بِسْمِ ٱللَّٰهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

# IDENTIFICATION OF FACTORS AFFECTING BITUMEN DRAINDOWN AND EFFECTS OF FIBER ADDITIVES


Tamim Fiyead Enan

Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)


2023

# PROJECT APPROVAL

This certifies that Tamim Fiyead Enan's thesis, **"Identifying of Factors Affecting Bitumen Drain Down and Effects of Fiber Additives,"** has been accepted as partial fulfillment of the requirement for the Degree Bachelor of Science in Civil and Environmental Engineering at the Islamic University of Technology (IUT).

Supervisor

______________________

**Dr. Nazmus Sakib**
Assistant Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT) Board Bazar,
Gazipur-1704, Bangladesh

# DECLARATION

I hereby attest that I worked under the skillful direction of Dr. Nazmus Sakib to complete the undergraduate research work described in this thesis. The work is original, and appropriate measures have been made to ensure that. This work hasn't been copied from another source and submitted there for any other reason (apart from publication).

Student
ID:180051145
Date:

# DEDICATION

I dedicate this thesis to my parents, who over the years gave up significant time, a source of income, and effort so that I could become the person I am today. They have inspired and pushed me to pursue my engineering goals without stopping. They have my lifelong gratitude.

Also deserving of my gratitude is my boss, Dr. Nazmus Sakib, without whose unwavering encouragement and motivation none of this effort would have been possible.

# ACKNOWLEDGEMENTS

"In the name of Allah, the Most Gracious, the Most Merciful."

All glory be to Allah (SWT) for providing me with the means and fortitude to successfully complete my thesis work, which includes this book. I want to sincerely thank my parents for their unwavering support and encouragement over the years.

I would like to thank our supervisor, Dr. Nazmus Sakib, an assistant professor in the Islamic University of Technology's Department of Civil and Environmental Engineering, for his wise counsel and ongoing encouragement. His technical and editing assistance was required to finish this scholarly research. Without his direction, I couldn't have finished my paper.

I also want to express my gratitude to everyone who has helped with this project, whether directly or indirectly.

# Abstract

The performance and durability of asphalt pavements may suffer as a result of bitumen drain down, which is the separation of bitumen from an asphalt mixture. Numerous studies and investigations have been conducted on the elements that influence drain down and the efficiency of fiber additives in reducing this problem. The investigations covered in this abstract were aimed at determining the causes of bitumen drain down and the results of adding fiber additions to asphalt mixtures. To assess the results and comprehend the underlying mechanisms, an extensive literature review was done. Pavement structures face a severe issue with bitumen drain-down. In order to reduce the bitumen drain down, certain steps must be performed because it weakens the structure. There have been numerous materials utilized, including fiber, mineral fillers, and polymers. We employ conventional fibers of several types in our research. The goal of this study is to compare the bitumen drain-down values in each fiber reinforcement with the initial sample which is no fiber reinforcement.

**KEYWORDS**: Drain-down test, Stone Matrix Asphalt, Drain down baske

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# Chapter 1 Introduction

The term "bitumen drain down" describes a phenomenon in asphalt pavements when, under specific circumstances, the bitumen binder separates or "drains" away from the aggregate particles. The sticky binder known as bitumen holds the aggregate particles of asphalt mixtures together, giving the pavement cohesiveness and strength. Bitumen drain down can result in the asphalt mixture being more porous, which lowers the pavement's performance and longevity. When this happens, the asphalt surface may become uneven, the binder may rise to the surface, or the bond between the binder and aggregate may be weakened. These issues include rutting, bleeding, and stripping. The pavement's structural integrity can be retained by limiting the drain down, maintaining its longevity and performance. Excess bitumen may build up on the pavement surface because of draining down, making the surface slick and sticky. This could jeopardize the security of anyone using the roads, particularly in the event of bad weather.. Furthermore, impairing the road's appearance, these areas could draw dirt and debris. Drain down problems can be resolved, improving the pavement's overall quality and aesthetic appeal. Significant financial inputs are required for both pavement development and upkeep. The pavement may prematurely deteriorate because of drain-down-related problems, requiring more frequent maintenance or perhaps full rehabilitation. The longevity of the pavement can be increased by minimizing drain down issues, which also results in long-term cost savings by eliminating the necessity for pricey repairs. Environmental issues may arise if excess bitumen builds up in stormwater systems or nearby areas because of bitumen draindown. Aquatic ecosystems may suffer when bitumen is washed into water bodies. Drain down can be kept to a minimum, reducing the possibility of environmental pollution and promoting environmentally sound infrastructure practices. Stone matrix asphalt has a high percentage of coarse particles and is a gap-graded mixture.There is better stone to stone contact and better interlocking due to the high percentage of coarse pebbles.

# Chapter 2 Literature Review

The use of human hair for bitumen draindown mitigation is a novel and creative strategy that has been investigated in several situations. Bitumen, a popular binder used in road construction, can undergo a process known as "draindown," when the bitumen separates from the aggregates and sinks towards the bottom of the mixture because of its high viscosity. It has been suggested that using human hair, which is naturally fibrous, could help with bitumen mix draindown. The theory is that the hair fibers can assist in binding the bitumen and preventing it from separating, enhancing the overall functionality and toughness of the road.The research focused on evaluating the physical and rheological properties of the modified bitumen, including draindown. The study found that incorporating human hair waste into bitumen significantly reduced draindown, improving the stability and consistency of the binder [16]. Another study focused on mechanical properties, including rutting resistance and fatigue life, as well as draindown characteristics. The results indicated that the addition of human hair fibers led to a reduction in draindown, suggesting their potential for improving bitumen stability [17]. in 2013. The study aimed to evaluate the impact of hair fibers on various asphalt properties, including draindown. It was found that the addition of human hair fibers reduced the draindown, indicating the potential effectiveness of this unconventional modifier [18]. Regarding bitumen draindown in asphalt mixtures, glass fiber has been proven to be efficient. In order to improve the mechanical qualities of asphalt mixtures and their resistance to various types of distress, including draindown, glass fiber can be added as a reinforcing element.

The cohesiveness and stability of asphalt mixtures are enhanced when glass fibers are added. Both draindown and the separation of bitumen from the aggregates can be efficiently avoided by using this reinforcement. In the asphalt, the glass fibers serve as a reinforcing matrix, assisting in a more equal distribution of stresses and forces. The research found that incorporating glass fiber into bitumen led to a substantial reduction in draindown, indicating improved binder stability [19]. The research found that incorporating glass fiber improved the cohesion of bitumen, resulting in reduced draindown and enhanced resistance to moisture damage [20]. The possibility of using jute fiber, a naturally occurring plant-based fiber, to solve bitumen draindown in asphalt mixtures has also been investigated. Jute fiber can be used to asphalt mixtures, much like other fiber kinds, such glass fiber, to improve their mechanical qualities and resilience to various types of distress, like draindown. High tensile strength, flexibility, and the capacity to strengthen materials like asphalt are all qualities of jute fibers. Jute fibers can help increase the cohesiveness and stability of asphalt mixtures, which lowers the likelihood of bitumen separation and draindown. The findings indicated that the incorporation of jute fiber significantly reduced draindown, suggesting enhanced binder-aggregate adhesion and improved mixture stability[21]. For addressing bitumen draindown in asphalt mixtures, coconut fiber, another natural fiber solution, has also been taken into consideration. Coconut husk is the source of coconut fiber, which is prized for its great tensile strength, inherent resilience, and capacity to strengthen a variety of materials.Coconut fibers may assist increase the cohesiveness and stability of asphalt mixtures, which could help lessen the likelihood of bitumen separation and draindown. Similar to other fiber types like jute or glass fiber, coconut fiber can assist in more uniformly dispersing stresses and forces throughout the combination, improving overall performance. In some circumstances, steel fibers have been used to asphalt mixtures as a reinforcement element to help with problems like bitumen draindown. Steel fibers, which are frequently brief, discontinuous, and haphazardly scattered throughout the asphalt matrix, can aid the asphalt mix's mechanical qualities and performance.

Steel fibers can improve the resistance of asphalt mixtures to many types of distress, such as rutting and cracking, which are connected to the problems of bitumen draindown. Steel fibers can aid in more evenly distributing stresses and forces throughout the mixture, enhancing its overall stability and toughness. The addition of steel fiber significantly reduced draindown in asphalt mixtures, indicating improved binder cohesion and reduced potential for bitumen separation [22]

According to Radzi et al., adding 0.3% of steel fiber to the SMA mixture is the ideal amount to employ as a modifier. Thus, it can be said that the performance and efficiency of the SMA mixture as a whole are greatly improved by the inclusion of steel fiber.

K.B. Raghuram and Venkaiah Chowdary (2013) conducted research on a variety of fibers, including glass, jute, and coir fibers. In this study, 10mm long fibers were employed. It states that cellulose fibers must be added at a minimum rate of 0.3%. The results of stability and flow value tests indicated that the compressive strength had increased and the drain-down characteristics had decreased.

# Chapter 3 Objectives

The main purpose of this study is to perform the draindown test. Then compare the drainage value of initial sample where no fiber reinforcement is added with fiber reinforcement fiber sample.

# Chapter 4 Methodology

The steps in our investigation are numerous. First, acceptable aggregates were selected through the use of sieve analysis. In order to get a percentage from different aggregate sizes, we secondly prepare SMA Mix. Different fibers are being incorporated into the mix at different percentages. The draindown test takes place third. Fourth, we use the drain down test to get drainage values for both the initial sample and the sample with fiber reinforcement. Finally, contrast each drainage of the fiber reinforcement sample with the baseline sample without the reinforcement.

## 4.1 Gradation

This gradation is used for BRT project. It starts from 37.5 mm sieve size to 0.075 mm sieve size. We take the percentage of aggregates from sieve size 10-20 mm and 5-10 mm. We choose coarse aggregates because of drain down basket. If we take finer aggregates, We did not get the proper drainage value from our sample. In our sample we take 76% sample from 10-20 mm size and 24% sample from 5-10 mm size.

**TABLE 1 Stone Matrix Asphalt Gradation Specification Bands (Percent Passing by Volume).**

| Sieve size, mm | 25 mm NMAS[1] | | 19 mm NMAS | | 12.5 mm NMAS | | 9.5 mm NMAS | | 4.75 mm NMAS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper |
| 37.5 | 100 | 100 | | | | | | | | |
| 25.0 | 90 | 100 | 100 | 100 | | | | | | |
| 19.0 | 30 | 86 | 90 | 100 | 100 | 100 | | | | |
| 12.5 | 26 | 63 | 50 | 74 | 90 | 100 | 100 | 100 | | |
| 9.5 | 24 | 52 | 25 | 60 | 26 | 78 | 90 | 100 | 100 | 100 |
| 4.75 | 20 | 28 | 20 | 28 | 20 | 28 | 26 | 60 | 90 | 100 |
| 2.36 | 16 | 24 | 16 | 24 | 16 | 24 | 20 | 28 | 28 | 65 |
| 1.18 | 13 | 21 | 13 | 21 | 13 | 21 | 13 | 21 | 22 | 36 |
| 0.6 | 12 | 18 | 12 | 18 | 12 | 18 | 12 | 18 | 18 | 28 |
| 0.3 | 12 | 15 | 12 | 15 | 12 | 15 | 12 | 15 | 15 | 22 |
| 0.075 | 8 | 10 | 8 | 10 | 8 | 10 | 8 | 10 | 12 | 15 |

[1] NMAS - Nominal Maximum Aggregate Size - one size larger than the first sieve that retains more than 10 percent.

Table 1: Stone Matrix Asphalt Gradation Specification

## 4.2 Fiber characteristics

Jute, coconut, glass, steel and human hair which are the traditionally available fibers have been used in our study. In our examination of the literature, we discovered that jute is used at various ideal percentages, such as 0.1% to 0.3% in size ranges of 5- 20 mm, 20-40 mm, and 40-60 mm. Coconut is used in various percentages, ranging from 0.5% to 1.25% in sizes between 5 and12.5 mm. Glass percentages in sizes between 6 and 12 mm range from 0.5% to 2.5%. The range in steel fiber is between 0.1% and 0.2% with a 13 mm length. The range of human hair is between 3% and 12%. In my analysis, I decided on the percentages of jute fiber (0.3%), coconut fiber (0.75%), glass fiber (0.25%), steel fiber (0.15%), and human hair (3%) that reduced drain down the best.

(a)

(b)

(c)

(d)

(e)

Figure 1: Various fiber reinforcement a) Coconut b) Glass c) Steel d) Human hair e) Jute

## 4.3 Sample Preparation

Total sample = 1200 gm.  4.9% bitumen is typically used. However, I utilize 7% in order to assess the state of more bitumen.

| Sample | Size (percentage) | | Bitumen content | Fiber content | Fiber weight (gm) |
|---|---|---|---|---|---|
| | 10-20 mm (76%) | 5-10 mm (24%) | 7% | | |
| | Weight Sample (gm) | | | | |
| Initial | 848.16 | 267.84 | None | None | None |
| Jute | 845.42 | 266.976 | 84 | 0.30% | 3.6 |
| Coconut | 841.32 | 265.68 | 84 | 0.75% | 9 |
| Glass | 845.88 | 267.12 | 84 | 0.25% | 3 |
| Steel | 846.79 | 267.408 | 84 | 0.15% | 1.8 |
| Human hair | 820.8 | 259.2 | 84 | 3% | 36 |

Table 2: Sample Preparation

## 4.4 Drain down test

The test is under the code of AASHTO T 305. When the sample is kept at high temperatures like those encountered during the production, storage, transport, and placement of the mixture, a test protocol can be used to assess how much drain down is present in an uncompacted asphalt mixture. Particularly suitable combinations for the test include open-graded courses and Stone Matrix Asphalt. Oven with forced ventilation that can maintain temperature within 3.6°F ( 2°C) of a range of 250-350°F (120-175°C) Plates or containers that can endure the test's required oven temperatures and are the right size for the basket.

Figure 2: Bitumen Drain down basket

Standard basket with a bottom 25 + 2.5 mm from the bottom of the wire basket assembly, measuring 165 16.5 mm deep by 108 10.8 mm wide. According to AASHTO M 92, the basket must be made with standard 0.25inch (6.3 mm) sieve cloth. In compliance with AASHTO M 231, balance, general-purpose G2.

A wire basket with a sample of asphalt mixture is put on a plate or other suitable object with a known weight. The sample, basket, plate, or container is heated to the production temperature for a predetermined amount of time. After the heating cycle is complete, the plate or container and the basket carrying the sample are taken out of the oven, and the weight of the plate or container is calculated. Sample preparation in accordance with AASHTO T 248.

# Chapter 5 Analysis

Drainage calculation = A-B/C x 100

Where, a= Final weight of plate or container, g

b=Initial weight of plate or container, g

c= Initial total sample weight, g

| Sample | Fiber content (%) | Initial weight of plate (gm) | Final weight of plate (gm) | Initial sample weight | Drainage (%) |
|---|---|---|---|---|---|
| Initial | None | 356.5 | 372.4 | 1200 | 1.30 |
| Jute | 0.30 | 356.5 | 371.5 | 1200 | 1.25 |
| Coconut | 0.75 | 356.5 | 368.6 | 1200 | 1.01 |
| Glass | 0.25 | 356.5 | 362.2 | 1200 | 0.48 |
| Steel | 0.15 | 356.5 | 370.42 | 1200 | 1.16 |
| Human hair | 3 | 356.5 | 358.3 | 1200 | 0.15 |

Table 3: Drainage calculation

We obtain the drainage value by using experimental data to the aforementioned formula. When we compare the drainage result to the initial sample, it is 1.3%. The drainage value then differs when fiber additions are used, such as when jute is used, when it is reduced by 0.05% to 1.25%. Then, in regards to coconut, it displays 1.01%, significantly lessening drainage. Jute, which has a steel fiber value of 1.18%, comes in second. A major contribution to drain reduction is made by glass and human hair. The figures, which are respectively 0.48% and 0.15%, are lower. The drainage changes within use of fiber reinforcement showing in a graph.

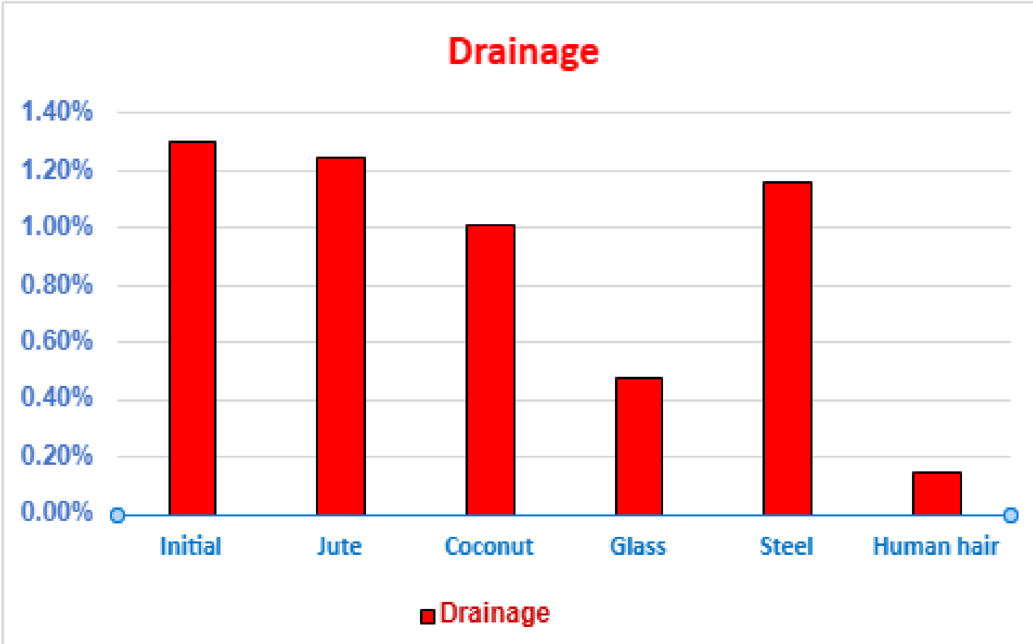


Figure 3: Fiber reinforcement Vs Drainage

Here are some pictures of the plate with the drained sample on it.

1

2

3

4

5

6

Figure 4: Bitumen drained sample after drain down test 1.Initial 2.Coconut 3.Glass 4.Jute 5.Human hair 6. steel

# Chapter 6 Results

We discovered through the experimental study that human hair is the most effective at decreasing bitumen runoff. The steel comes in second place and does a good job of reducing drainage. We get less draindown when use various fibers. Glass fiber effectively reduces drainage. Jute and coconut are less affected by the decline. We found that there is a limited amount of human hair utilized in bitumen drain down. Steel has emerged as one of the potential reinforcements for draining down. Glass fiber is frequently employed to minimize draindown. Jute and coconut fiber are receiving some attention for their potential to stop bitumen draindown.

For efficiently decreasing bitumen drain down, the choice of fiber type and content is essential. Numerous fiber kinds, including polyester, polypropylene, cellulose, and aramid, have been researched; however, additional comparative studies are required to determine which fiber type is best appropriate for the various pavement uses and climatic conditions. Further research is necessary to determine the ideal fiber content to accomplish the desired reduction in drain down without adversely affecting other pavement qualities. Long-term performance assessments are required, even though short-term laboratory and field studies have produced encouraging results in lowering drain down with fiber additions. Determine the long-term advantages and potential disadvantages of fiber integration by evaluating the robustness and efficiency of bitumen modified with fibers over lengthy periods. It is yet unclear how fiber additions interact with bitumen and change its rheological characteristics, notably via reducing drain down. In order to improve the design and functionality of fiber-modified bitumen, more study is required to clarify the mechanisms behind fiber-bitumen interactions, including fiber dispersion, entanglement, and reinforcement effects. To improve its functionality, bitumen frequently has a number of additives added to it, including polymers, rejuvenators, and anti-stripping chemicals. The combination does not cause negative interactions or performance concerns, the compatibility of fiber additions with various other additives needs to be researched.

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