Evaluation of Hot Mix Asphalt properties using Non-Woven Fabric Mask Waste as Bitumen replacement

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Islamabad, Pakistan

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This is to certify that

The Final Year Project Titled

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In

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DEDICATION

CREDIT GOES TO OUR FAMILY MEMBERS AND TEACHERS, WHO HELPED AND INSPIRED US THROUGHOUT OUR LIFE.

ACKNOWLEDGMENTS

All praise be to ALMIGHTY ALLAH, who made everything possible and simple for us to accomplish during our incredible NUST journey. We owe a debt of gratitude to our parents who sacrificed and prayed for us to succeed in our studies and research.

A very special thanks to A/P Mansoor Ahmad Malik, the team's respected advisor and mentor for his constant guidance, motivation, and assistance in completing the team's final year requirements, without whom this would not have been possible. Special thanks to the cooperative staff of NIT lab who diligently assisted us in our experimental work no matter how tough things got.

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AASHTO	American Association of State Highway and Transportation Officials
ASTM	**American Society for Testing and Materials**
HMA	**Hot Mix Asphalt**
ITS	**Indirect Tensile Strength**
NHA	**National Highway Authority**
OBC	**Optimum Bitumen Content**
VA	**Air Voids**
VFB	**Voids Filled with Bitumen**
VMA	**Voids in Mineral Aggregate**
HWT	**HAMBERG WHEEL TRACKER**
PPE	**Public Protecting Equipment**

ABSTRACT

In the daily lives of social beings, transportation infrastructure is crucial as it not only connects different parts of a society but also plays a major role in the economy of a country. Transportation infrastructure requires large quantities of construction materials, any reduction in material percentages and replacement of material have a greater impact on the construction cost of infrastructure. Many countries have shifted towards green construction in which they replace aggregate or bitumen with waste materials to enhance the performance of asphalt mix and to combat the pollution caused by the waste material. There are two plastic roads constructed in Pakistan recently as Pakistan is started to realize the potential of using replacement of waste materials in pavements. Unfortunately, the world has recently experienced a significant increase in plastic waste due to the Covid-19 pandemic. The transfer of millions of public protective equipment (PPE) in the form of masks has contributed to plastic waste and caused damage to the ecosystem. N95 and surgical face masks contain about 11g of polypropylene and 4.5 grams of other plastic derivatives such as polystyrene, polyethylene etc. Given the world population of 7.8 billion people in 2021, if we suppose that one out of every five individuals wear face mask daily, approximately 6240 tons of PP is introduced to the environment only through the masks. This unchecked disposal of polypropylene in the environment can cause more weight of masks than fish in oceans by 2050, according to world health organization. Face masks have become an environmental problem since they take a long time to decompose and remain in the environment as micro plastic waste. This research study is done to utilize face masks waste in asphalt mix and analyze the performance of asphalt mix samples containing face mask fibers. Rutting resistance and moisture susceptibility are the two asphalt performance parameters studied in this research. Face masks are used as a bitumen replacement as they melt at 110 C and become semi liquid at 150 C, the mixing temperature of asphalt mix. Therefore, face masks can act as binding agent in asphalt mixture. Moreover, the use of face masks in pavements not only enhances the properties of it but a significant amount of face masks waste is eliminated from the environment.

CHAPTER 1

INTRODUCTION

1.1 Background

Due to severe climatic conditions and economic crisis that Pakistan is facing and the uncertain conditions that are prevailing in the country over the last decade, the overall situation has escalated drastically. The change in climatic conditions is due to global warming caused by the pollution due to waste material that remains in the environment and does not degrade. The incorporation of waste in pavements has been practiced all over the world. There is a need to promote the trend of green construction in Pakistan to combat the waste material in order to reduce global warming and to reduce the material cost in pavements as waste material is used either as an aggregate or bitumen replacement.

Polymer waste has been incorporated in asphalt mix as a bitumen replacement all over the world because the main problem is that polymer waste does not degrade in the environment easily. Polyethylene based waste material has been generally used in pavements however research has also been conducted on use of polypropylene as bitumen replacement in asphalt mix. Recently Covid-19 outbreak has proposed public health emergency across the world. The use of face masks was made compulsory for protection against disease. On one hand the face masks use has controlled covid-19 spread and on the other hand the disposal of used masks in the environment caused an increment in plastic waste to an alarming extent. The reason for waste increment due to disposal of masks in environment is that it does not degrade in the environment because of the larger molecules in face mask composition, hydrophobic nature, high rugosity of face masks. That is why a large portion of melt blown and spun bound fibers remain in the environment as non-degraded plastic. The presence of plastics in the environment has been reported as a significant contributing factor to global warming. Micro plastic not only enters the food that humans consume but also ends up in oceans resulting in disturbance of ecosystem and food chain.

Face masks contain fibers of melt blown and spun bound and both are non-woven. The fibers in masks have pores with larger surface area that helps in performing better filtration. Whereas fibers used in asphalt mix are generally woven and are manufactured differently. Adding polymers to asphalt forms a composite composition in asphalt mixture. Fibers form a strong networking in asphalt mix that causes bitumen to stabilize on aggregate and it stops movement at higher temperature and force. These fibers can also withstand the applied load on asphalt mixture as there is good adhesion between asphalt mix components containing fibers.

Due to these properties of polymer fibers their addition in asphalt mixtures will certainly enhance the performance of the mixture against applied loading and climatic conditions. So in this way the face masks waste can be mitigated and the increase in global warming due to the micro plastics in environment can be substantially reduced.

1.2 Collection of Face masks.

For collection of face masks, safety boxes are installed in various areas of the city and people are encouraged to deposit their used masks in these designated boxes. Safety containers that are generally present in hospitals and in locations containing hazardous materials can also serve as receptables for face mask disposal. In order to minimize virus transfer risk, safety bins are sealed with nylon bags. Many researchers have suggested ways to sterilize face masks such as by heating mask at 70 C, it can be made sure that they are not contaminated. To destroy virus on masks, physiological saline should be sprayed on it and placed for 1 min in 800 W microwave.

1.3 Problem Statement

Due to ever increasing traffic volume and financial conditions of the country it is necessary to construct pavements having better performance, more workable and have better compaction properties. Moreover, the global climatic change due to pollution especially caused by face masks that contains polymer like polypropylene and plastic derivatives of polystyrene (does not degrade completely once disposed in environment and remain as micro plastic), after the outbreak of covid19 has pushed us to manage waste plastic and incorporate it in such a way that society get benefit of it. Many countries have already started to make green pavements (incorporating waste materials). Although in recent years we have constructed two plastic roads in Islamabad but we are still lagging behind in this regard. To utilize mask waste in efficient manner and decompose micro plastic waste which have the ability to destroy any ecosystem easily by ending up in oceans and rivers and disturbing food chain, the statement endorses us to promote utilization of waste in pavement construction in Pakistan.

Therefore, in this study the two parameters against which asphalt performance is checked are: -

- **Resistance against rutting**
- **Moisture susceptibility**

1.4 Research Objective

The foremost purpose of this research work is to utilize shredded face masks in pavements, further breakdown is as follow: -

- To evaluate resistance against rutting of asphalt incorporating nonwoven fabric masks
- To evaluate moisture susceptibility of asphalt incorporating non-woven fabric masks
- Comparing the performance of virgin samples with samples containing face masks

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides research study results related to the response of asphalt mixes containing polypropylene generally and face masks particularly. This chapter contains some research that was done previously on the impact of incorporating polypropylene polymer and face masks on the properties of hot mix asphalt. The properties under examination are generally performance properties like resistance to rutting, beam fatigue and moisture damage.

2.2 Transportation-need of the hour

The significance of well-defined, interconnected routes within country is critical to country's progress. The number of passengers who use this method are significant. Other mobilizing facilities like railway are not as good as they are in other developed countries such as in China and Japan, so the focus in on highways and motorways, which are currently developing at a breakneck pace. A well-developed transportation system is also critical for economic growth of a country. In this context, Pakistan has worked hard to build strong road networks throughout the country.

Pakistan is also constructing a trade route known as China Pakistan economic corridor with the help of China (CPEC). The total cost of developing such a massive undertaking was $54 billion. As part of CPEC, a 1100-kilometer motorway will connect Karachi and Lahore. The Karakoram highway, that connects Khunjrab China border with Rawalpindi, is also nearing completion. By December 2019, the primary rail line between Karachi and Peshawar will be upgraded to make trains travel up to 160km per hour. Despite its rapid growth, the country is unable to meet the country's needs because deprived areas still lack adequate road networks.

2.3 Previous work

Numerous studies have been carried out to check performance of pavements incorporating virgin and waste polymers. Polymers like polyethylene, polypropylene having different properties due to which they enhance pavement performance one way or the other. Hence it would be useful if we incorporate polymer-based plastic waste in pavement structures to enhance its performance. Some important studies that discussed the use of polypropylene waste include :**Otiose and Shuaiba (2017).** The research showed that strength and durability of asphalt mix in heavy traffic conditions can be achieved by high density polypropylene penetration index. **Goud et al (2018)** showed that polypropylene use in asphalt mix can increase mix resistance towards permanent deformation. It also helps to recycle plastic waste and solves the problem of solid waste disposal to some extent. The utilize of polypropylene modifiers changes the performance of asphalt mix as illustrated by **Al-Hadidi and Yi-Qui (2009)**. They explored the benefits of chemical modification by pyrolysis of altered PP in asphalt mixtures and strong matrix asphalt in flexible pavements. The results appeared as the addition of PP decreases asphalt thickness and temperature vulnerability. As of late investigate has been conducted in Australia in which different percentages of polypropylene based shredded masks are utilized and different tests like unconfined compression test, resilient modulus test were done. The masks were incorporated to recycled concrete aggregate. The comes about appears that SFM not only increased stiffness but also increased mixture flexibility **(Saberian et al. 2021).**

Chapter 3

RESEARCH METHODOLOGY AND TESTING

3.1 Introduction

This chapter deals with the methodology used to achieve desired objectives of our research. The chapter includes information about testing material acquisition, experiments done on the acquired material, sample preparation and experiments on prepared samples. The tests were performed on controlled samples as well as samples containing masks of 1% and 2% in hot mix asphalt. Evaluation of OBC on different percentages of additives, Hamburg wheel tracking test and Indirect tensile strength test were the main tests that are performed. Further, procedures for sample preparation of certain tests and input parameters of tests are also included in this chapter.

3.2 Research Methodology

For this study fine and coarse aggregates are acquired from Margalla crush. Bitumen of penetration grade of 60/70 was used and sourced from PARCO. This bitumen grade is selected keeping in view the climatic conditions of Pakistan as it is most suitable for it. Maximum resistance against permanent deformation which is about 95% of asphalt mix structure, is provided by aggregate and 5% is by bitumen. The surface texture, gradation and shape of aggregates highly affect the properties of asphalt mix. A more angular and rough texture exhibits greater resistance against load and temperature stresses. Several tests are performed per ASTM and BS to check aggregate properties that may affect pavement performance. Three-layer face masks are used in shredded form with percentages of 1% and 2% by weight of sample.

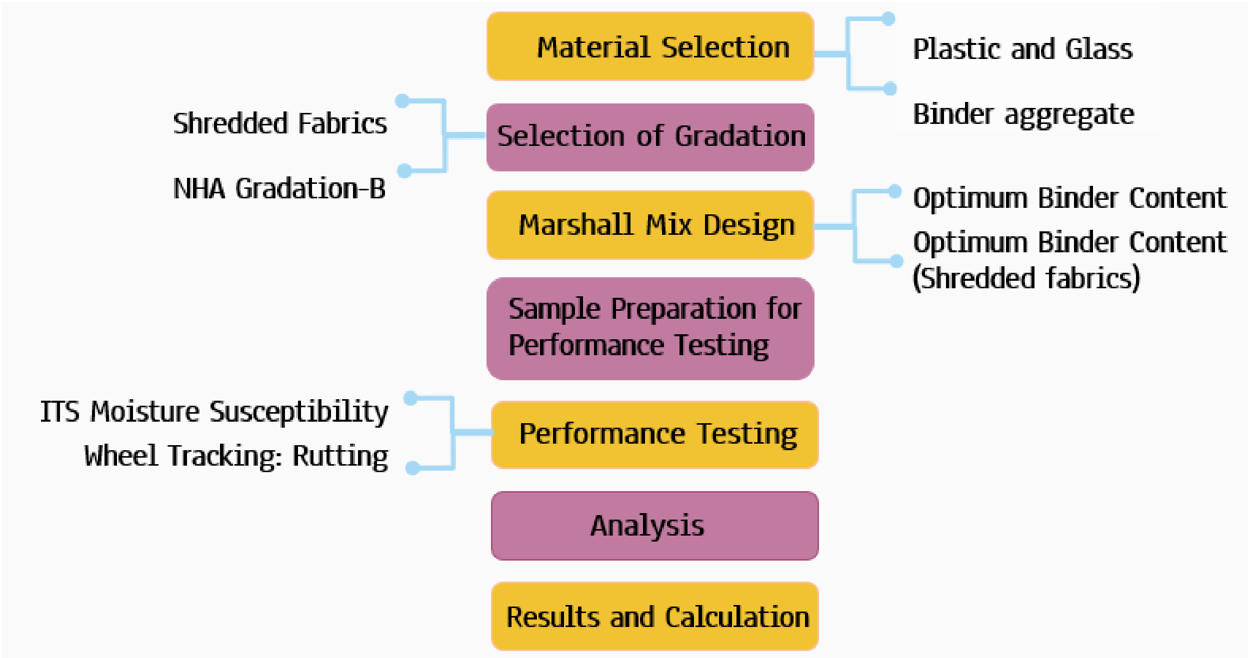


Fig 3.1 Methodology

3.2.1 Material Characterization

3.2.1.1 Aggregate tests

Aggregates are the central portion of asphalt mix that bears maximum stresses and should have the ability to resist the deformation stresses. Aggregates should have the appropriate texture, strength, toughness, durability, absorption indices and shape to fulfill the criteria essential to be used in asphalt concrete mix. Therefore, to investigate aggregate properties several quality controls tests have been performed and three samples were taken for each test and results are averaged. The tests performed include:

- Aggregate shape test
- Impact value of aggregate
- Los Angeles abrasion test on aggregate
- Specific gravity and water absorption test

3.2.1.2 Shape test of aggregate

Strength and workability of asphalt mix mostly depends on shape of aggregates. It moreover depicts compaction effort of blend to acheive the desired density. Concurring to ASTM D4791, aggregates are categorized as flaky having smaller dimensions less than 0.6 of their mean seive size whereas totals with length of more than 1.8 of their mean seive size are called elongated. These two types of aggregates tend to break easily under traffic loads. Aggregates shape should be angular for better interlocking and offering more resistance to loading.

Fig 3.2 Elongation Index

Fig 3.3 Flakiness Index

3.2.1.3 Impact value test of aggregate

BS 812 was the standard followed in this test. This is measure of aggregate resistance to impact load which is different to progressive compressive load. Toughness is a material property that describes its ability to withstand impact. Aggregates are subjected to impact loads due to traffic and should have the strength to deter it. Impact value of aggregate measures the resistance against a sudden shock. The method followed for this test is:

- Impact testing machine
- Sieves of sizes 1/2”,3/8” and #8 (2.36mm)
- Tamping rod

Around 350g of aggregate passing through the sieve 1/2” and retaining on 3/8” sieve was taken and filled in mould in three layers. Each layer is tamped 25 times. The sample was transferred to larger mould of machine and 15 blows from height of 38 cm were given from hammer weighing 13.5 to 14 kg. The resulting material is passed through sieve #8. Impact value is measured by taking percentage of material passing sieve #8.

Fig 3.4 Equipment for Impact Test

3.2.1.4 Los Angeles abrasion test

This test gives value of hardness and toughness of aggregates. Aggregates must be hard enough to resist wear and tear due to heavy traffic loads. Apparatus for this test was:

- Loa Angeles abrasion machine
- Balance
- Set of sieves and steel balls

Aggregate gradation of **NHA Class B** was selected. 2500 g of aggregate retained on sieve 1/2" and 3/8" sieves, which makes total of 5000 g (W1) along with 11 steel balls were placed in Los Angeles machine. Machine was rotated at 33 rpm for 500 revolutions. After the revolutions were completed the material from machine was sieved through 1.7mm sieve. Weight of sample passing through this sieve is taken as (W2).

Abrasion value was found out by **W2/W1*100**

Fig 3.5 Apparatus for LOS Angles

3.2.1.5 Specific Gravity Test of Aggregate

Specific gravity tells us the weight volume characteristics of aggregates. Weight of given volume of aggregate divided by weight of equal volume of water at 25C gives specific gravity value. The test was performed on coarse aggregate per ASTM C 127-88. To calculate specific gravity three weights were determined such as oven dry weight, sample weight while submerged in water and saturated surface dry weight of aggregate. ASTM C 128 was followed for specific gravity of fine aggregate. Absorption of aggregates that how much water percolates the pores of aggregate is of immense importance because:

- High absorption means that high asphalt binder quantity may get penetrated in aggregate pores resulting in strength reduction of mix
- High absorption also leads to non-durability

Absorption value should be less than **3%.** The procedure to find saturated surface dry and submerged weight was that aggregate sample was taken and weighed. Sample was immersed in water, for 24 hours and then sample is removed when pores of aggregate were almost fill with water. The aggregates are dried from surface and the sample weight was measured that gave saturated surface dry weight.

Test description	Specification reference		Results	Limits
Elongation index	ASTM D 4791		2.60%	≤15
Flakiness index	ASTM D 4791		10.50%	≤15
Aggregate absorption	Fine	ASTM C 127	1.47%	≤3%
	Course		1%	≤3%
Impact value	BS 812		17%	≤30%
Loss angles abrasion	ASTM C131		23%	≤45%
Specific gravity	Fine Agg	ASTM C 128	2.61	b/w 2.5-3.0
	Course Agg	ASTM C 127	3%	b/w 2.5-3.0

Table 3.1 (Aggregate Test Result)

3.2.2 Asphalt testing

Bitumen plays an integral role in binding the materials in asphalt mix. According to asphalt institute MS-4 manual, bitumen should be safe, pure and consistent. Consistency of bitumen varies with temperature so a standard temperature is required to measure its consistency. To ensure better performance results several tests were performed to ensure quality of bitumen being used. The tests are as follows:

- Penetration test of bitumen
- Flash and fire point test
- Ductility test
- Softening point of bitumen test

3.2.2.1 Softening Point Test

AASHTO-T-53 standard was followed to find softening point of bitumen. Bitumen is a elastic material and having high viscosity. It loses its viscosity with increase in temperature. AASHTO-T-53 ring and ball apparatus was used to find softening point of bitumen. The temperature at which sample of bitumen of standard size cannot hold steel ball of 3.5 gm and the ball falls a distance of 25mm by passing through bitumen is called softening point of that bitumen sample.

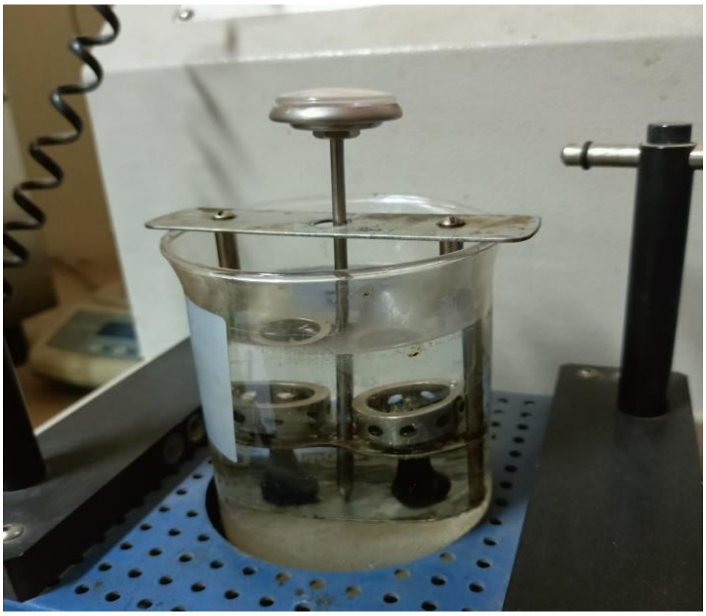


Fig 3.6.1 (Softening Point Test Equipment)

3.2.2.2 Penetration Test

AASHTO T49-03 standard was followed for this test. This test is used to measure hardness and softness of bitumen by a standard needle in five seconds while maintaining bitumen temperature at 25 C. Three penetration values were taken and they all passed the required specifications as described in manual.

3.2.2.3 Ductility Test

AASHTO T 51-00 standard was followed in this test. Ductility shows asphalt behavior with change in temperature. According to specifications in manual ductility is the distance to which a standard specimen of bitumen lengthens without breaking when its two ends are pulled away from each other at a speed of 5 cm/min and at a temperature of 25 C. Three samples were taken and all satisfies 100mm criteria.

Fig 3.6.2 (Ductility Test Equipment)

3.2.2.4 Flash and Fire point test

D 3143/D 3143M-13 standard was used. This tells us that how much temperature is safe to which bitumen is exposed.

Table 3.2 (Bitumen Test Results)

Sr No	Test Description	Specification	Result
1	Penetration test @25 ©	ASTM 5	67
2	Flash point ©	ASTM D 92	359
3	Fire point ©	ASTM D 92	388
4	Softening point ©	ASTM D36-06	51.5
5	Ductility test (cm)	ASTM D 113-99	108.11

3.2.3 Face Masks:

Surgical face masks were widely used all over the world even before the outbreak of covid. But after outbreak of covid there frequent use cause threat to environment as they are been disposed of. They have excellent resilient properties as well as toughness and flexibility. So, they can be used as an asphalt binder modifier as they contain polymers which melt at 110 C and can create effective binding of aggregates and enhance performance of pavements even with less use of asphalt binder.

Fig 3.6.3 (Shredded Face Mask)

3.2.4 Gradation Selection

Aggregate gradation of NHA Class B for asphalt wearing course was selected. The nominal maximum aggregate size selected for NHA class B was 19mm which standard following the Marshall mix design.

Sr. No	Sieve Size (mm)	NHA Specification range (% Passing)	Our Selection	Retained (%)
1	**19**	**100**	**100**	**0.00**
2	**12.5**	**75-90**	**82.5**	**17.50**
3	**9.5**	**60-80**	**70**	**12.50**
4	**4.75**	**40-60**	**50**	**20.00**
5	**2.38**	**20-40**	**30**	**20.00**
6	**1.18**	**5-15**	**10.00**	**20.00**
7	**0.075**	**3-8**	**5.5**	**4.50**
8	**Pan**	**…**	**…**	**5.50**

3.2.5 Asphalt Mixture Preparation

Two types of samples were prepared. One is controlled samples having virgin aggregates and bitumen and the other one is samples containing percentages of face masks 1% and 2% respectively. The samples are prepared according to Marshall mix design procedure. Samples are prepared to determine of OBC for both types. After OBC determination, volumetric properties are tabulated and further samples were prepared for performance testing.

3.2.5.1 Preparation of Aggregate and Bitumen

After sieving aggregates according to selected gradation, they were oven dried at 110 C. The weight of Marshall mix sample was 1200 gm. Bitumen weight varies according to its percentage from 3.5% to 5% of mix. While preparation of samples containing masks same procedure is followed only the weight of bitumen is replaced by weight of face masks fibers depending upon the percentages of fibers used in sample. Fiber percentage is taken of weight of sample. The weight of bitumen in samples can be obtained as:

$W_t = W_a + W_b$

$W_b = X/100 * W_t$

Whereas,

W_t = Total sample weight

W_b= Bitumen weight

W_a= aggregate weight

X=Bitumen percentage used in sample

3.2.5.2 Mixing of Aggregate, Bitumen and Face Masks

For controlled samples bitumen is heated at 150 C and then oven dried aggregates are added into it and thoroughly mixed until homogenous mix is formed. For samples containing masks, first bitumen is heated to 150 C and then aggregates and face masks are added to it. As face masks melts at 110 C so they would assist bitumen in binding aggregate and make a homogenous mixture.

3.2.5.3 Compaction of specimen

According to Marshall mix design criteria, there are three different criteria's for compaction depending for which surface samples are being prepared. In our case, samples are prepared for wearing course so 75 blows should be given on either side of sample by placing filter paper on each side.

Fig 3.7 (Marshall Samples)

Fig 3.8 (Marshall Test Equipment)

3.2.6 Determination of OBC

Optimum bitumen content is calculated depending upon the volumetric properties of sample. For volumetric properties, Gmb and Gmm are calculated by performing tests according to standards **ASTM D2736** and **ASTM D2041** respectively. For Gmb determination first weight of sample in air is taken after which weight in water and SSD weight is taken. After this sample is transferred to water for 30-40 mins at 60 0C. Then Stability and flow values are measured using Marshall equipment.

Fig 3.9 (Gmb Equipment)

The load is applied at constant deformation rate of 5mm/min until specimen fails. For sample to pass design criteria it should have stability value greater than 8.006kN and flow value should be between 2 to 3.5mm. For Gmm calculations, weigh the loose mix then determine the calibrated weight of apparatus.

After this mix is transferred to vacuum chamber and vacuum is applied. After removal of entrapped in chamber, weigh the chamber again containing mix in it.

Fig 3.10 (Gmm Test Equipment)

3.2.6.1 Number of samples for each mix design

Three tests were arranged for each rate of bitumen in controlled tests. For tests containing covers, three tests were arranged for each rate of bitumen comparing rates of confront veils. Total of 36 samples were prepared that are shown in following matrix.

Face mask %	Bitumen %	No of Samples
0	3.5	3
	4	3
	4.5	3
	5	3
0.1	3.5	3
	4	3
	4.5	3
	5	3
0.2	3.5	3
	4	3
	4.5	3
	5	3
	Total samples	**36**

Table 3.4 (Test Matrix for Marshall Mix design)

3.2.7 DETERMINATION OF FLOW AND VOLUMETRIC STABILITY

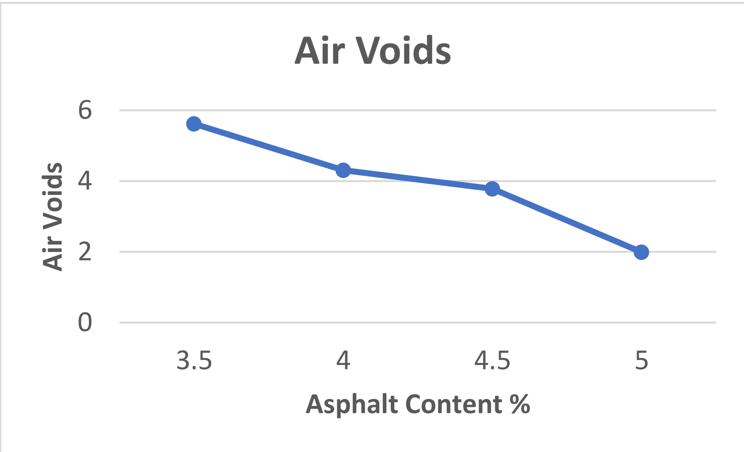
After determining Gmb and Gmm we found volumetric parameters containing percentage of air voids, voids in mineral aggregates and voids filled with bitumen using equations from MS-2 design manual. The flow and Marshall stability for each sample had been determined using Marshall apparatus. Volumetric properties graphs and tables are represented below for virgin samples as well as for samples containing additive.

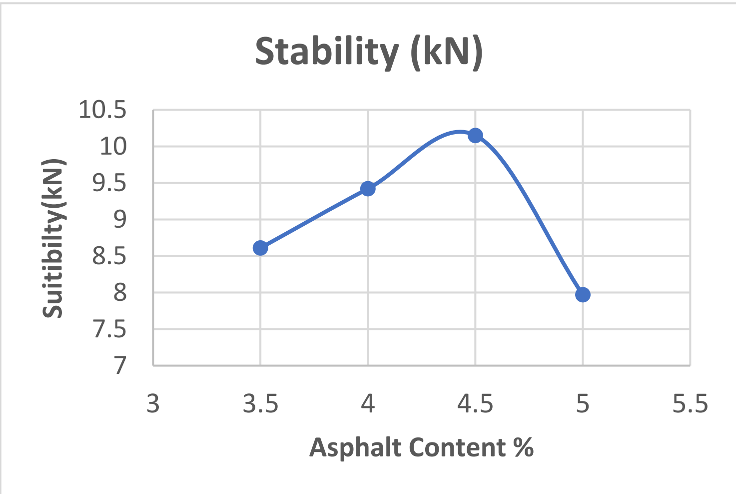
3.2.7.1 Volumetric properties of mix having 0% Face Mask

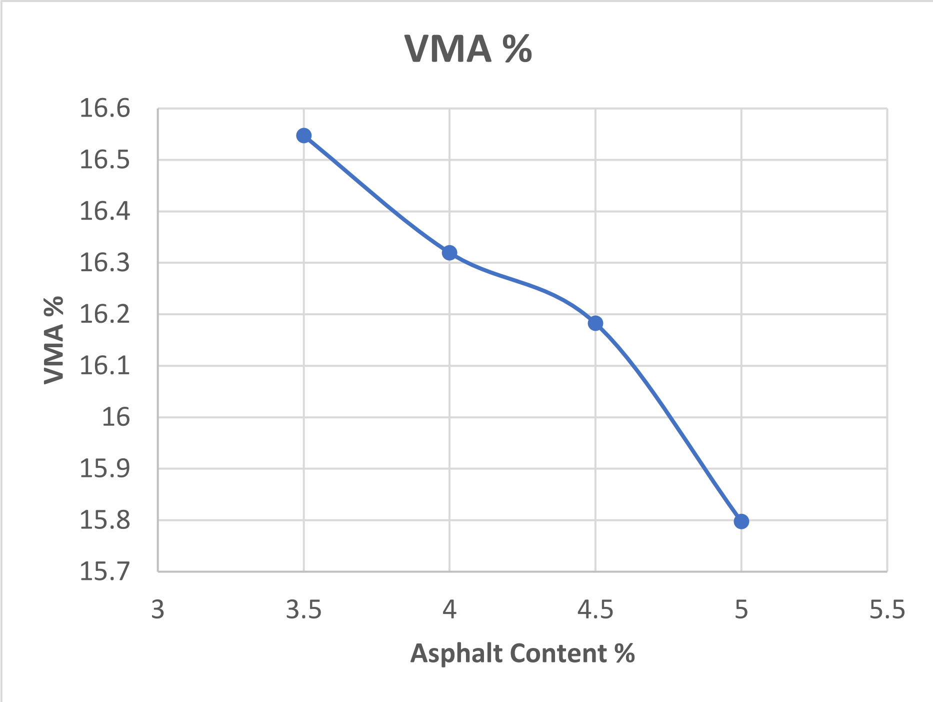
Asphalt content	Air voids	Flow (mm)	Stability (kN)	VMA %	VFB %
3.5	5.616272	3.12	8.61	16.5471	60.4471
4	4.309618	3.25	9.42	16.3197	67.5262
4.5	3.781437	3.43	10.15	16.1825	74.4371
5	1.989912	3.55	7.97	15.7976	85.2427

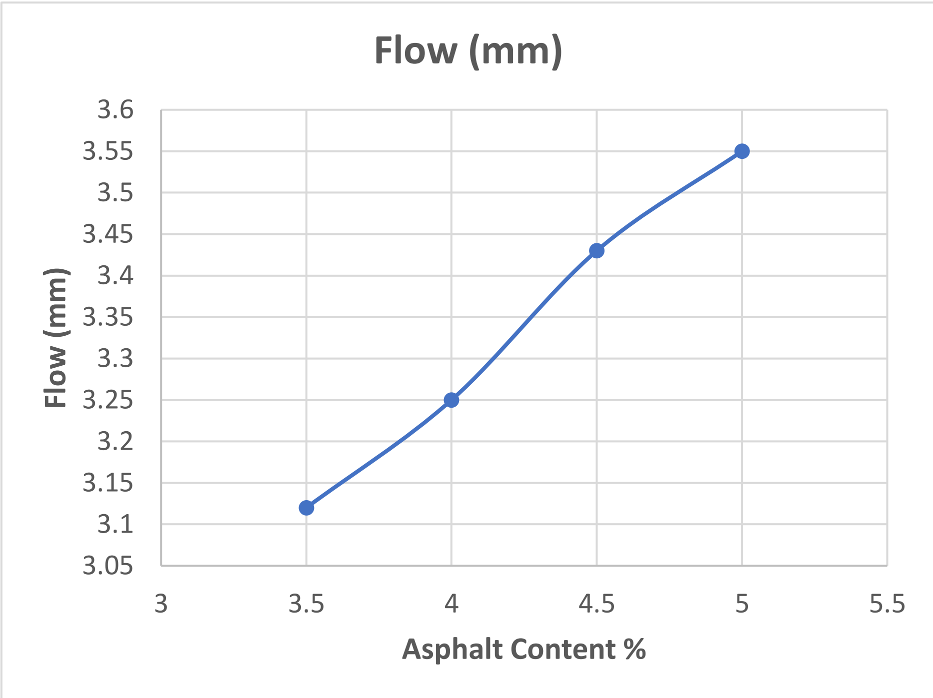
Table 3.5 (Volumetric properties of mix having 0% Face Mask)

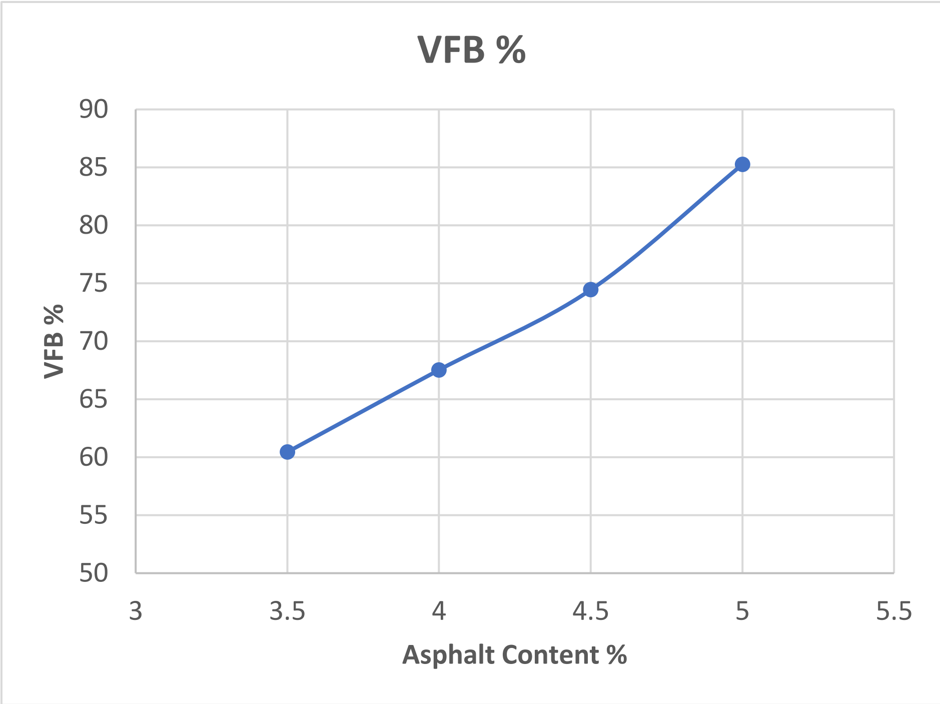
The Air Voids of 4% came out to be at Asphalt content of 4.3%.






VMA %
16.6
16.5
16.4
16.3
16.2
16.1
16
15.9
15.8
15.7
VMA %
3
3.5
4
4.5
5
5.5
Asphalt Content %


Flow (mm)
3.6
3.55
3.5
3.45
3.4
3.35
3.3
3.25
3.2
3.15
3.1
3.05
Flow (mm)
3
3.5
4
4.5
5
5.5
Asphalt Content %



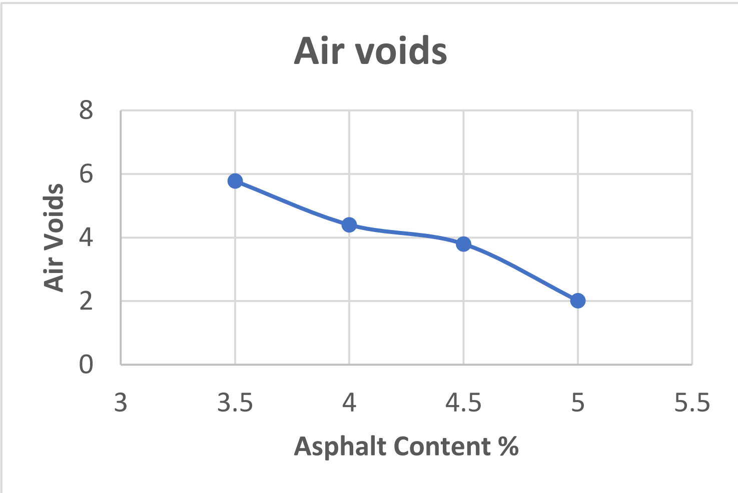
PROPERTY	RANGE	OBTAINED	REMARKS
VMA (%)	MIN 16	16.237	OK
VFA (%)	68-75	71.6727	OK
STABILITY (kN)	MIN 8KN	9.858	OK
FLOW (mm)	2-3.5 mm	3.358	OK

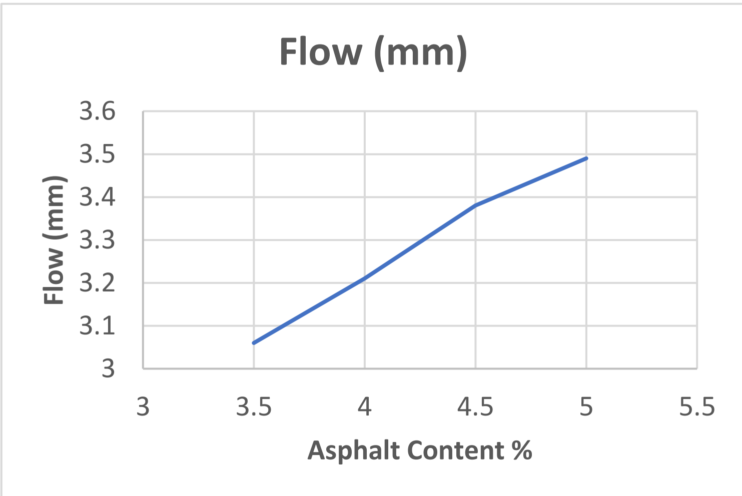
3.2.7.2 Volumetric properties of mix having 0.1% Face Mask

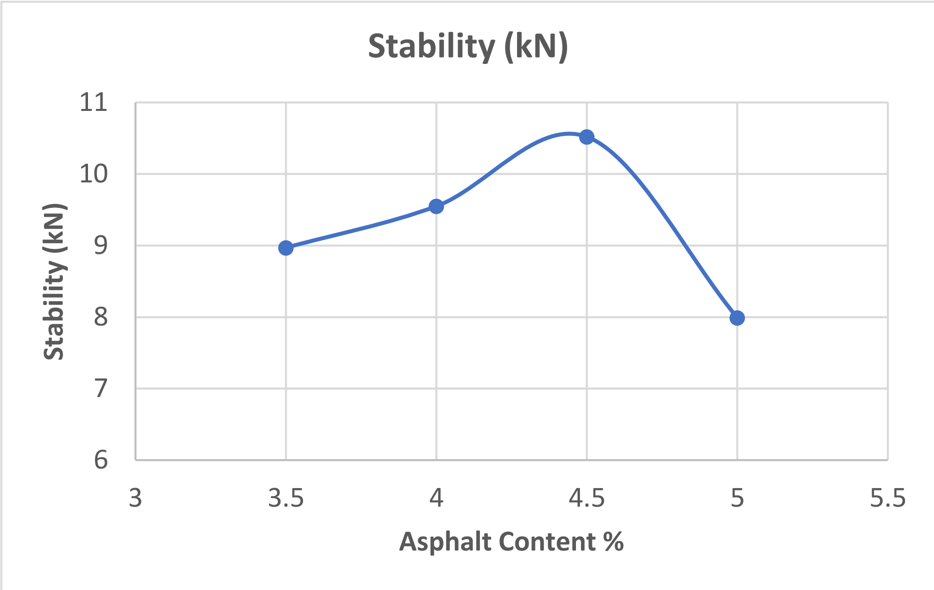
Asphalt content	Air voids	Flow (mm)	Stability (kN)	VMA%	VFB%
3.5	5.778201	3.06	8.97	16.4509	62.4761
4	4.402838	3.21	9.55	16.2877	70.5511
4.5	3.799382	3.38	10.52	16.1502	76.1462
5	2.01727	3.49	7.99	15.8377	85.3002

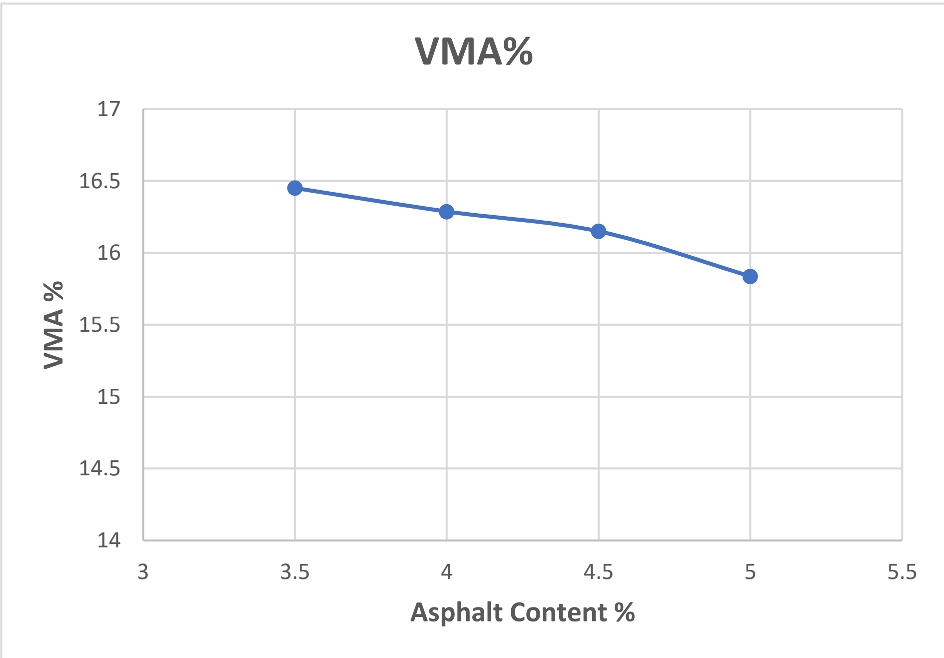
Table 3.6 (Volumetric properties of mix having 0.1% Face Mask)

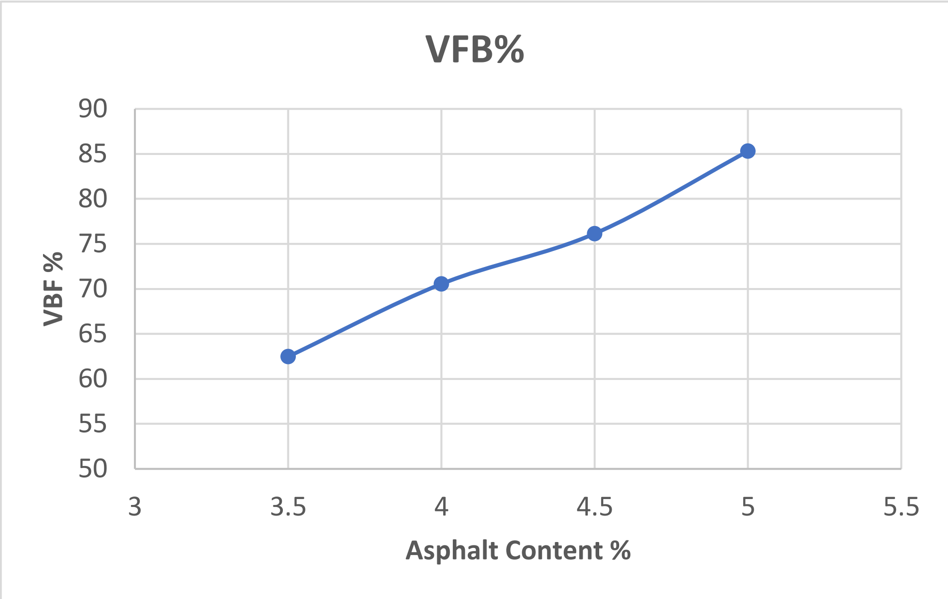
The Air Voids of 4% came out to be at Asphalt content of 4.28%.






Stability (kN)
11
10
9
8
7
6
Stability (kN)
3
3.5
4
4.5
5
5.5
Asphalt Content %


VMA%
17
16.5
16
15.5
15
14.5
14
VMA %
3
3.5
4
4.5
5
5.5
Asphalt Content %



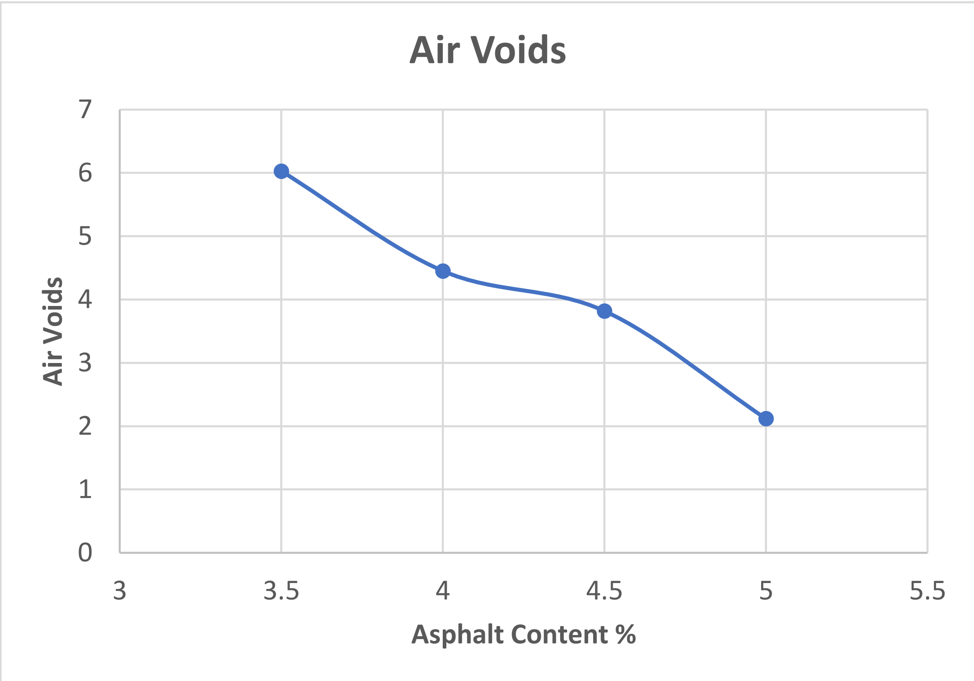
PROPERTY	RANGE	OBTAINED	REMARKS
VMA (%)	MIN 16	16.2107	OK
VFA (%)	68-75	73.684	OK
STABILITY (kN)	MIN 8KN	10.09	OK
FLOW (mm)	2-3.5 mm	3.3052	OK

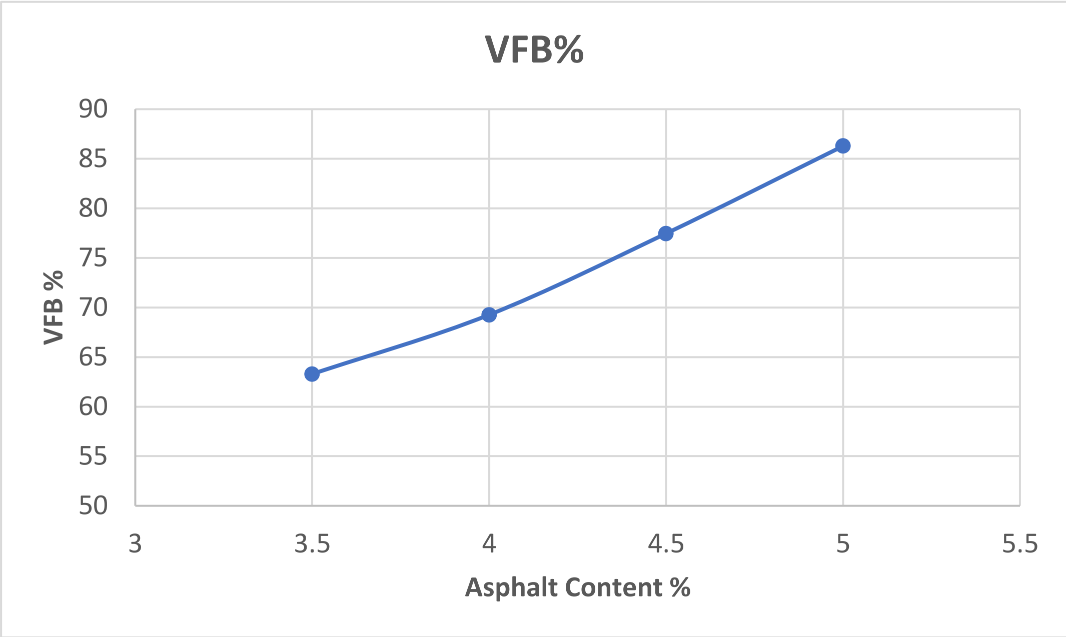
3.2.7.3 Volumetric properties of mix having 0.2% Face Mask

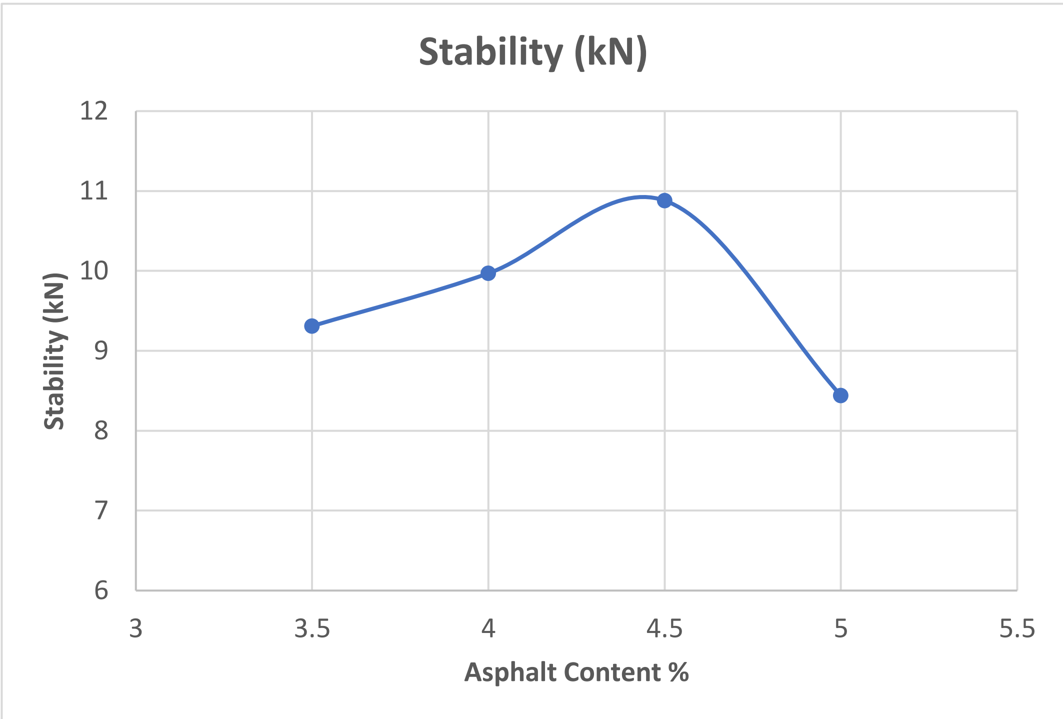
Asphalt content	Air voids	Flow (mm)	Stability (kN)	VMA%	VFB%
3.5	6.029491	2.91	9.31	16.400021	63.28872
4	4.452488	3.11	9.97	16.279391	69.26268
4.5	3.819392	3.33	10.88	15.983881	77.46102
5	2.118273	3.47	8.44	15.793013	86.27718

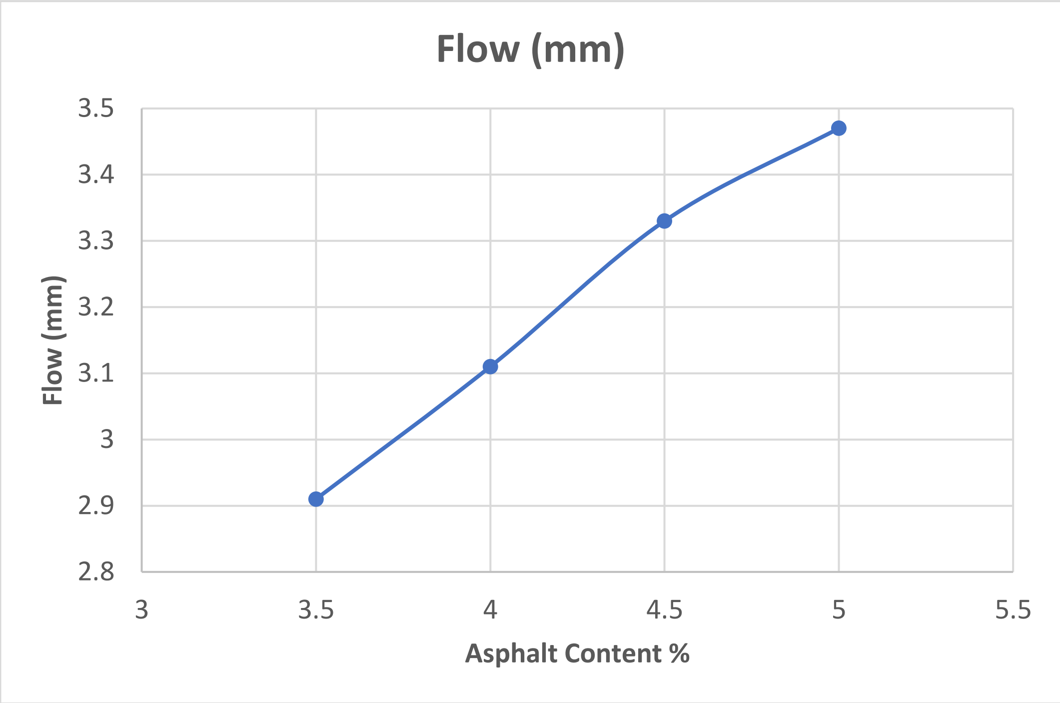
Table 3.7 (Volumetric properties of mix having 0.2% Face Mask)

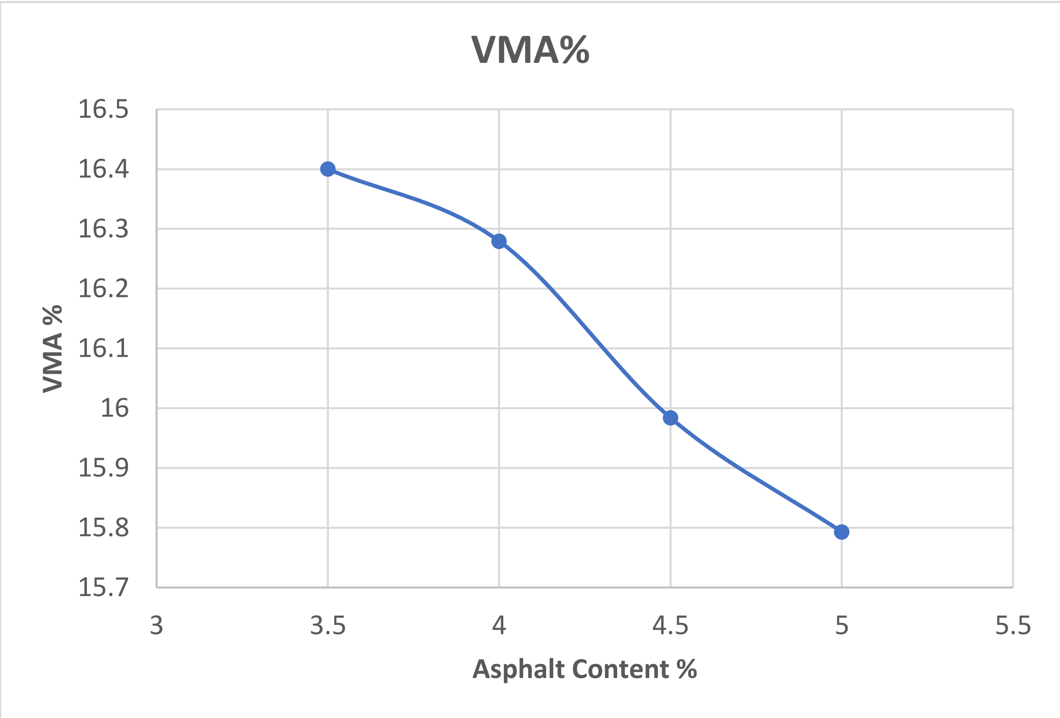
The Air Voids of 4% came out to be at Asphalt content of 4.25%.




VFB%
VFB %
90
85
80
75
70
65
60
55
50
3
3.5
4
4.5
5
5.5
Asphalt Content %


Stability (kN)
Stability (kN)
12
11
10
9
8
7
6
3
3.5
4
4.5
5
5.5
Asphalt Content %


Flow (mm)
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
Flow (mm)
3
3.5
4
4.5
5
5.5
Asphalt Content %


VMA%
16.5
16.4
16.3
16.2
16.1
16
15.9
15.8
15.7
VMA %
3
3.5
4
4.5
5
5.5
Asphalt Content %

PROPERTY	RANGE	OBTAINED	REMARKS
VMA (%)	MIN 16	16.13	OK
VFA (%)	68-75	73.36	OK
STABILITY (kN)	MIN 8KN	10.425	OK
FLOW (mm)	2-3.5 mm	3.22	OK

From the over charts it can be clearly delineated that Marshall steadiness has been expanded with the increment in rate of confront covers. The reason for usually that the polypropylene filaments make solid fiber arrange which in return can increment the solidness against the connected powers on the test.

3.2.7.4 Preparation of samples for performance tests

After OBC determination of virgin samples and sample containing waste, samples were prepared for performance tests. The parameters for which asphalt study is done in this research are:

- Resistance against rutting
- Moisture susceptibility

For these parameters two tests were performed which were

Hamburg Wheel Tracer Test (ASTM 324)

Indirect Tensile Strength Test (ASTM D 6931-07)

For indirect tensile strength test total of 18 samples were prepared. Six samples were of virgin asphalt concrete while 12 samples contained waste. Also, 9 samples were conditioned i.e., placed in water for 24 hours and other 9 samples were unconditioned.

For Hamburg Wheel Tracker Test, total of 9 samples were prepared each of 6kg. Diamond cutter was used to cut the samples according to dimensions of machine. 5000 cycles were selected as per standard and samples were tested under room temperature. Rut depth of any sample should not exceed 12mm according to TEXAS department of transportation.

Fig 3.11 (Performing ITS Test)

Fig 3.12 (Performing HWT Test)

Fig 3.13 (Diamond Cutter)

Table 3.8 TEST MATRIX FOR PERFORMANCE EVALUATION TESTS

Sr. No	Face Mask (%)	Indirect Tensile Strength Test		Hamburg wheel tracker
		Conditioned	Unconditioned	
1	0	3	3	3
2	0.1	3	3	3
3	0.2	3	3	3

RESULTS AND ANALYSIS

4.1 INTRODUCTION

Our study is based on incorporating face masks waste as a binder replacement in hot mix asphalt and check samples performance against rutting and moisture damage. Aggregates are acquired from Margalla crush and bitumen was acquired from PARCO. Samples for performance tests were prepared after determining OBC for various controlled samples and for 1% and 2% face masks respectively. NHA class B gradation was used.

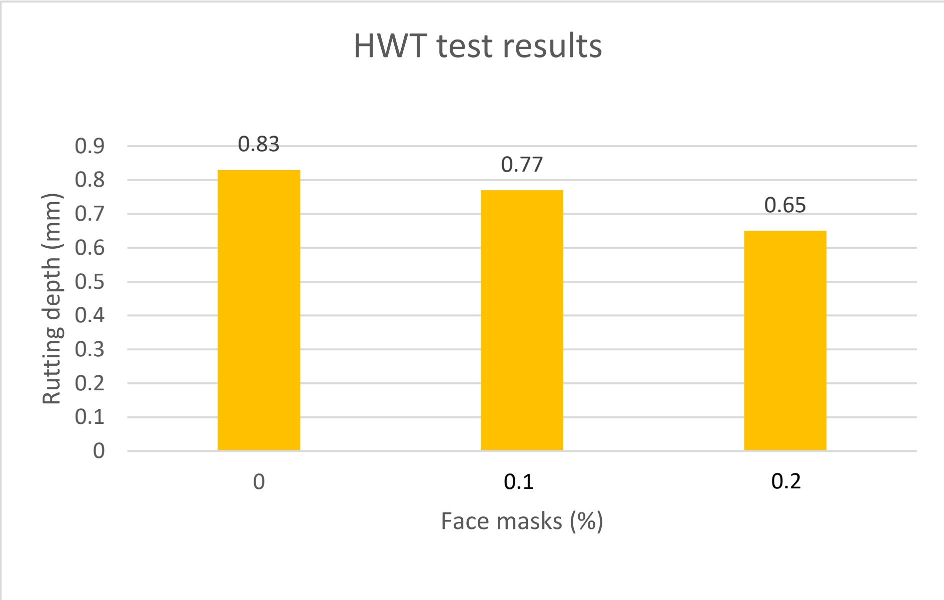
In this chapter results are shown and analyzed for Wheel tracking test and Indirect tensile strength test. The results of samples containing face masks are compared with the performance of controlled samples.

4.1.1 WHEEL TRACKING TEST

Wheel tracking test was performed to check the resistance of samples against rutting. Total of 9 samples were tested containing both controlled and uncontrolled samples and mode of testing was dry. Samples were cut by diamond cutter according to required dimensions in Hamburg machine. Each sample was cut in two equal parts and placed in the machine and average value of rutting is taken from both samples to void any error. Temperature was 25 C and 5000 passes were set. Failure criteria was that the rut depth value increasing 12mm cutoff length.

Sr. No	Face Masks %	Rutting depth (mm)	Remarks
1	0	0.83	OK
2	0.1	0.77	OK
3	0.2	0.65	OK

Table 4.1 (HWT Test Result)



The lessening in rutting due to confront mask addition can be since of the change in aggregate-binder grip force, that creates the asphalt substance adhere superior to the surface of totals and needs more drive to groove. The face mask layer shapes a tall viscosity composite blend in black-top blend and stabilizes the black-top cover on total surface. This wonder makes the face mask contained asphalt mixture perform way better against rutting.

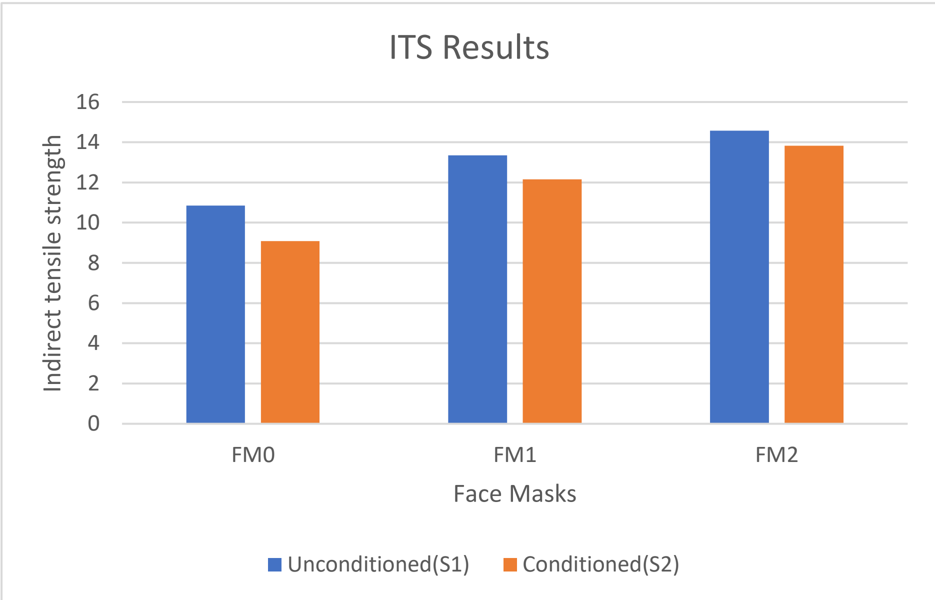
4.1.2 INDIRECT TENSILE STRENGTH TEST

This test was performed according to ASTM D6931-07 standard. After completing the mix design, total of 18 samples were prepared at different OBC for controlled and uncontrolled samples. 9 samples were conditioned and 9 were in unconditioned state. TSR value should be greater than 80% according to super pave criteria. Results show that all samples have TSR value greater than 80% and samples containing face masks performed better than controlled samples.

Summary of the results are given in tabulated form as well as in histogram form below:

Sr. No	Sample specifications	Unconditioned(S1)	Conditioned(S2)	TSR=S2/S1(%)
1	FM0	10.851	9.084	83.716
2	FM1	13.352	12.159	91.065
3	FM2	14.571	13.832	94.928

Table 4.2 (ITS Test Result)



The results clearly shows that the face mask layers increase the tensile strength of samples because face masks strengthen the aggregate-binder adhesion thus more force is required to break the bond. Also, there's an increase in resistance against dampness harm due to expansion of face masks. The reason for this can be that the face masks make a thin layer around the totals which diminishes the water retention by aggregates. The face masks increment cohesion between asphalt layers and anticipates surface splits in asphalt layer additionally removal of asphalt which eventually stands up to water to enter in asphalt.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The main aim of this research was to conduct performance evaluation of hot mix asphalt containing shredded face masks as binder replacement. This will provide an efficient way of disposal of face masks that remain in environment in form of micro plastics and are non-biodegradable.

This research work compares the performance of HMA containing masks with HMA controlled samples. The parameters that are compared in research include:

- Resistance against rutting
- Moisture susceptibility

Hamburg wheel tracker is an equipment to evaluate the rutting resistance of asphalt samples whereas indirect tensile strength test is used to measure moisture damage. Aggregates were sourced from Margalla crush and bitumen of 60/70 grade was taken from PARCO. After determining OBC for each sample using Marshall mix design performance samples were prepared containing different percentages of face masks. After that performance tests like Hamburg wheel tracker test using 5000 cyclic load repetitions and indirect tensile strength test were performed. After that moisture susceptibility was checked for both controlled and uncontrolled samples was checked by calculating tensile strength ratio (TSR). The findings from performance-based tests are explained in below section.

5.2 CONCLUSIONS

- Using face masks waste in asphalt not only enhances its performance but also helps in making environment more sustainable.
- OBC of asphalt mix decreases with increase in addition of waste material.
- TSR of samples containing waste have larger value as compared to that of controlled samples.

- TSR of uncontrolled samples increased about 14% with that of controlled samples.
- Rut depth have decreased considerably by about 29% when waste material is added to asphalt mixtures.
- Least rut depth was obtained for samples containing 2% face masks waste.

5.2.1 ENVIRONMENTAL IMPACTS

There are several environmental impacts that are caused by waste pollution such as global warming, floods, melting of glaciers etc. Face masks have been disposed of in the environment by many people not knowing about the pollution they cause in the habitat and ultimately play a role in destruction of ecosystem. By incorporating face masks in asphalt concrete mixtures not only reduce its pollution in the environment but it may also hinder the production of bitumen to some extent as it is used as a bitumen modifier in asphalt mix. The production of bitumen causes the production of Sox, NO_x, CO_2 and other volatile organic compounds. Plastic waste is a major concern for Pakistan as 3.9 million tons of plastic waste is generated in 2020 in Pakistan out of which only 10% has been recycled. The remaining portion will certainly cause damage to ecosystem as it may end up in seas and disturbs the food chain.

From this research it is clear that we should shift the trend towards making of green pavements as it not only reduces the environmental pollution but also an improvement in asphalt performance can be achieved.

5.3 RECOMMENDATIONS

Based on the research results following recommendations are given:

- In this research only two performance parameters are studied i.e. rutting resistance and moisture damage. Other parameters like beam fatigue, resilient modulus can also be studied incorporating face masks waste.
- Face masks have been added in only two different percentages 1% and 2%. By increasing percentages of face masks further studies can be done.

- Other non-woven fabric waste like carpet backings, home furnishing fabrics, floor duster cloths, nonwoven fabric bags can also be incorporated in asphalt mix and studied.
- It is recommended to construct a road section to study the performance in traffic and temperature conditions of Pakistan.

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