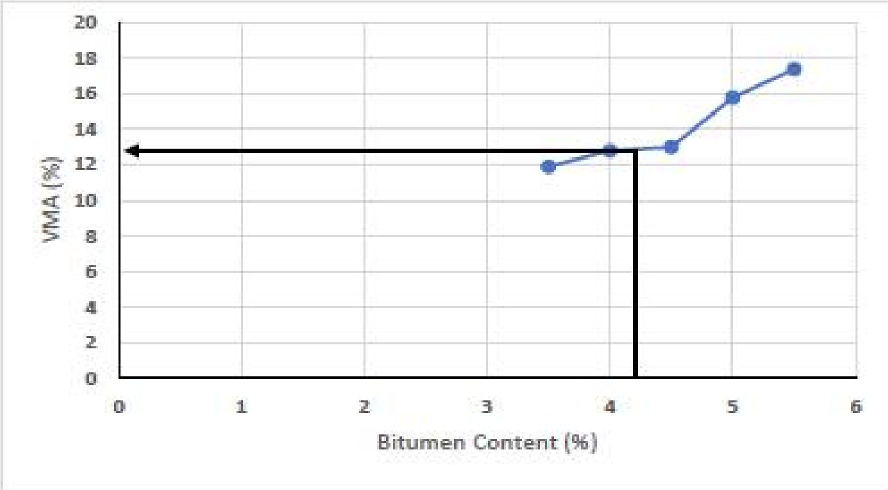

Figure 5: Bitumen Content vs. VMA

This graph is plotted between optimum bitumen content and Voids filled with Asphalt. The value of VFA is 75%.

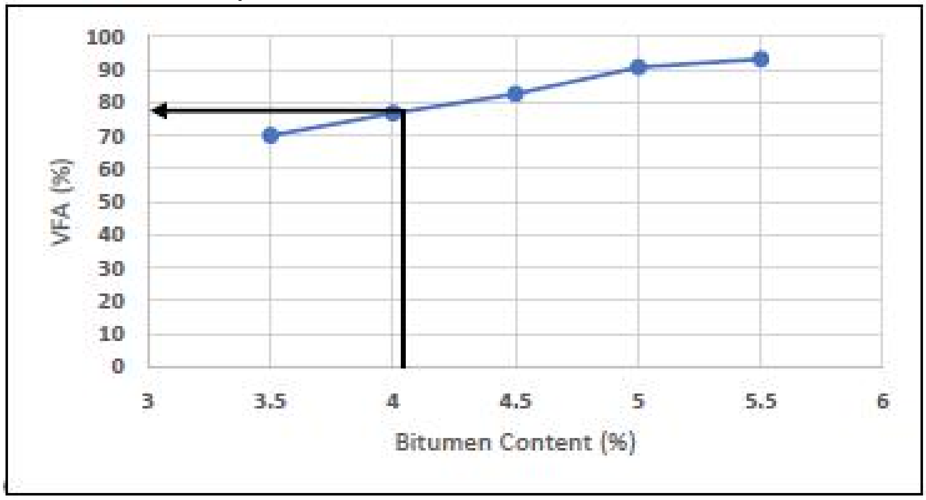

Figure 6: Bitumen Content vs. VFA

The value of OBC was found to be 4.20%. The stability against OBC is 18.92KN.

Effect of Polymers

Since the addition of the polymers has a great impact on the modification of bitumen According to the literature the polymers are found to be the best modifiers as they reduce moisture susceptibility of hot mix asphalt.

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Mix Prepared with 4%Polypropylene

By the addition of 4% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polypropylene on 4% was 2.32 and the value of Gmm was 2.47 the value of flow and stability was 3.2 mm and 16.34KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 6% Polypropylene

By the addition of 6% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polypropylene on 6% was 2.35 and the value of Gmm was 2.36. The value of flow 3.34 mm showed a variation and the value of stability 18.25KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 8% Polypropylene

By the addition of 8% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polypropylene on 8% was 2.31 and the value of Gmm was 2.42. The value of flow 3.5 mm showed a variation and the value of stability 20.01KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 10% Polypropylene

By the addition of 10% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polypropylene on 10% was 2.30 and the value of Gmm was 2.44. The value of flow is 3.6 mm and the value of stability is 20.56KN respectively. The results have been summarized in tabulated form.

Polypropylene Results

The following table shows the polypropylene results.

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Table 5: Final Results (Polypropylene)

BC (%)	Gmm	Gmb	Air Void (%)	VMA	VFA
4	2.32	2.49	4.7	15.7	62.3
6	2.35	2.36	4.2	17.6	68.6
8	2.31	2.42	4.0	19.8	73.3
10	2.30	2.44	3	21.7	78.1

This graph is plotted between optimum Polypropylene content and Air voids.

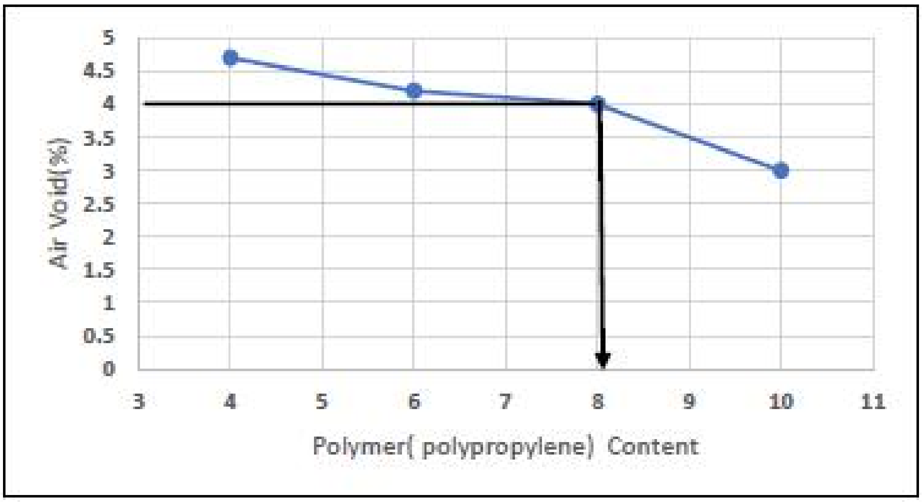

Figure 7: Polymer (Polypropylene) Content vs. Air Voids

The optimum polymer content of polypropylene is checked against the 4% Air Voids.

This graph is plotted between optimum polypropylene content and Flow.

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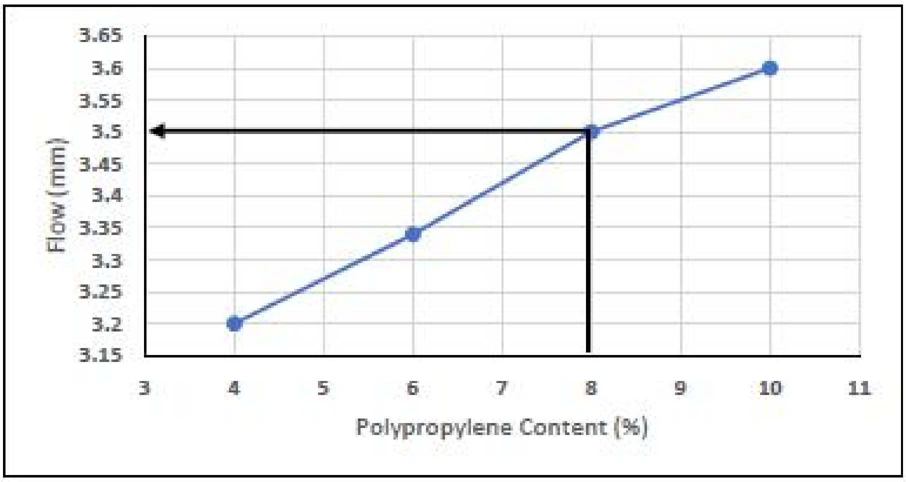

Figure 8: Polymers (Polypropylene) vs. Flow

This graph is plotted between polypropylene content and stability. The value of stability is 20KN.

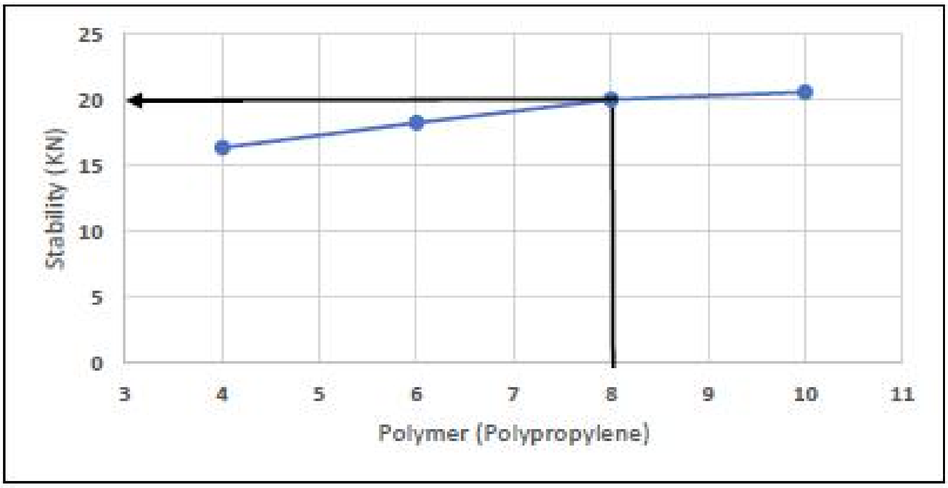

Figure 9: Polymers (Polypropylene) Content vs. Stability

This graph is plotted between polypropylene content and VMA. The value of VMA is 20%.

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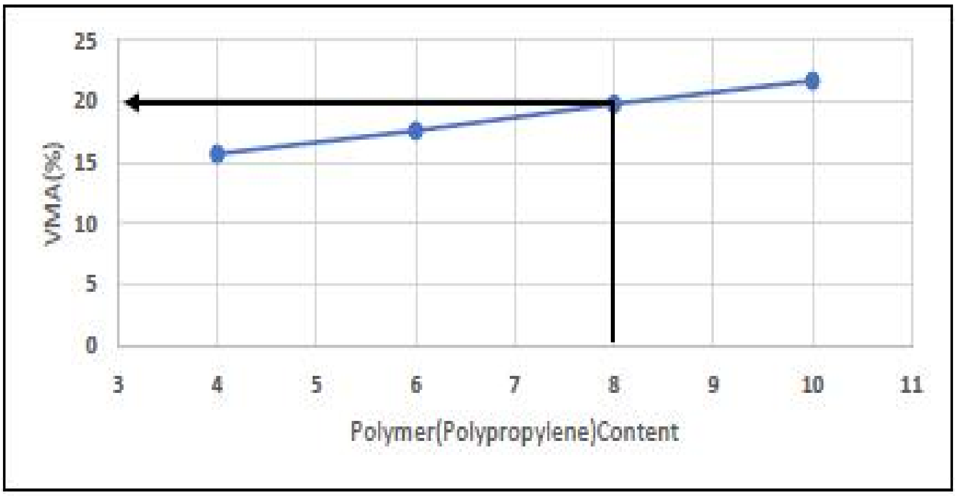

Figure 10: Polymers (polyethylene) Content vs. VMA

This graph is plotted between polypropylene content and VFA. The value of VFA is 75%.

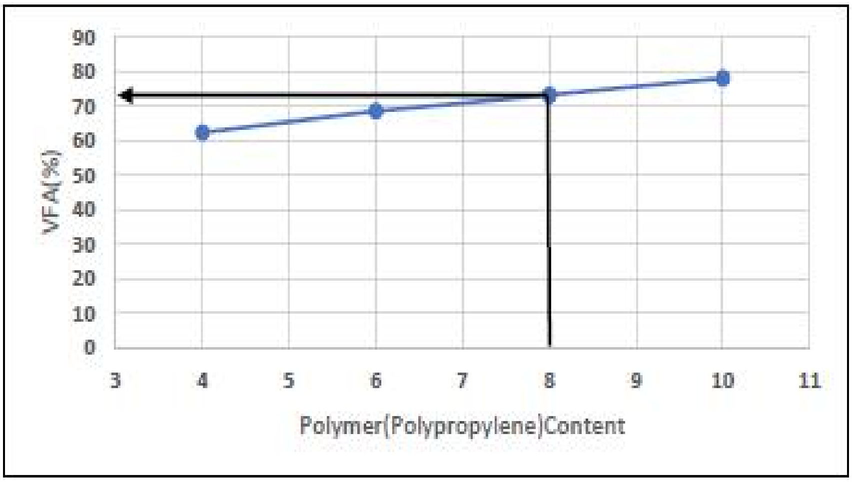

Figure 11: Polymer (Polypropylene) Content vs. VFA

Mix Prepared with 4%HDPE

By the addition of 4% polymer content while using the Marshall Mix design criteria. The average value of Gmb for HDPE on 4% was 2.37 and the value of Gmm was 2.47 the value of flow and stability was 2.9 mm and 18.5KN respectively. The results have been summarized in tabulated form.

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Mix Prepared with 6% HDPE

By the addition of 6% polymer content while using the Marshall Mix design criteria. The average value of Gmb for HDPE on 6% was 2.32 and the value of Gmm was 2.42. The value of flow 3.1 mm showed a variation and the value of stability 20.5 respectively. The results have been summarized in tabulated form.

Mix prepared with 8% HDPE

By the addition of 8% polymer content while using the Marshall Mix design criteria. The average value of Gmb for HDPE on 8% was 2.34 and the value of Gmm was 2.23. The value of flow 3.3mm showed a variation and the value of stability 22.0KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 10% HDPE

By the addition of 10% polymer content while using the Marshall Mix design criteria. The average value of Gmb for HDPE on 10% was 2.39 and the value of Gmm was 2.40.

The value of flow is 3.5 mm and the value of stability is 21.7KN respectively. The results have been summarized in tabulated form.

HDPE Result

Table 6: Final Results (HDPE)

BC (%)	Gmb	Gmm	Air Void (%)	VMA	VFA
4	2.37	2.47	7.2	15.2	51.3
6	2.32	2.42	6.3	17.4	63.9
8	2.34	2.65	4.0	19.6	76.1
10	2.39	2.40	3.5	20.2	78.3

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3007-3138
Print ISSN
3007-312X

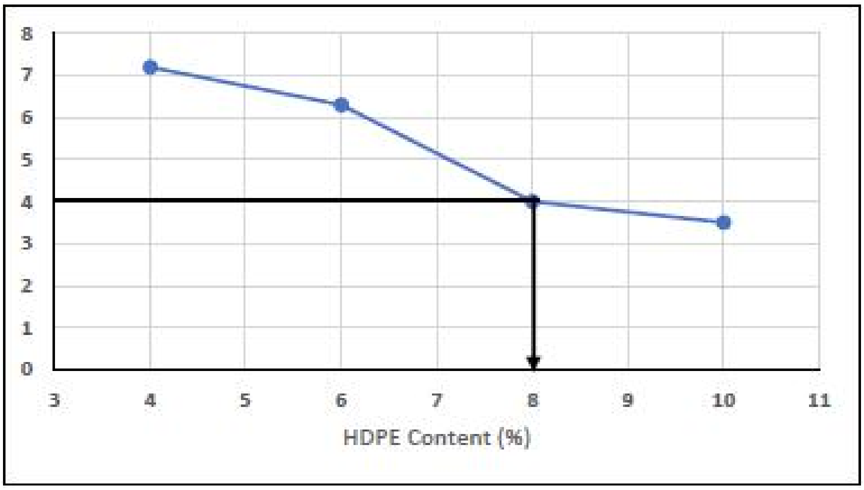

Figure 12: Polymer (HDPE) Content vs. Air Void

This graph is plotted between HDPE content and Air voids.

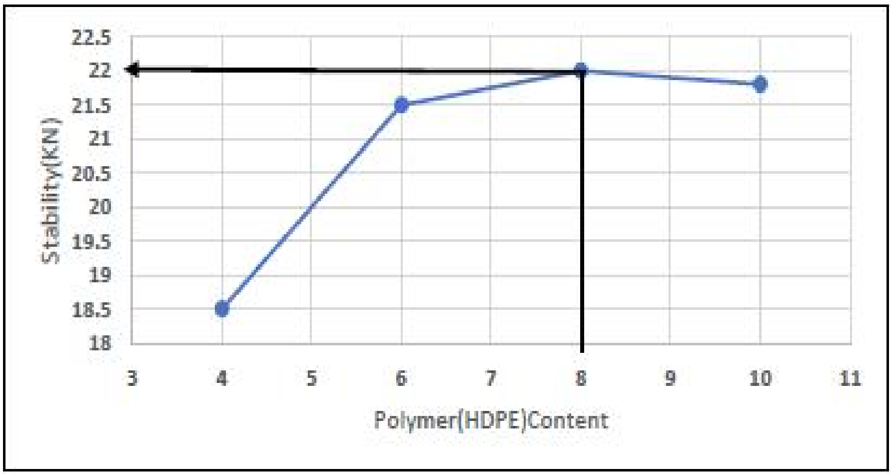

Figure 13: Polymer (HDPE) Content vs. Stability

This graph is plotted between HDPE content and Stability. The value of stability is 22KN.

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Online ISSN 3007-3138

Print ISSN 3007-312X

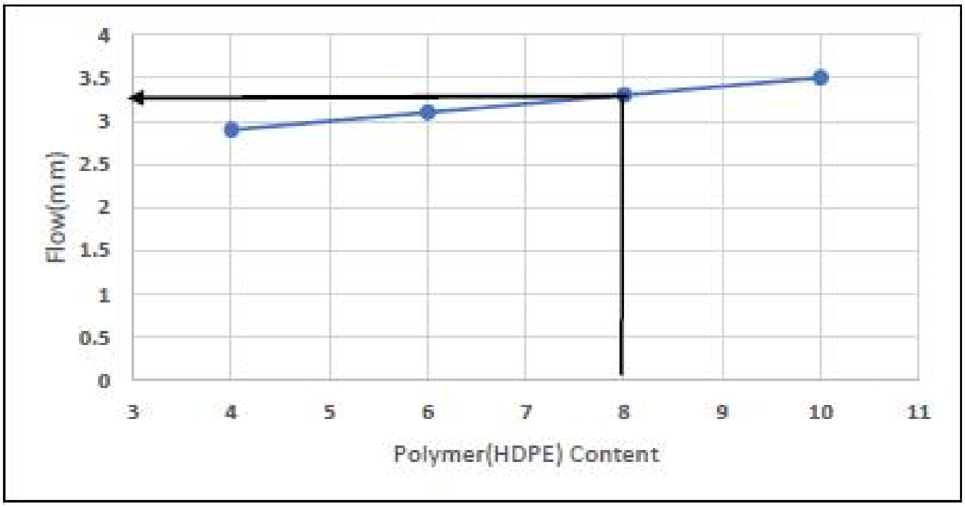

Figure 14: Polymer (HDPE) Content vs. Flow

This graph is plotted between HDPE content and Flow. The value of Flow is 3.45mm.

Mix Prepared with 4% Polyvinyl Chloride

By the addition of 4% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polyvinyl Chloride on 4% was 2.31 and the value of Gmm was 2.34 the value of flow and stability was 3.1mm and 13.68KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 6% Polyvinyl Chloride

By the addition of 6% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polyvinyl Chloride on 6% was 2.33 and the value of Gmm was 2.37. The value of flow 3.3 mm showed a variation and the value of stability 15.49KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 8% Polyvinyl Chloride

By the addition of 8% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polyvinyl Chloride on 8% was 2.36 and the value of Gmm was 2.25. The value

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of flow 3.4 mm showed a variation and the value of stability 17.19KN respectively. The results have been summarized in tabulated form.

Mix Prepared with 10% Polyvinyl Chloride

By the addition of 10% polymer content while using the Marshall Mix design criteria. The average value of Gmb for Polyvinyl Chloride on 10% was 2.32 and the value of Gmm was 2.39. The value of flow is 3.45 mm and the value of stability is 21.18KN.

Polyvinyl Chloride Results

Following are the polyvinyl chloride results.

Table 7: Final Results (PVC)

BC (%)	Gmb	Gmm	Air Void	VMA	VFA
4	2.31	2.34	5.19	16.17	86.16
6	2.33	2.37	4.8	17.73	87.66
8	2.36	2.35	4.3	18.94	94.01
10	2.32	2.39	4.05	21.17	98.23

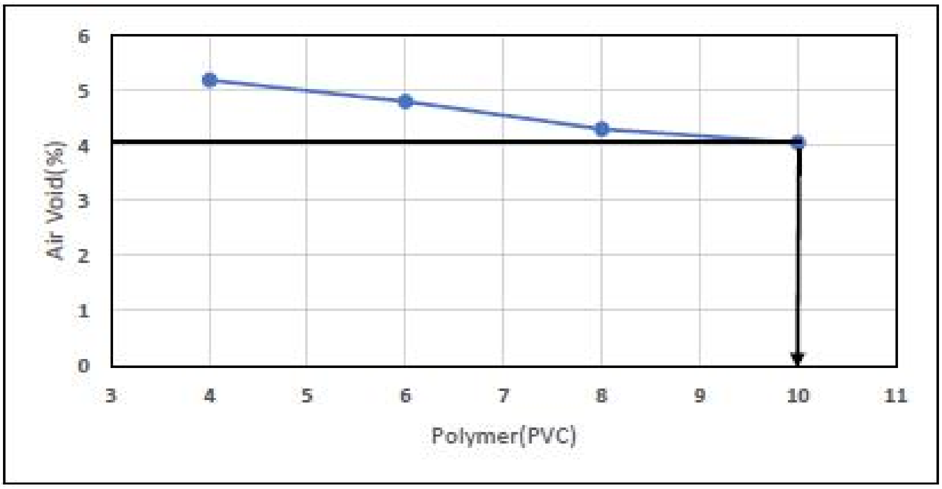

Figure 15: Polymer (PVC) Content vs. Air Void

The optimum polymer content for PVC is determined to be 10%.

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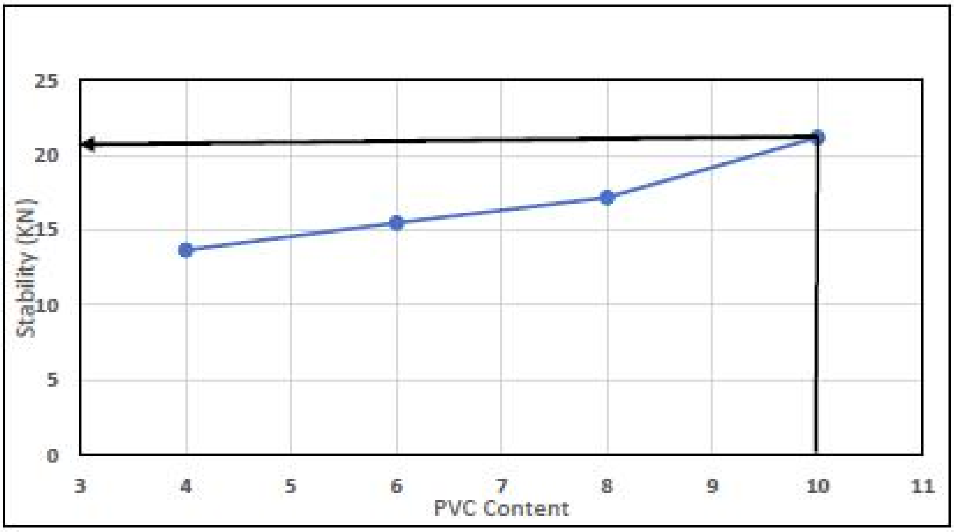

Figure 16: Polymer (PVC) vs. Stability

This graph is plotted between HDPE content and Stability. The value of stability is 21.5KN.

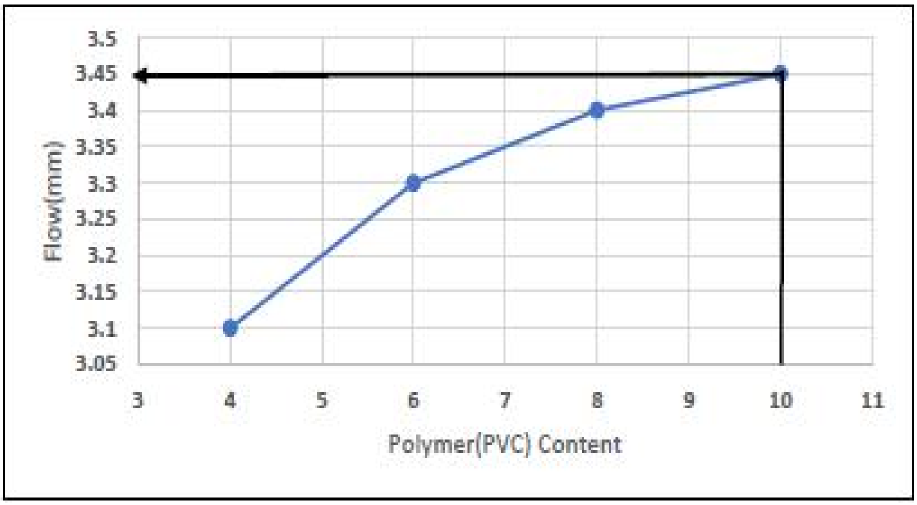

Figure 17: Polymer (PVC) Content vs. Flow

This graph is plotted between HDPE content and Flow. The value of Flow is 3.45mm.

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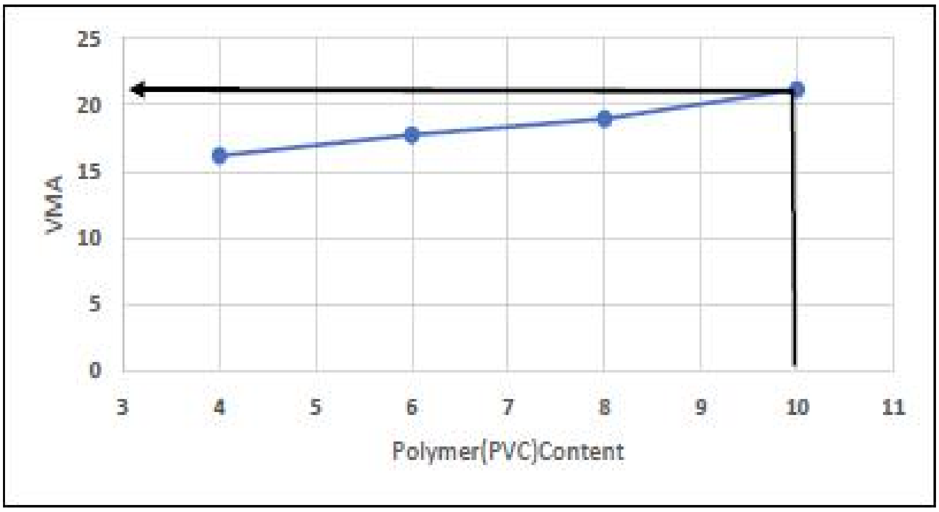

Figure 18: Polymer (PVC) Content vs. VMA

This graph is plotted between HDPE content and VMA. The value of VMA is 21.5 (%).

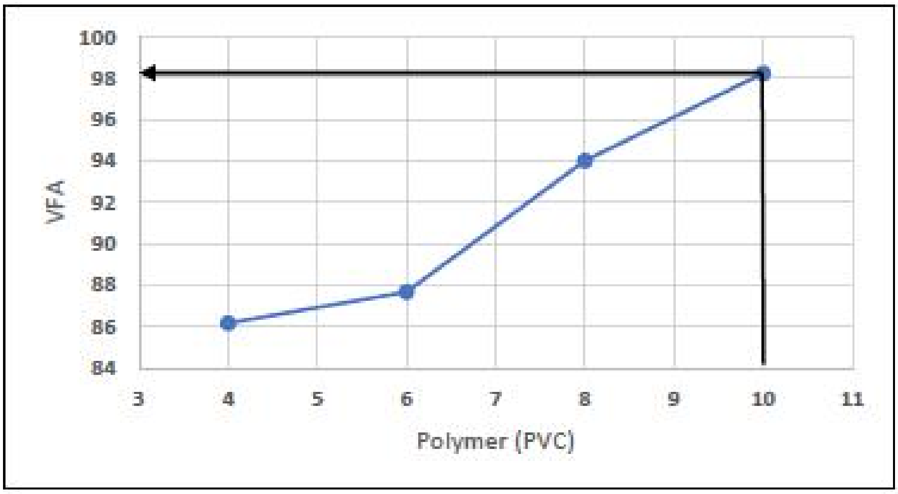

Figure 19: Polymer (PVC) Content vs. VFA

This graph is plotted between HDPE content and VFA. The value of VFA is 98 (%).

Final Results of Stability and Flow

The detailed results of Flow and stability of Modified samples have been summarized below:

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Table 8: Final Stability Results of PC

BC (%)	HDPE	Polypropylene	PVC
4	18.5	16.34	13.68
6	20.5	18.25	15.49
8	22.0	20.01	17.19
10	21.7	20.56	21.18

The stability of 8% HDPE was 22 KN while the Polypropylene on 8 % was 20.01 KN and the stability of PVC on 10% was 21.18 KN respectively.

Table 9: Final Stability Results of PC

PC (%)	HDPE	Polypropylene	PVC
4	2.9	3.2	3.1
6	3.1	3.34	3.3
8	3.3	3.5	3.4
10	3.5	3.6	3.45

The flow on 8% HDPE was 3.3 mm while the flow on 8% Polypropylene was 3.5 mm and the flow of PVC on 10% was 3.45 mm.

Table 10: Results

Plastic Polymers	Polypropylene	HDPE	PVC
Optimum Polymer Content (%)	8	8	10
Stability (KN) at OPC	20.01	22.0	21.18
Stability (KN) at 0% Polymer Content	18.92	18.92	18.92
Flow (mm) at OPC	3.5	3.3	3.45
Percent Stability Increase w.r.t	6	16	12

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0% Polymer Content (%)

Conclusion and Recommendations

This section deals with the conclusion of the research investigation and recommendations for future related studies.

Conclusion

The following conclusions are drawn from experimental results:

The study on the use of Polypropylene (Syringes, plastic trays), HDPE(Glucose bottles) and PVC (blood bags, surgical gloves)shows that the Marshall stability value which is the strength parameter of bituminous concrete has shown an increasing trend by the addition of these biomedical plastic waste polymers. Maximum increasing values are about 6, 16 and 12 for polypropylene, HDPE and PVC respectively hence from this study it is concluded that:

- The addition of Biomedical plastic waste polymer has a positive impact on the Marshall stability of HMA.
- A comparative study of attained results shows that HDPE significantly improves more stability of HMA.
- This study shows that the use of these biomedical plastic waste polymers will have a positive impact on the environment as it will reduce the volume of plastic waste to be disposed of by incineration.
- It will not only add value to Biomedical Plastic waste but will develop an eco-friendly technology.

Recommendations

From this study, it is recommended that:

- Road development agencies and health departments should make a joint effort to assess its health Impacts on construction

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3007-3138
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Industry personnel, Road users and environments only in this way can achieve its true benefits

- Proper specifications must be formulated for the use of these biomedical plastic waste polymers.
- A study must be conducted to assess the resistance against moisture damage of this Biomedical Plastic waste modifier hot mix asphalt.

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