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Influence of Water on Bituminous Mixes Using Modified Binders

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Abstract

The amount of plastic waste produced by different kinds of polyethylene bags used for transportation has significantly increased in recent years. With rising population and widespread use of polybags, the rate of polyethylene waste is rising. Throwaway polyethylene has developed into a threat to the environment because it cannot decompose naturally. The use of waste polyethylene in bituminous paving mixes has demonstrated satisfactory results, and this strategy will aid in the partial control of the pollution issue. Prior studies have shown that adding polyethylene up to 10% as an additive to bituminous mixes produced satisfactory outcomes for Marshall Properties. However, some of them suggested studying the impact of water on bituminous mix. In order to assess the final performance of hot mix asphalt, this paper has concentrated on Marshall Stability and Retained Strength in Presence of Water. According to experimental studies, the retained strength in pure bituminous mixtures stays above the desired 70%, but in modified bituminous mixtures, it stays up to 70% for the soaking period before falling below 70%.

Keywords: *Polyethylene; Asphalt; Optimum bitumen content.*

1 Introduction

Water has a significant impact on bituminous mixes using modified binders, which are commonly used in pavement construction. While controlled water content can enhance mix workability, cohesion, and stability, excessive moisture can lead to moisture-induced damage, rutting, and accelerated aging. Understanding these effects is crucial for optimizing mix design and construction practices to ensure durable and long-lasting pavements. Many researchers have worked on this.
(Prasad et al., 2013) examined the performance of recycled bitumen before and after the addition of plastic garbage using 1-9% plastic waste by weight of recovered bitumen. The mixture that resulted showed increased density, water resistance, and binding properties. In order to considerably increase the Marshall stability, strength, fatigue life, and other desirable characteristics of the mix, (Gawande et al. 2012) used modified bitumen with a 5–10% by weight addition of processed plastic waste. (Rasel et al. 2011) examined the properties of bitumen grade 80/100 mixed with PVC (2.5-20% by weight of bitumen) at the ideal bitumen concentration in order to verify the design criteria of bituminous mixes utilizing bitumen-PVC binder. The results demonstrated that bitumen might be altered by PVC debris to produce high-strength blends. Marshall stability of modified mixes was found to be 1.2 and 1.18 times higher than normal mixes after (Sabina et al. 2009) investigated the comparative performance of bituminous mixes including plastic/polymer (8% and 15% by wt of bitumen).
The goal of this investigation is to ascertain how much strength bituminous pavement can maintain when there is water present. This study will look at the impact of water on this modified mix throughout the course of 24, 48, 72, and 96 hours of soaking.

2 Methodology

Numerous field and lab experiments are required for the investigation of plastic waste, aggregates, and bitumen. Plastics were gathered in Rajshahi's various neighborhoods. Sand and stone dust were added to the mix to produce the required aggregate gradation (filler passing 0.075 mm filter). Aggregate tests were conducted to examine engineering characteristics relevant to flexible pavement.

2.1 Materials Used

a. Modified binders: In this research, Poly-ethylene has been used as modified binders.
b. Aggregates: Stone chips were used as coarse aggregate and sand as fine aggregate.
c. Fillers: Mineral filler was used as filler in this research. Moreover, bitumen was also used.

2.2 Preparation of Blend

The scissors were used to cut the polyethylene bags into fragments. These were put through a sieve, and the plastic fragments that passed through a sieve with a mesh size of 4.75 mm but remained in the 2.36 mm sieve were collected. Plastic pieces were gradually added to the hot bitumen, which was about 170-180 °C. For 20 to 30 minutes, the mixture was agitated using a mechanical stirrer. Mixtures of various compositions were made to complete many tests.

2.3 Preparation and Testing of Mold

The test samples were submerged for 30 minutes in a thermostatically controlled water bath that was regulated at (60±1) °C. Following that, experiments were conducted to determine the Marshall Stability Test and Flow value. Following that, samples were ready for testing to ascertain the impact of water. For 24 hours, 48 hours, 72 hours, and 96 hours, these prepared specimens were submerged in water to measure their compressive strength and index of maintained strength.

3 Results and Discussions

Table 1. Comparison of values of different properties of Bitumen and Modified Bitumen

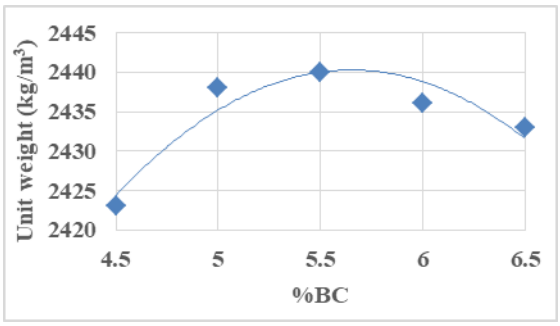
Properties	AASHTO Designation	Binder	
		Bitumen	Modified Bitumen
Specific gravity	T229	1.0225	0.998
Penetration(0.1 mm)	T49	83	59
Ductility (cm)	T51	100(+)	55
Solubility (%)	T44	97.93	82.8
Softening Point(°C)	T53	52.5	73
Flash Point(°C)	T48	295	230
Fire Point(°C)	T48	305	240

According to the data in Table 1, modified bitumen has lower specific gravity and melting temperature than pure bitumen, which causes a decrease in penetration, solubility, ductility, and specific gravity. On the other hand, modified bitumen's softening point values rise as a result of polyethylene's increased elastic properties. Modified bitumen can be used in warmer climates because of the modified bitumen's lower penetration value, lower ductility value, and higher softening point.

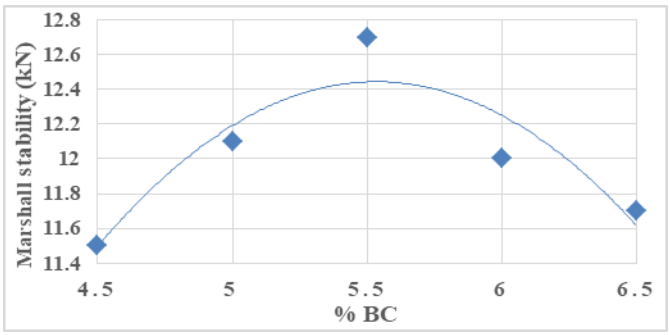
Table 2. Characteristics of Bituminous Mixes for different types of binder with 50 blows

Types of Binders	Optimum %BC	Bulk Specific gravity	Unit Weight (Kg/m^3)	Marshall Stability (KN)	Flow (0.25 mm)	% Voids in total mix	% Voids in mineral aggregates	% Voids filled with bitumen
Pure Bitumen	5.5	2.440	2440	12.44	12.0	3.9	14.70	74
Modified Bitumen	5.82	2.465	2465	12.57	14.2	3.7	13.32	71

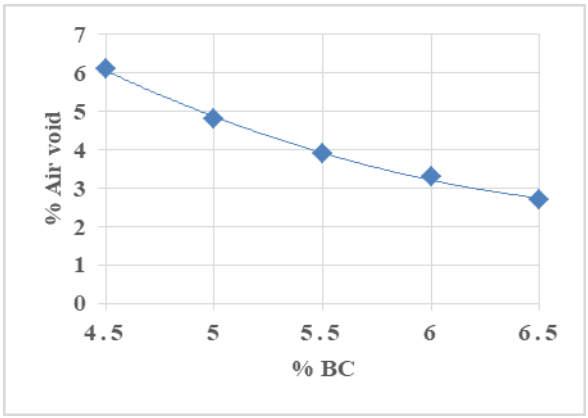
Table 2 demonstrates different values of Marshall Stability test property. It indicates that all the characteristics of modified bitumen except %voids in total mix, %voids in mineral aggregate and %voids filled with bitumen has higher value than pure bitumen.



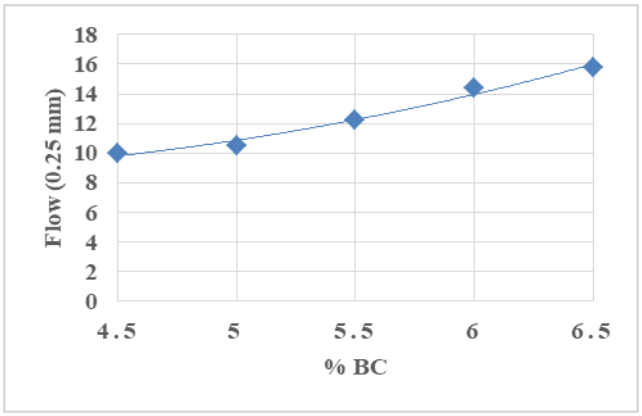
1(a) Relationship between unit weight and bitumen content



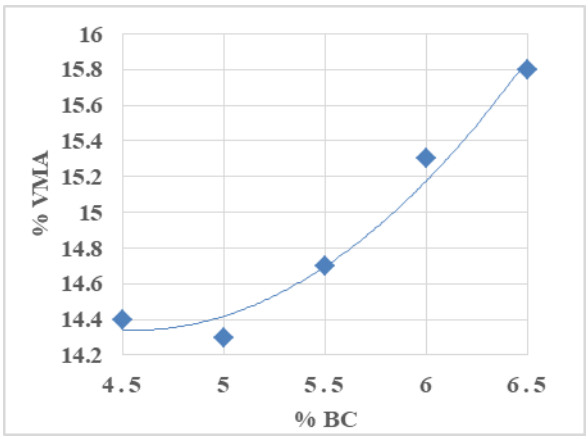
1**(b)** Relationship between Marshall stability and bitumen content



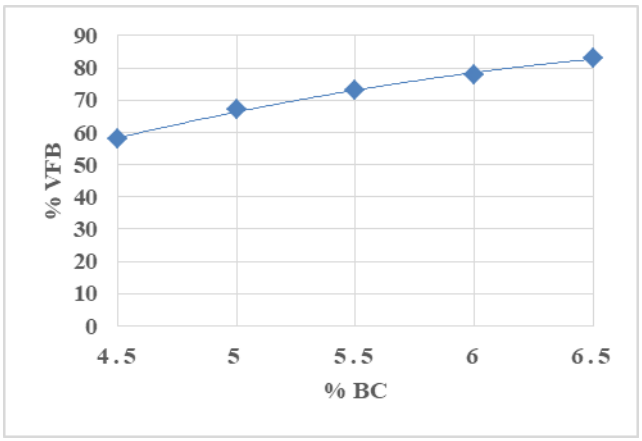
1(c) Relationship between voids in total mix and bitumen content



1(d) Relationship between flow and bitumen content

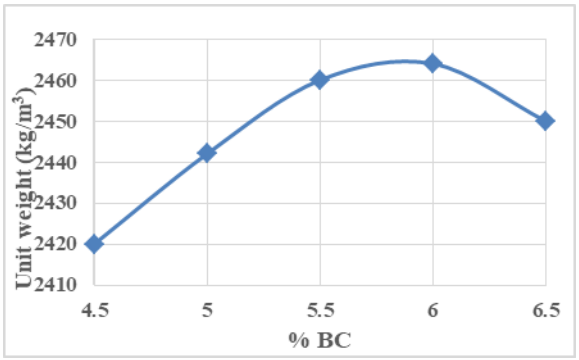


1(e) Relationship between void in mineral aggregate and bitumen content

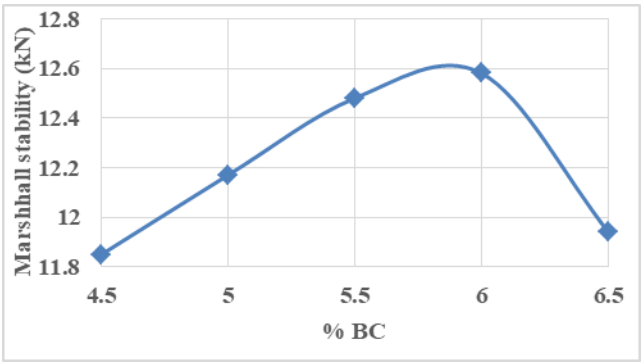


1(f) Relationship between voids filled with bitumen and bitumen content

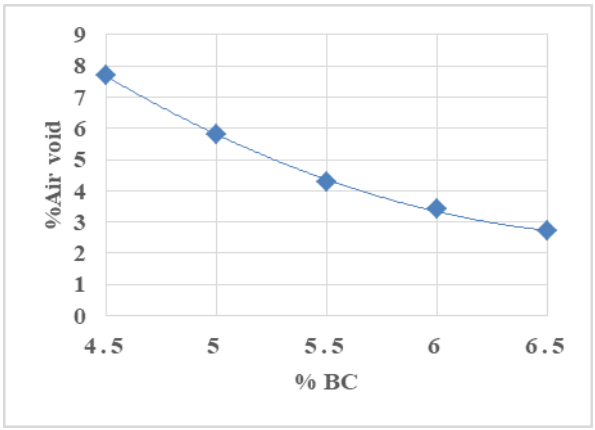
Figure 1. Marshall Test Property Curve for Bituminous Mix with 50 Blows for Pure Bitumen



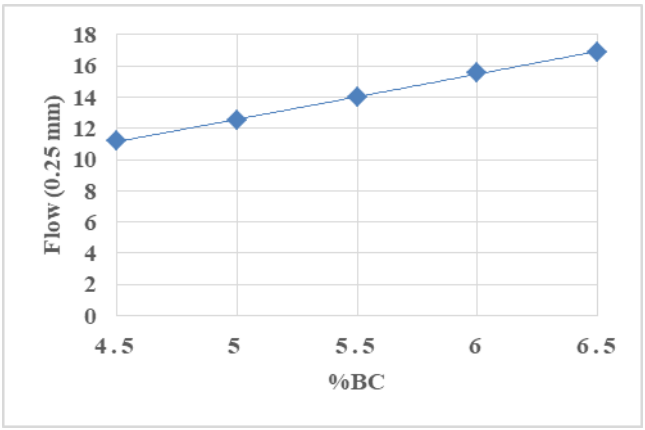
2(a) Relationship between unit weight and bitumen content



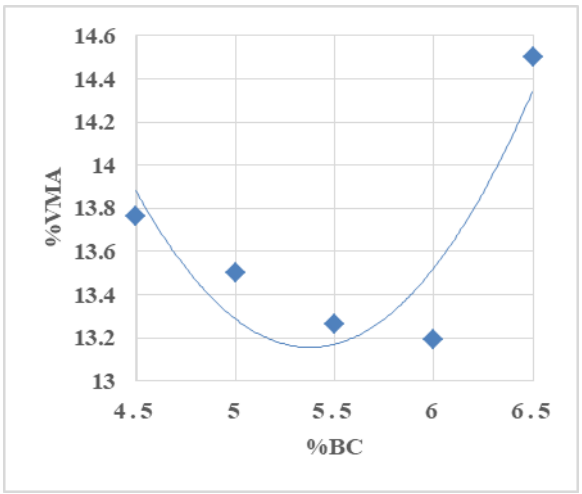
2(b) Relationship between Marshall stability and bitumen content



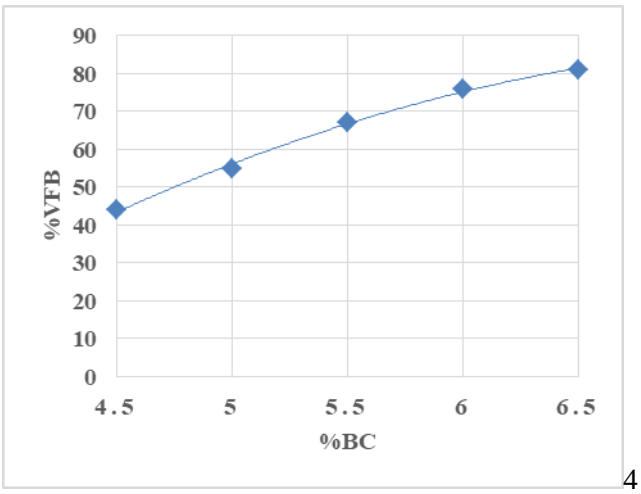
2(c) Relationship between voids in total mix and bitumen content



2(d) Relationship between flow and bitumen content



2(e) Relationship between void in mineral aggregate and bitumen content



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2(f) Relationship between voids filled with bitumen and bitumen content

Figure 2. Marshall Test Property Curve for Bituminous Mix with 50 Blows for Modified Bitumen.

Analyzing Figure 1, Optimum Bitumen content for pure bituminous mix = (%BC for Max unit weight + % BC for Max Stability+%BC for 4% air void)/3

= (5.65.5+5.92+5.4)/3 =5.5

Analyzing Figure 2, optimum Bitumen content for modified bituminous mix = (%BC for Max unit weight + % BC for Max Stability+%BC for 4% air void)/3

= (5.9+5.92+5.65)/3 = 5.82

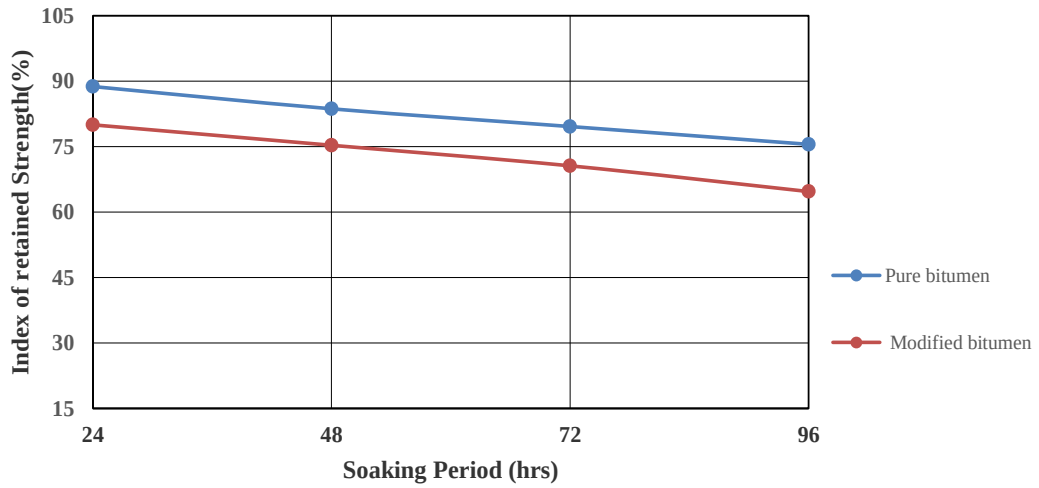

Figure 3. Variation of Retained Strength with Respect to Maximum Value for Different Soaking Periods for Pure and Modified Bituminous Samples

The values of retained strength up to 96 hours are found to be higher than the limiting value of 75% for pure bitumen in Figure 3. According to ASTM D1075, pure bitumen has an index of retained strength that is greater than 75% up to 96 hours. The values of retained strength for modified bitumen are above the limiting value of 75% up to 48 hours and then fall below the limiting value after 48 hours. This is because the cohesive link between the bitumen and aggregate system is becoming weaker due to the increased absorption of water. Experiments have shown that prolonged soaking times reduce the strength of bituminous blends.

3 Conclusions

In conclusion, water has a major impact on the retained strength of bituminous mixtures with modified binders. Up to 96 hours, pure bitumen constantly exceeds the 75% criterion, whereas modified bitumen initially exceeds it but gradually drops. Water absorption has degraded cohesiveness, causing the drop. Water impacts must be considered in mix design and maintenance. Water-resistant binders and suitable drainage systems are critical for limiting water's negative impact. Additional elements and approaches to improve mix durability should be investigated in future research. Bituminous pavements can be constructed to tolerate water exposure by considering its influence and implementing appropriate procedures. This improves their longevity and performance.

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