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# THE EFFECT OF USING JUTE FIBER ON DEFORMATION RESISTANCE OF ASPHALT CONCRETE

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***Abstract-*** Pavement distresses are a major problem not only in Pakistan but throughout the world which leads to premature pavement failures. As the pavement construction is expected to increase with passing time, studies and research have been done for the improvement of asphalt pavements performances from both sustainability and functional perspectives. Reinforcing the bituminous mixture with fibers could provide an improvement in Asphalt Concrete (AC). Asphalt concrete modified with fibers is termed as Fiber Reinforced Asphalt Concrete (FRAC). In this study jute fiber is used as a reinforcing material to investigate the FRAC materials specifically its effect on deformation resistance. The effects of jute fiber modification on mixing procedure and performance of modified AC were observed later by several laboratory tests. Results showed that the optimum binder content increases 4-5% and the stability of jute fiber modified asphalt concrete increases up to 29% however, the flow value decreases up to 7% at 0.5% jute-fiber concentration. Addition of jute fiber significantly improved the deformation resistance of asphalt concrete. Whereas from the sustainability perspective, it leads to concept of the new market to utilize waste fibers thereby lessening the environmental consequences.

***Keywords-*** Asphalt Concrete, Fiber-reinforced asphalt concrete (FRAC), Jute Fiber.

## 1 Introduction

Transportation system of any nation is of great significance for its advancement and economy [1, 2]. An economy appears to be on track if an efficient infrastructure exists. It is too difficult to put the economy on the high quick way without an efficient transport framework. The huge increment in traffic volume in recent couple of decades has causes premature pavement failures of the entire road structure in Pakistan. A resultant penetration of water is caused by temperature cracking, fatigue or alligator cracking and rutting distresses leading to partial or complete pavement-failure, making it necessary to improve the properties of pavement. In hot weather extremes problem is aggravated due to bitumen's lower stiffness [3]. In this situation it is an ideal opportunity to explore this issue and propose suitable solution and methodology.

These limitations call for research and innovation in materials and techniques and innovations in pavement engineering to advance the pavements in terms of durability and resistance to distresses and thereby requiring lesser maintenance [4]. The research to achieve these goals has culminated into development of the techniques that are collectively known as 'modification of asphalt' [5]. They employ various types of fibers and polymers that are applied to the asphalt. Fiber application is very advantageous for increased durability as it improves fatigue and rutting resistance, increases service life, and reduces thermal cracking [4]. Fiber-reinforced asphalt concrete materials (FRAC) are utilized for overlays and maintenance of pavements and bridge-deck membranes in traditional mixes. They're also employed in multi-course flexible pavements and composite pavements. Performed studies show that fiber increases dynamic modulus [6], rutting resistance [7], freeze-thaw resistance, the tensile strength at low temperature and the fatigue cracking resistance [8]. Jute fiber is compatible with hot mix asphalts (HMA) and jute fiber modified asphalt mixtures have appropriate mechanical properties (modulus, rut resistance and tensile strength) [9]. Jute fiber absorbs light components of bitumen increasing bitumen viscosity resulting in higher fracture resistance in tension mode for HMA mixtures [10]. From different tests like Marshall test and Drain down test, it is concluded that stone mix asphalt with using jute fiber gives very good result and can be used in flexible pavement [11]. The increase in length of jute fiber causes reduction in flow values [12]. This study uses different percentages of jute fiber incorporating fiber size of 20 mm to explore the impact on dry mixing process. Marshal Stability test was performed for flow and stability values to investigate jute fiber's impact on Optimum Binder Content (OBC) and to find resistances against distresses in asphalt concrete.

### *1.1 Jute Fiber.*

Jute is a long, lustrous, soft vegetable fiber that may be spun into strong, coarse threads. Jute is one of the most cost-effective natural fibers, second only to cotton in terms of production and number of applications. Jute fiber is composed of lignin (12-14%), pentosan (14-16%), cellulose (50-64%), and other materials like moisture, ash, proteins and fats [13]. Jute is the most affordable natural fabric, and it is completely biodegradable and recyclable, making it environmentally friendly [14].

Asphalt modification with addition of jute fiber gives higher which restricts road cracking and the crack propagation along with having the additional benefit of jute encased with asphalt, offering higher resistance to biodegradation [15]. Additionally, benefits like drain down prevention and improved fatigue performance by enhancing crack resistance of asphalt material are also achieved. For asphalt overlay applications, the abundantly available and low-cost jute materials make it a stronger competitor than the high-cost synthetic materials derived from scarce resources.

## 2 Research Methodology

Initially, aggregate to be used for the project was selected and brought from Margalla stone quarry. Then the bitumen grade of 60/70 was selected. Based on material properties, a fine gradation of NHA class B was preferred over the NHA class A gradation. The dosages of 0.5% and 1.0% were selected by weight to determine Optimum Binder Content through Marshal Mix Design. In the end, a comparison was drawn for different results obtained from unmodified, 0.5% jute modified and 1% jute modified asphalt concrete. A conclusion was drawn through experimental results.

The primary goal of this study was to determine the impact of fiber addition in the dry technique on the performance of hot mix asphalt. This research is a part of the research study that used various types of fibers with an explicit focus on their effects on the permanent deformation behavior and was done only to facilitate the future researches with the fact that despite any significant effect of the permanent deformation behavior, there are other horizons that can and should be explored as far as the Jute Fiber Modification of Asphalt Concrete is concerned.

## 3 Experimental Details

Various type of tests performed on the aggregate, bitumen and asphalt concrete mixtures have been discussed. For this study, Class B aggregate of NHA Specification was used because it is easy to make a comparison of the test results in case of fine classifications. The physical properties of the aggregate and the bitumen used in this study are listed in Table 1. In dry method, fibers are added to the pre-heated aggregate in accordance with ASTM-D1559 standard. After this, bitumen is added to the aggregate & fiber mixture gradually and Marshall Mix design test is performed on unmodified and polypropylene modified asphalt concrete samples to select suitable type of aggregate and corresponding economical asphalt binder content. This recommended mixture is known as job-mix formula (JMF).

### *3.1 Sample Preparation*

Minimum requirement of NHA is of 3.5 percent of asphalt content by weight of the total mixture for Class A and Class B. Normally, bitumen in 3 to 6 percent by total weight of mixture is added for the OBC determination. Mixture for jute fiber-modified and unmodified mixtures was prepared for 3.5, 4.0, 4.5, 5.0, and 5.5% asphalt. Three samples, two compacted and one loose one with a total weight of each sample 1200g are prepared. 0.5% (6g) and 1.0% (12g) fiber by weight of the total sample were added. Compacted samples were prepared at first by the dry method and after being placed in testing mould, 75 blows on each side were subjected using hammer of 4.5 kg. Resultant sample was cylinder with 4-inches inner diameter and 2.5 inches height. Mixture was then prepared for the loose sample with no compaction effort (Blows). Calculation of values different parameters was the performed using the formulae listed in Table 2.

***Table 1 - Physical properties of the aggregates and bitumen***

| **Aggregates** | | | **Bitumen** | | |
|---|---|---|---|---|---|
| Source | | Margalla | Source | ARL 60/70 | |
| Type | | 100 % crushed | Penetration Test (25ºC) | 64 | ASTM D5 |
| Los-Angeles Abrasion Value | | 23.18 % | Flash point | 264ºC | ASTM D92 |
| Soundness | Coarse aggregate | 3.20 % | Softening point | 48ºC | ASTM D36 |
| | Fine aggregate | 4.80 % | Ductility (5cm / min) | > 100 cm | ASTM D113 |
| Elongation Index | | 2.30 % | Specific gravity | 1.034 | ASTM D70 |
| Flakiness Index | | 6.10 % | | | |
| Sand Equivalent | | 76 % | | | |

***Table 2 – Different parameters for Marshal Stability Test***

| | | | |
|---|---|---|---|
| Bulk specific gravity of aggregates, $\boldsymbol{G_{sb}}$ | $G_{sb} = \frac{P_1 + P_2 + \cdots\cdots + P_N}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots\cdots + \frac{P_N}{G_N}}$ | Voids in Mineral Aggregates, VMA | $VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$ |
| Effective specific gravity of aggregate, $\boldsymbol{G_{se}}$ | $G_{se} = \frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}}$ | Air voids, $\boldsymbol{V_a}$ | $V_a = 100 \times \frac{G_{mm} - G_{mb}}{G_{mm}}$ |
| Effective Asphalt Content, $\boldsymbol{P_{be}}$ | $P_{be} = P_b - \frac{P_{ba}}{100} \times P_s$ | Voids filled with asphalt, VFA | $VFA = 100 \times \frac{VMA - V_a}{VMA}$ |

### *3.2 Determination of Stability using Marshall Stability and Flow Test.*

Stability maybe defined as the maximum load resistance of the sample and flow is defined as the deformation corresponding to maximum load (Stability) at standard temperature of 60ºC. For determining stability, compacted Marshall samples are kept in the water bath at 60ºC ±1ºC temperature for 30 to 40 minutes and then tested in Marshall Stability tester. Loading is applied on the specimen at the constant rate of 51 millimeters per minute, until sample fails. Total number of Newton (lbs.) or kgs force at which sample fails is recorded as Marshall Stability value. Deformation corresponding to this force is recorded as flow and expressed in units' of 1/100 inches.

a)  b)  c) 

*Figure 1: a. Jute fibers before addition. b. Jute-fiber modified sample being prepared. c. Compacted and loose samples ready for Marshall stability test*

### *3.3 Calculation of Optimum Binder Content*

After calculations six graphs are plotted between asphalt content on x-axis and unit weight, VMA, VFA, $V_a$, flow, and stability on y-axis. Of the various methods used worldwide to find out Optimum Binder Content are used worldwide; one is to use following three graphs against mentioned criteria for the calculation of optimum asphalt content (a) Bitumen content against maximum stability (b) Bitumen content against maximum unit-weight (c) Bitumen content against 4% air voids. Average of all three asphalt contents obtained from above three graphs is reported as optimum asphalt content (OAC) or optimum bitumen content (OBC).

# 4 Results

The results of various tests performed on the asphalt concrete mixtures and their analysis, have been discussed. Results of three kind of asphalt concrete mixtures were tabulated. Graphs between unit weight, VMA, VFA, $V_a$, stability and flow against asphalt content have been plotted. For modified mixture, results showed in Table 3 reveal that the optimum binder content's value increases by adding jute fiber.

***Table 3 - Optimum binder content of unmodified and Jute modified mixtures***

| Criteria | Unmodified | | Jute Modified | | | |
|---|---|---|---|---|---|---|
| | | | Fiber percent | | OBC | |
| | | OBC | 0.5 | 1.0 | 0.5 | 1.0 |
| Bitumen content against maximum stability | 4.5 | 4.57 | 4.2 | 4.45 | 4.73 | 4.78 |
| Bitumen content against maximum unit-weight | 4.7 | | 5.5 | 5.5 | | |
| Bitumen content against 4% air voids | 4.5 | | 4.5 | 4.4 | | |

Figure 2 to Figure 4 show graphical plot between asphalt content and various parameters of Marshall test for unmodified and jute fiber modified asphalt mixtures. Stability of the jute fibers samples is more when compared to the unmodified samples with 0.5% Jute-fiber modification being more stable than 1.0% Jute-fiber modified asphalt mixture, meaning that low jute fiber content can achieve greater stability as compared to higher one. Flow values of jute modified samples are less than those of unmodified samples at 0.5% and slightly increases at higher fiber concentration which means modified samples are more stable against the traffic loads.

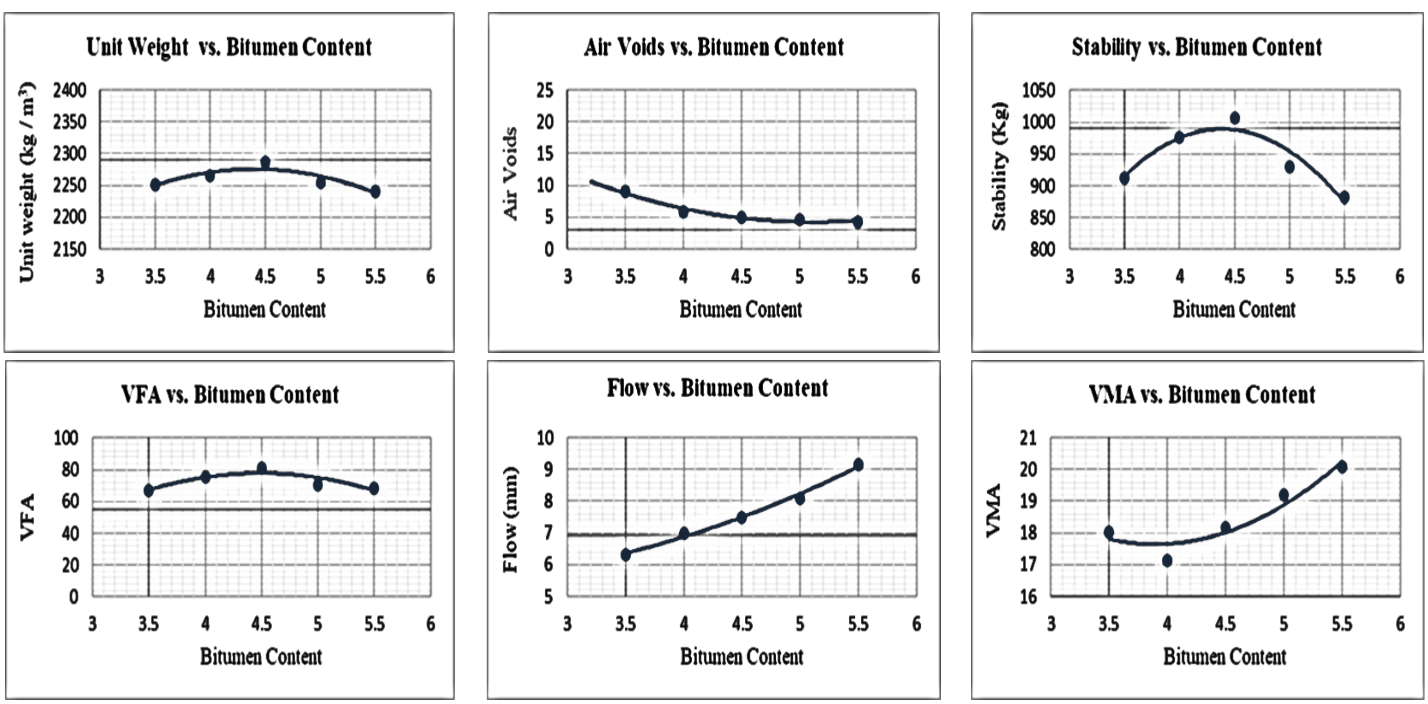



*Figure 2: Graphs for unmodified specimen*

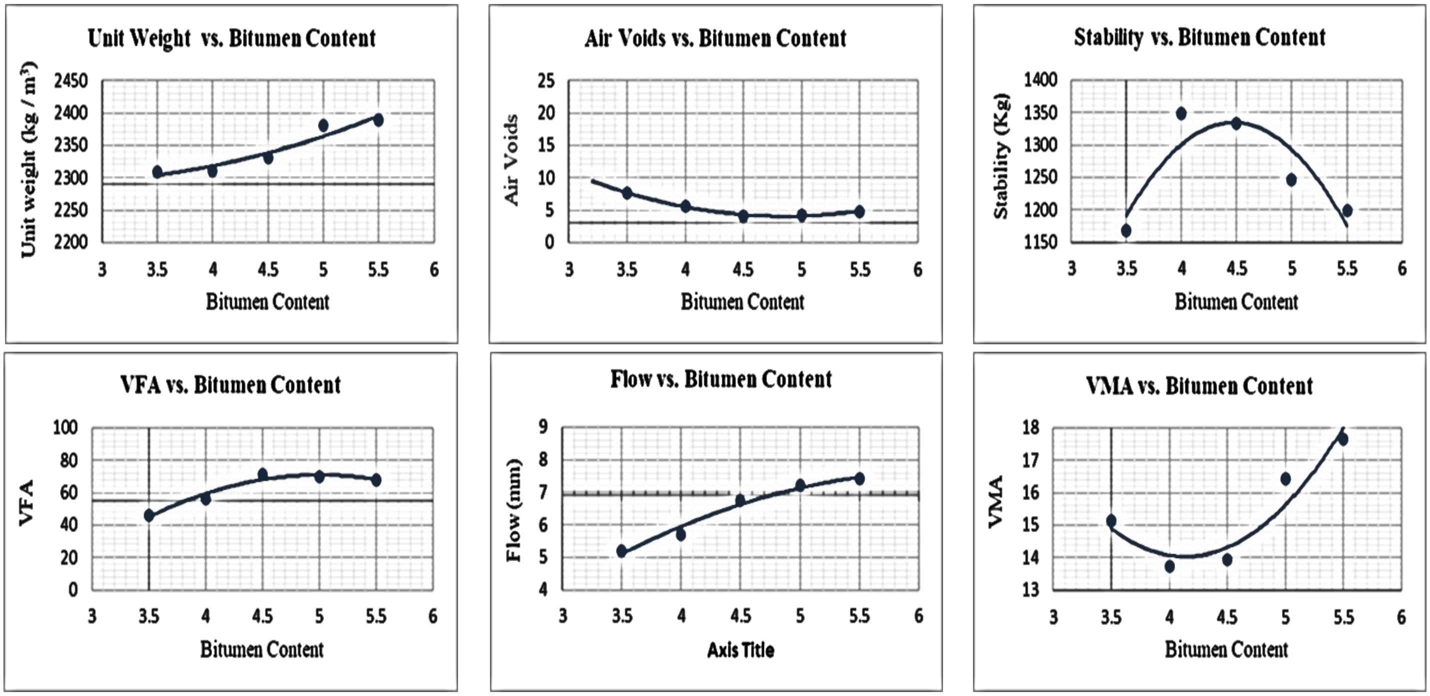



*Figure 3: Graphs for 0.5% jute modified mixture*

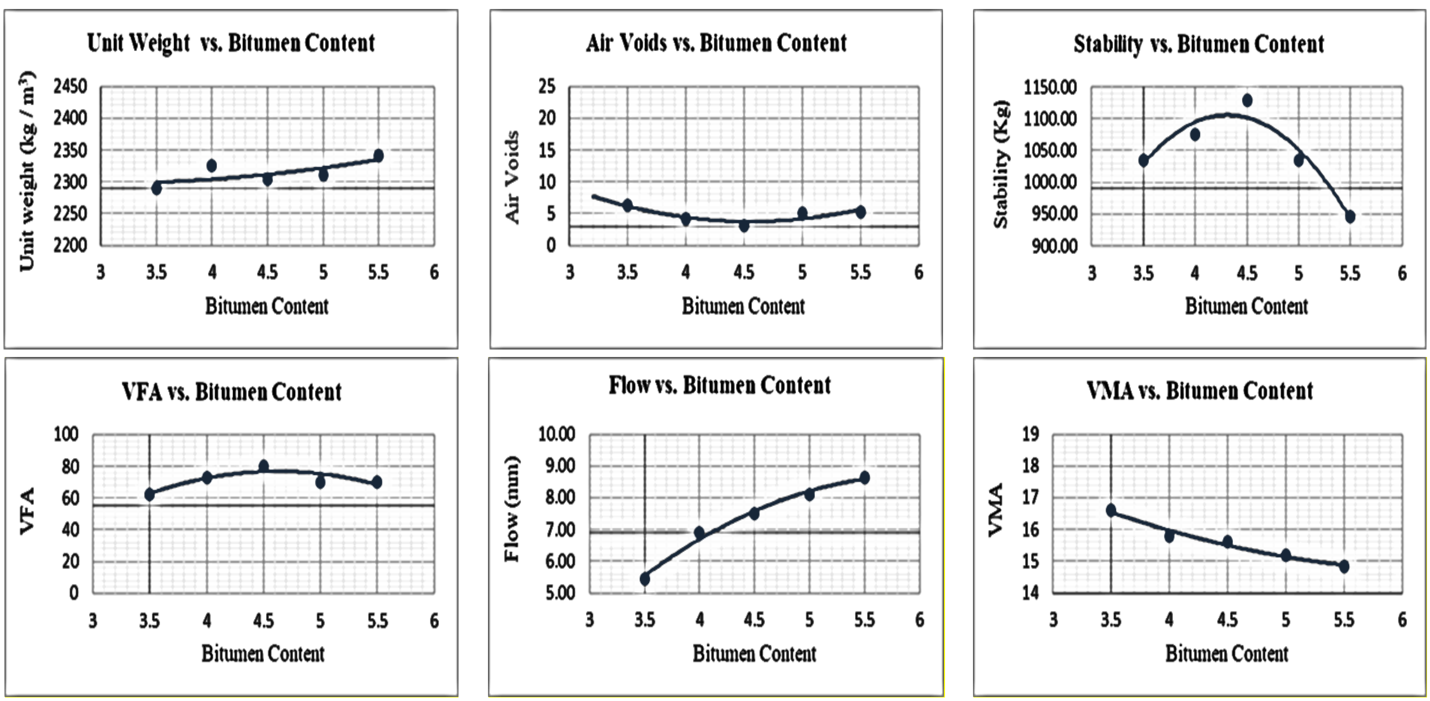
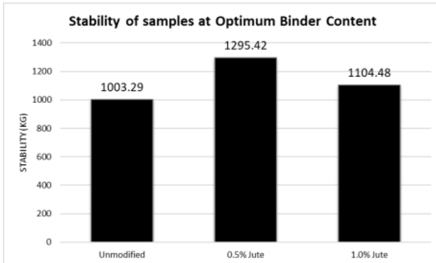



*Figure 4: Graphs for 1.0% jute modified mixture*

Figure 5a reveals the stability of 0.5% jute fiber modified sample is highest among all other samples at OBC while Figure 5b shows minimum flow at optimum asphalt content in case of 0.5% jute modified samples as compared to other samples. Also, mix-design criteria at optimum binder content is also verified for unmodified and jute modified samples.



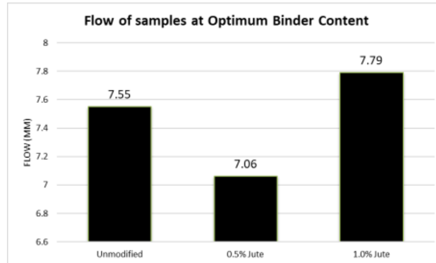




*Figure 5: a. Stability of the control & modified samples at OBC. b. Flow of the control & modified samples at OBC*

# 5 Conclusion

In this study, jute fibers were used as modification in asphalt concrete. The primary goal of this study was to determine the impact of fiber addition in the dry technique on the performance of hot mix asphalt. For the experiment, jute fiber was added to the asphalt mixture at 0.5 percent and 1.0 percent by weight. Based on the findings, it can be inferred that modifying jute fibers improved the HMA's various qualities. Jute addition, for example, increased the stability of asphalt mixtures by up to 29% and 10% at 0.5 percent and 1.0 percent Jute-fiber content, respectively, and increased the Optimum Binder Content by up to 4-5 percent. In comparison to the unmodified asphalt mixture, VFA, overall unit weight, air voids, and flow all decreased with the inclusion of jute fiber. At 0.5 percent jute fiber, the modified mixture performed best.

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