PERFORMANCE EVALUATION OF ASPHALT CONCRETE USING BINDER (ROCK WOOL) AS A MODIFIER

FINAL YEAR PROJECT UG 2017

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DEDICATION

This thesis is dedicated to our parents who taught us that with persistence one can accomplish any objective in his life, our companions for their full and motivational moral support, and last but not the least all our Professors who have been mentoring us throughout our University life

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LIST OF ACRONYMS

AASHTO – American Association of State Highway and Transportation Officials

AC – Asphalt Concrete

ASTM – American Society for Testing and Materials

HMA – Hot Mix Asphalt

ITFT – Indirect Tensile Fatigue Test

ITS – indirect Tensile Strength

NHA – National Highway Authority

OBC – Optimum Bitumen Content

RTFO – Rolling Thin Film Oven

UTM – Universal Testing Machine

VA – Air Voids

VFA – Voids Filled with Asphalt

VMA – Voids in Mineral Aggregate

RWF – Rock Wool Fiber

ABSTRACT

Transportation infrastructure plays a key role in the everyday life of social beings. For its design, highway agencies focus on appropriate and cost-effective design technique s for this purpose Engineers are carrying research on Rock Wool Fiber to introduce it as a Pavement modifier in Market. The use of RWF will not only reduce the use of our natural resources but also help in using the waste materials (i.e., slag from steel mill) for a useful purpose, meeting economic and environmental friendly needs of a country.

Pavements over time gets damaged by rutting, fatigue, moisture susceptibility render it unusable for vehicles. Therefore, it is needed to have such design which are cost effective and environment friendly. The use of Rock wool Fiber acts as a distinct part in achieving national prosperity. This project is based on evaluating the performance of Hot Mix Asphalt (HMA) by using different contents of Rock Wool fiber as an additive in Asphalt Concrete. NHA gradation B, PARCO grade 60/70 Bitumen and RWF from INCOM ROCKWOOL LTD Karachi were used in this study. Penetration, Ductility and Temperature testing were done on virgin bitumen. The RWF contents used were 0%, 0.4%, 0.6% and 0.8% of Bitumen content. Performance testing was done after finding out the OBC, volumetric, stability and flow of AC mixtures. Using those OBC and adding RWF as an additive in bitumen, different samples were formed and tested for evaluation and compared with the performance testing results of AC mixtures without RWF. Moisture Susceptibility Test using Universal Testing Machine (UTM) was performed for performance evaluation.

CHAPTER 1

INTRODUCTION

1.1 Background

Rockwool is naturally occurring product produced during eruption of volcanos when high winds flow upon lava streams of basalt or diabase. This happened in early 1900s, when volcanologists of Hawaiian found an unknown, wool like rock fiber hanging on trees, and it is not older than the fiber's exceptional qualities were discovered.

In present, commercial furnaces has replicated that process where other raw materials along with various minerals are heated to temperature of 1,600° C and subjected to a current of air or steam. To reduce the formation of dust Oil is added as a retarder. Following advanced technologies molten rock is rotated in a spinning wheel at high speed, like the way that cotton candy is made. Finished rock wool is a product having fine intermingled fibers that are held together with starch and assembled into blankets (batts and rolls) or used as loose fill. In United States main manufacturers of rockwool. are in Washington, North Carolina, Indiana, and Texas.

1.2 Problem Statement

Many years of satisfactory service life of pavement can be achieved by properly designing and maintaining it . But still there are certain conditions which can affect pavement. Failure of pavement is result of several factors like stress because of heavy vehicles, water intrusion, seasonal temperature changes causing expansion and contraction, and sun exposure.

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For the residents and owner sudden failure of pavement structure can be frightening and dangerous, the formation of sinkhole and other structural roblems of pavement can add to that fear. When there are problems of potholes formation, rutting failure or crumbling edges then applying a second layer or top coat can serve the purpose of treatment. But these solutions will not be beneficial for underlying structural problems of pavement which can cause potential damage. In case of structural problems suitable solution should be considered instead of saving time and money in quick fixing. This quick fixing will add to secondary cost.

It is necessary to avoid these road problems so that the maintenance and repair cost of the roads can be reduced and can have positive impact on economy.

1.3 Purpose of Research

Pakistan is currently going through a transportation revolution. Under the present government, we have seen immense sums income committed to the development of underpasses and overhead scaffolds and repairing and widening of already built roads. The historic agreement of providing economic corridor to China via Pakistan involves construction of 1200 km long motorway between Lahore and Karachi and overhauling and widening of Karakoram Highway between Rawalpindi and the Chinese border.

Our project is based on using the RWF (Rock Wool Fiber) as an additive in HMA (Hot Mix Asphalt). The reason of choosing RWF as an additive is because of its properties. Those properties which are deficient in Hot Mix Asphalt can be covered by using some optimum amount of RWF. Also because of RWF properties the road problems will be addressed and will reduce the maintenance and operational cost.

1.4 Research Objective

The main objective of our project is to use RWF in HMA as an additive in Bitumen. The objectives are as follows:

- To assess Moisture Susceptibility of HMA with and without Rock Wool Fiber (RWF).
- To Reduce maintenance costs by using RWF in construction of asphalt pavements.
- To accomplish these objectives by not affecting the pavement performance.

1.5 Report Organization

This thesis is composed of five chapters. Short overview of these chapter is explained below.

Chapter 1 gives a brief overview to problems associated with pavement, rock wool, their possible use in HMA pavement, its usage and problems associated with its usage, problem statement, research objectives.

Chapter 2 includes literature review on needs of transportation, design methods of flexible pavements, previous research related to incorporation of RWF in pavement and problems associated with it. Finally, it includes research of different test methods used for Moisture susceptibility.

Chapter 3 explains the methodology adopted in this research which includes the collection and laboratory characterization of materials, the Marshal mix design and performance testing.

Chapter 4 presents the performance test results and their analysis.

Chapter 5 summarizes the conclusion of laboratory testing. Future recommendations are also discussed.

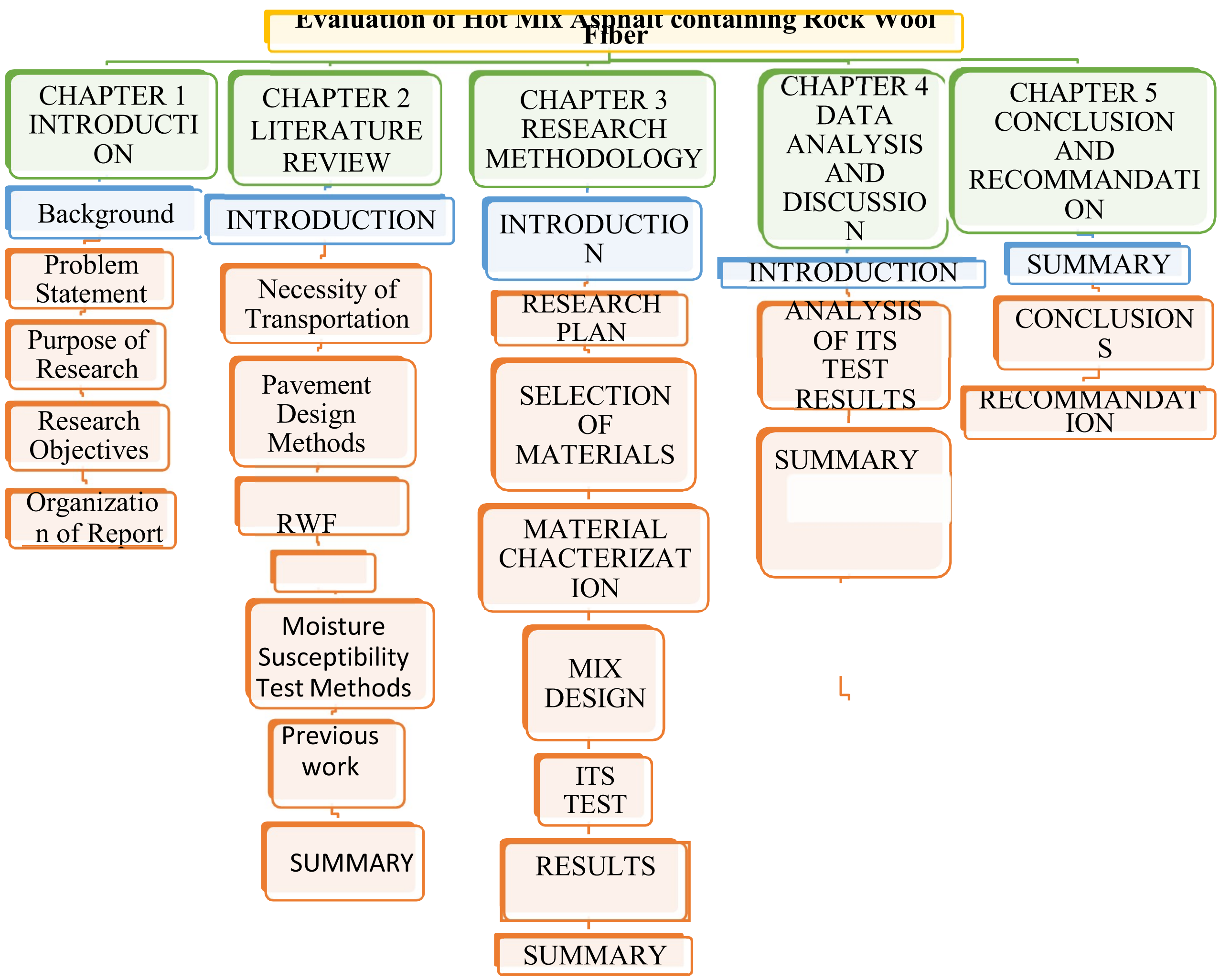


Figure 1.1: Organization of Report

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter contains a short review of the theory and literature related to necessity of transportation, different methods to design flexible pavement. Some overview to rock wool Fiber, previous works on incorporating itin pavement and the results of doing so. This chapter also discusses response of pavement having RWF and previous works on it. The details of Moisture susceptibility test on asphalt mixes are also explained.

2.2 Need of transportation!

The foundation of economy for any nation is its proficient and practical transportation network. A huge number of individuals travel by means of roads in our nation. The disintegration in the measures of Pakistan Railway and the absence of inconceivable and satisfactory open transportation framework like the London Underground, Moscow Metro, Shanghai Metro, Indian Metro has led to poor transport facilities. It connects the countries parts by creating an efficient transport communication between different locations. Better transportations not only help in increasing economy of country but also lead the country to development. Shortly, country with better transportation network will be more prosperous.

Pakistan was under the situation of worse transportation system but now it has developed a lot. Motorway is being constructed and still its expansion is in progress. The aggregate length of Pakistan's motorways is 3741 km as of May 2021. Around 2429 km of motorways are operational, while an additional 1312 km are under construction or planned. A large portion of these motorway ventures is finished. Recently tender of Sialkot Kharian Motorway has been passed and the construction will start from June 2021 and will be completed by 2022, Similarly Rawalpindi-Kharian Motorway is planned, construction will start from June 2021 and expected to complete by 2023.

Since 2013 Pakistan in collaboration with China is constructing a trade route called China Pakistan Economic Corridor (CPEC). It is a collection of different infrastructure projects of worth 54 billion $. It includes thousands of Kilometers Road projects. Many road projects have been completed and are now operational. Karakorum highway that connects Khunjerab-China border with Rawalpindi is completed and is functional. In short Pakistan is seeing a huge progress in Road Sector with more upcoming projects of Motorways planned under PTI Government.

2.3 Flexible Pavements

Flexible pavements are constructed with a bituminous-treated surface or an asphaltic surface over one or more layers of aggregates i.e., unbound base courses resting on a bed of compacted granular material made of subgrade. Its strength is derived from the load-distributing characteristics of a layered system designed toultimately protect each underlying layer including the subgrade from compressive shear failure.

The design of flexible pavement is based on the load-distributing characteristics of a layered system designed to ultimately protect each underlying layerincluding the subgrade from compressive shear failure as the intensity of load diminishes as it is transmitted from the surface deep into the ground through the successive layers, with better weather resistant and those resistant to environmental action used in the top bituminous layer designed such that it is resistant to fatigue damage and shows stability under traffic loads when pavement temperatures go beyond 150ºF.

Figure 2.1 typical cross section of the layered system in conventional flexible pavement

2.3.1 Design Methods

Two methods are used for the design of Flexible pavements which include:

- Marshall Mix Design
- Super pave Mix Design

2.3.2 Marshal Mix Design

This method of flexible pavement design was first developed by Bruce Marshal in 1939 and then modified by US Army. It is one of the most popular and cheaper method use. This method focuses to find optimum bitumen content (OBC) for different blend of aggregate used. It also encounters traffic level in the design of pavement.

For the determination of OBC samples are prepared for different asphalt content generally in the range of 3 % to 5% of total sample weight. 2 samples are prepared for each asphalt content. After that following test are performed on these samples.

- Bulk density determination
- Stability and flow test
- Density and void analysis

Five different curves are plotted versus asphalt content at x-axis.

By taking mean of these three bitumen contents OBC for mix design can be determined found. It can be determined from form the graphs obtained in the last step.

1. Bitumen content corresponding to maximum stability.
2. Bitumen content corresponding to maximum bulk specific gravity (G_m)
3. Bitumen content corresponding to the median of designed limits of percent air voids (V_v) in the total mix (i.e., 4%)

2.4 Mineral Wool

Mineral wool includes rock wool and glass wool (fiberglass), which is produced as boards and mats normally, but sometimes also as a filler. Soft and light mineral wool products are used in frame houses and other structural cavities. The thermal conductivity of mineral wool varies with temperature, moisture content, and mass density. Taking an example, with increasing moisture content of mineral wool from 0 to 10 vol%, the thermal conductivity can also increase from 37 to 55 mW/(mK) respectively. Products made from mineral wool can be perforated, and can be cut and adjusted at the site, so there is not any any loss of thermal resistance.

2.4.1 Types of Mineral Wool

The best known of the whole range of insulations is mineral wool. For acoustic, thermal, and fire-protection purposes It is widely used in all sectors of industry, building and transport. Common misconception about mineral wool is that it is a specific product type while it is not. It is a general term for a range of inorganic non-metallic fibers which are man-made. The following terms can help to clear the misconceptions:

1. *Mineral fiber*: product of non-metallic inorganic fibers.
2. *Mineral wool*: mineral fibers normally made from molten glass, rock, or slag.
3. *Glass wool*: product of molten glass.
4. *Rock wool*: product of naturally igneous rock.
5. *Slag wool*: product of molten furnace slag.

2.4.2 ROCKWOOL Characteristics

The peoperties and characteristics of rock wool such as aeration, holding capacity of moisture or hygroscopic property and the gradient of moisture from top to bottom of growing slab. By just cahnging these RWF characteeristics, different RWF products for different uses can be made availble in market.

Lets take an example of a product used for plant development. One produvct available is used for rapid root development while the other is uded in slightly drier zone of root. This enables growers to have the product which can best suit their purpose.

2.4.3 Previous work

Bituminous concrete is widely used for most of the construction projects inPakistan like road surfacing, airports, parking lots etc. The bituminous concrete is a blendof asphalt and aggregate mixed as to achieve proper performance criteria.

The reason of deterioration of roads of Pakistan is continuous increase of traffic and insufficient degree of maintenance due to lack of funds. To secure the roads several types of measure are find effective, secure the funds for the maintenance, use material of better quality, improved the roadway design, and use of better construction methods.

Around the globe, Research on rockwool as an additive is going on. Means the world is using the RWF for some beneficial purpose. This project is focused on replacing some percentage of bitumen with RWF tomake some beneficial use of fibers.

2.4.4 Problem Statement

Overloading, temperature and Permanent deformation are various factors for the failure of hot mix asphalt pavements. To address the pavement performance issues RWF modified asphalt concrete has been introduced recently few years back by taking into account the traffic loads as well.

This research focuses on determining optimum RWF% that can be added in bitumen so as not affecting the performance of pavement and at the other hand increase resistance to road failures.

2.4.5 Literature Review

To determine pavement performance incorporating varying percentage of RWF numerous research have been carried out. Work has been started few years ago. researchers discussed the use of RWF in road and its results.

2.5 Moisture Susceptibility

Moisture Susceptibility is the damage caused by water to asphaltic pavement by reducing strength of bond between the binder and aggregate. It has become a serious concern for the Asphaltic Pavement performance (HUNTER 2001).

The low compaction temperature while producing HMA is known to be causing inadequate drying of aggregate leading to susceptibility to moisture induced damage (HURLEY 2006).

Moisture susceptibility is related to the presence of air voids which gets filled with moisture causing damage to pavements. Commonly two types of moisture induced failures are related. Cohesive failure is related to reduction in bond strength of binder and Adhesive failure is caused between binder and aggregate. (ZOLLINGER, 2005).

Loss in strength and durability of Asphalt Pavement due to interaction of binder and fine aggregate with moisture if there is aproblem of bonding between the two, is termed as moisture susceptibility. Greater the bonding between binder and aggregate, less will be the potential for moisture induced damage.

Moisture Susceptibility result in gradual loss of strength over time which may result in Stripping, the phenomena in which aggregate is detached from asphalt cement, leading to development of rutting, and shoving in the wheel paths. Therefore, it is necessary to determine that whether the pavement designed is capable to resist damage from moisture presence.

Procedures for Evaluating Moisture Susceptibility

Moisture induced stress Test (MIST) simulates the field conditions. It exposes the HMA specimen to repeated pore pressures as experienced by the pavement on filed due to repeated tire load. It is basically an assembly consisting of a compressor to load air anda vacuum to load air in and out of the HMA specimen.

Determining the Dynamic Modulus can aid in evaluating the moisture susceptibility of HMA mix as Dynamic modulus is the indicator of viscosity of Mix. Determining Dynamic modulus before and after the condition of Mix can be handy to check the Tensile strength ratio of HMA sample.

Moisture Damage can also be evaluated from Hamburg wheel-tracking device. Several different factors influenced the result from this device. Several studies were done to list down the factors affecting the results from Hamburg device. These were identified as quality of aggregate, asphalt cement stiffness, long and short-term aging of asphalt cement, the properties of crude oil from which asphalt was extracted, compaction temperature.

Zhao, et al. (2013) proposed consideration of contact angle measurement and dynamic modulus results to reinforce the conventional test method of Moisture Susceptibility, which proved to valuable in recent findings.

Determination of Surface energy was employed by ZOLLINGER in evaluating the Moisture Susceptibility. Universal Sorption device and Wilhelm plate were employed to measure surface energy from aggregate and binder. Possible Problematic combinations of aggregate and binder were identified from the ratio of adhesive bond energy under wet conditions to adhesive bond energy under dry conditions.

ZOLLINGER also employed dynamic mechanical analyzer to determine moisture susceptibility. The ratio of number of cycles to failure of wet specimen to number of cycles to failure of dry specimen was employed to evaluate the moisture damage of pavement.

McCann, et al. evaluated moisture damages by applying accelerated moisture conditioning. In this method, a loose mix specimen is kept in water bath at 60 °C while subjecting it to ultrasonic energy. To quantify moisture damage, the percent material lost from specimen is recorded for five hours and plotted against conditioning time. The slope of the curve is a measure of moisture damage to pavement.

In 1998, Maine Dot recommended of determining Tensile Strength Ratio (TSR). Most appropriate measure of moisture damage to pavement (Washington State Department of Transportation, 2009) is TSR. This method can be more acceptable by consideration of contact angle measurement and dynamic modulus results (TAO & MALLICK, 2008).

The procedure used in this research is based on ALDOT 361-88 which determines Tensile Strength Ratio of conditional sample to unconditional sample. The conditioning of sample is done in water bath at 60 °C for 24 hours after which it is placed for another 1 hour at 25 °C. The unconditioned sample is placed for 25 °C in temperature-controlled sample for 1 hour. The TSR ratio should be minimum 80% for satisfactory functioning of road.

2.6 Summary

In this chapter benefits of transportation were discussed on how it contributes to the development of country economy by quoting examples from developed countries like UK, Russia. After that an overview was given about design of flexible pavement, Marshall and super pave methods were discussed in this regard. After which Mineral fibers specifically Rock Wool fiber was discussed how it is made. Many researchers have used Rock Wool fiber in pavement and have found satisfactory performance of pavement. Many previous research in this regard were discussed. Through incorporation of RWF, pavement showed enhanced performance. After that, a review was given on different test methods used for determining Moisture susceptibility. The most widely method used for determining moisture susceptibility isALDOT 361-88.

CHAPTER 3

RESEARCH AND TESTING METHODOLOGY

3.1 Introduction

This chapter discusses about the research methodology acquired to accomplish the goals of the study which are material acquisition and its testing, preparation of specimens and different performance tests on specimen. Tests was conducted on controlled sample and on samples with RWF. This chapter also discuss about OBC determination at varying content of bitumen using Marshal Mix Design Method. Based on the OBC, performance tests will be conducted on specimens with and without RWF. Performance testing includes Moisture Susceptibility. This chapter will also discuss equipment used, procedure followed, samples preparation and input parameters used during testing on the prepared specimen.

3.2 Research Methodology

From Margallo hills crush plant site Virgin aggregate was collected and RWF was procured from Karachi. These materials were then brought to laboratory of NUST INSTITUTE OF TRANSPORTATION (NIT) and different tests of aggregate and bitumen were conducted. After that, specimens for Marshall Mix Design were prepared to determine OBC of samples having only bitumen. Then performance test samples were prepared using obtained OBCs.

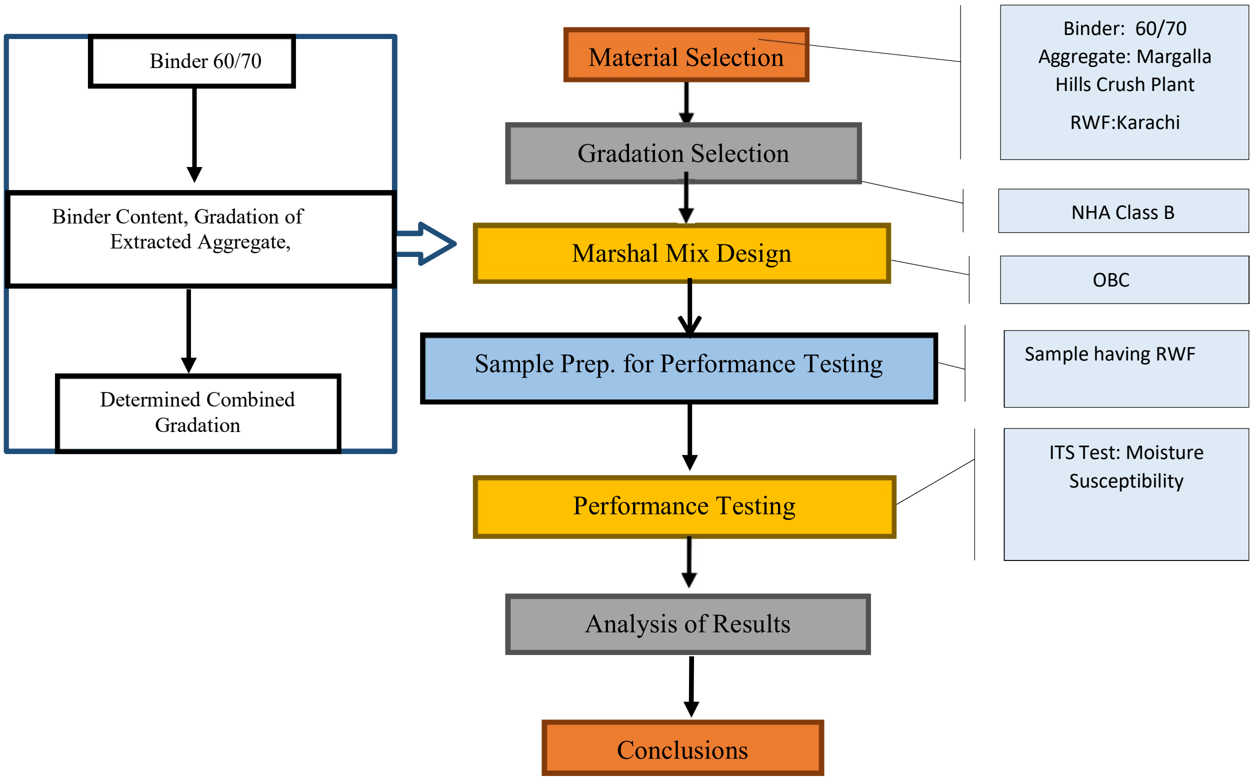


Figure 3.1: Research Methodology

3.3 Material Collection

3.3.1 Aggregate

Collection of aggregate was done from Margalla hills crush site. Aggregate has a vital role in defining the durability and strength of HMA pavements. It takes maximum load of pavement. These strength related properties of aggregate are greatly influenced by the texture and shape. Generally, more angular and rougher textured the aggregate, more it is capable to resist stresses in pavement due to application of repeated loads. Several tests are performed per ASTM and BS to check properties of aggregate affecting pavement.

Figure 3.2: Margalla Hills Crush Plant

3.3.2 Bitumen

In Pakistan, mostly bitumen of grade 60/70 is utilized per weather conditions. So, grade 60/70 bitumen was procured from Parco Oil Refineries (PRL).

3.3.3 Rock Wool Fiber (RWF)

Rock Wool is not in much use in Pakistan. Therefore, we faced difficulty in its procurement. In Punjab, there was no company manufacturing or importin g Rock Wool. We searched on Internet and found company in Karachi. We procured around half kg of wool from there. It was of very good quality.

Figure 3.3: Rock Wool Fiber

3.4 Material Testing

3.4.1 Aggregate Tests

Aggregate should have enough strength and texture so that pavement deformations can be avoided. Following tests were carried out to determine aggregate characteristics.

- Shape Test
- Specific Gravity and Water absorption
- Impact value Test.
- Los Angles Test.

Three samples were prepared separately for each test and then result was compiled in tabulated form.

3.4.1.1 Shape test of Aggregate (ASTM D 4791-99)

This test tells us about the percentages of elongated and flaky particles in aggregate. If aggregates have their least dimension lesser then 0.6 times their mean dimension, then they are called as flaky aggregates. And elongated particles are those which have their largest dimension larger than 1.8 times their mean dimension. Preferred shape of aggregates is angular so that it can have better interlocking property. Both flakiness index as well as elongation index should be less than 15%.

Figure 3.4: Shape Test

3.4.1.2 Specific Gravity Test

Weight of given volume of aggregate divided by weight of equal volume of water at 23 °C gives value of specific gravity. This test was performed only on coarse aggregate per ASTM C 127-88. To calculate specific gravity three weights were determined i.e., oven dried aggregate weight, weight of completely submerged aggregate in water, and Saturated surface dry weight of aggregate. Specific Gravity of Fine aggregate and water absorption was determined using ASTM C 128.

Figure 3.5: Specific Gravity Test

3.4.1.3 Impact Value of Aggregate

This value indicates relative strength of aggregate when subjected to impact loading. The required apparatus includes sieve of sizes ½'', 3/8'' , No.8, along with tamping rod and impact testing machine . Sample weighing 350 grams was ttransferred to impact testing machine cup having passing of ½'' aand retain of 3/8''. Transferred in 3 layers and then each layer was tamped with tamping rod 25 times. Then 14 kg rammer of impact machine having a free fall of 38cm was used to make 25 blows on sample.Then after removing material from impact machine cup it was passed through sieve no.8. Impact value is determined through the passing percentage from sieve no.8. The result is summarized in table below.

Figure 3.6: Impact value Test Apparatus

3.4.1.4 Los Angles Abrasion Test

This test is used to check resistance of aggregate to wear and tear against heavy load of traffic. Greater the value of abrasion more will be the damage to pavement. Apparatus includes sieve set. Steel balls and LOS angles machine. NHA Gradation B was used. About 5000g of sample, having 2500g retain of ½" and 2500g retain of 3/8'', was added in Los Angles Abrasion Machine along with 11 steel balls and for 500 revolutions drum was allowed to rotate at constant speed of 30-33 revolutions per/min. Then 1.7mm sieve was used to pass the material from machine through it and weight of sample passing was recorded as W2.

Abrasion Value = (W2/W1) *100

Fig. 3.7
Abrasion Machine

Test results of Aggregate

Test Type	Standard Value	Test Result	Specification
Impact Value	<30%	27%	BS-812
Los Angeles Abrasion Test	<45%	35%	ASTM-C-131
Shape Test			
Flakiness Index	<15%	4.5%	ASTM-D-4791
Elongation Index	<15%	2.7%	ASTM-D-4795
Specific Gravity		2.53	ASTM-C-127

Table 3.1 Test results of Aggregate

3.5 Test on Bitumen

With the preparation of control samples, we entered experimental phase of our research. After finding the optimum bitumen content in conventional mix, optimum RWF content was found following the presented study methodology. Lastly, a comparative analysis, based on performance evaluation, of both the mixes was then carried out and important conclusions are proffered. The tests made on the binder are as follows:

Penetration test
Ductility Test

Softening Point
Flash and Fire Point.

3.5.1 Penetration Test (AASHTO T 49-03)

The test which is used to determine bitumen's penetration grade under given conditions of loading, time and temperature by measuring the depth up to which a standard loaded needle will vertically penetrates into specimen in tenths of a millimeter is called penetration test. Softer the binder greater will be the value of penetration. According to AASHTO T49-03 temperature, until unless the situations are not explicitly, stated temperature used 25°C, 100 grams of load, while 5 seconds time for the test. Using two PARCO 60/70 specimens, five values from each specimen were taken after performing penetration tests. All values obtained fulfilled the required criteria as per specifications. Results of Penetration test are presented in Table 3.3.

Figure 3.8 Penetration Test Apparatus

3.5.2 Softening Point (AASHTO-T-53)

It can be defined as the temperature required to bring material to its degree of softness following standard conditions. Ring and Ball test is used for determination of bitumen softening point. For bitumen the two disks of bitumen soften adequate at average temperature to make steel balls (3.5 grams) to fall 25 mm. For softening point determination of asphalt as per AASHTO-T-53 specifications ring and ball apparatus was used.

3.5.3 Ductility (AASHTO T 51-00)

Ductility is defined as the maximum elongation/distance in cm without breaking with a specific speed of 5 cm per min and at a specified temperature of 25 ± 0.5 °C. Ductility value greater than the least limit of 100 cm was obtained by performing ductility test on different samples of bitumen.

Figure 3.9 Ductility Test

3.5.4 Flash and Fire point (D3143/D3143M-13)

Flash point is that least temperature at which the bitumen flashes momentarily under specific conditions.

Fire Point is that temperature at which specimen gets fire under specific conditions and burn. Flash and Fire point test was conducted as per D3143/D3143M-13 standards.

3.5.5 Viscosity test (ASTM D 4402 – 06)

Viscosity test is used to measure asphalt viscosity at elevated temperature range of 60 to over 2000 Celsius. A rotational viscometer uses the concept of torque. It measures the torque required to rotate an object submerged in fluid. (Asphalt in this case) and relates it to the viscosity of the fluid. This test is performed per the test standard ASTM D 4402 – 06.

Figure 3.10 Viscosity Test Apparatus

Test results of Bitumen

Test Type	Standard Value	Test Result	Specification
Ductility @ 25°C, cm	100 min	102	ASTM-113-99
Flash Point, °F	232	290	ASTM-D-92
Penetration @ 25°C,mm	60-70	63.11	ASTM-D-5-06
Specific Gravity	1.00-1.05	1.02	ASTM-D-70
Softening Point °C	49-56	49.2	ASTM-D-36

Table 3.2 Test results on Bitumen

3.6 Gradation Selection

For mix of surface course, we selected NHA gradation B following NHA (1998) Specifications. For this gradation following MS2 19mm is the nominal Maximum aggregate size. The gradation selected is shown in table 3.7 per percent passingagainst each sieve and corresponding gradation curve is plotted in Fig 3.16.

Sieve Size	Passing (%)	Retained (%)	Mass Retained (g)
19 mm	100	0	0
12.5 mm	82.5	17.5	200.9
9.5 mm	70	12.5	143.5
4.75 mm	50	20	229.6
2.38 mm	30	20	229.6
1.18 mm	10	20	229.6
0.075 mm	5.5	4.5	51.66
PAN	0	5.5	63.14

Table 3.3 NHA Gradation B

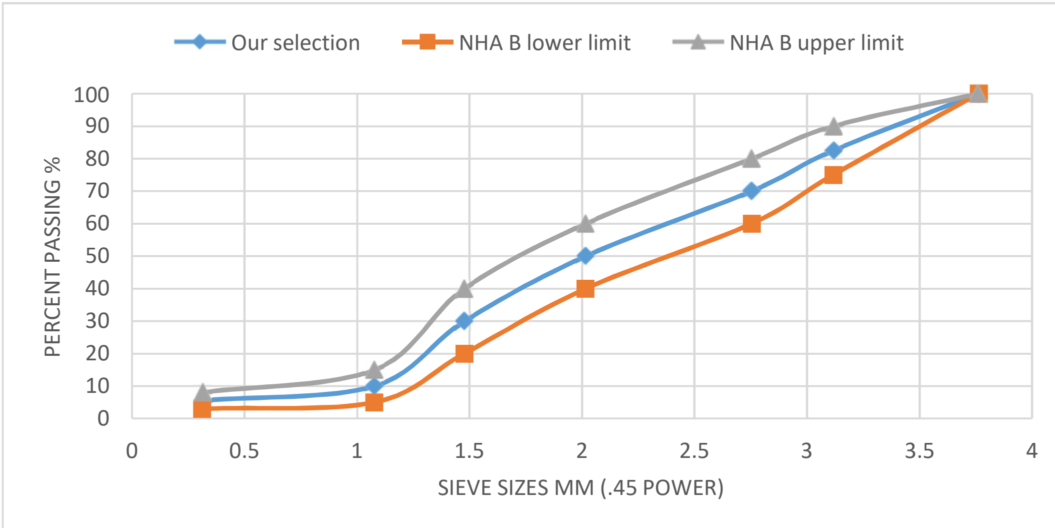


Figure 3.11 NHA Gradation B plot

3.7 Asphalt Mixture Preparation

Two types of asphalt mixtures are prepared, one is the controlled mix having only virgin aggregate, the other having varying percentage of RWF from 0% to 0.8%. The specimens without RWF are prepared to determine OBC.These specimens are prepared per Marshal Mix Design Procedure. After determination ofOBC, samples were prepared for Performance Testing.

3.7.1 Preparation of Bituminous Mixes for Marshall Mix design

There are five categories of sample in the research. OBC was determined for each category i.e. samples having 3%, 3.5%, 4%, 4.5%, 6% bitumen content. Marshall Stability, flow and volumetric properties were measured to obtain OBC for each Category of Sample. The Test Matrix for determining OBC is shown in table 3.9.

Bitumen	No. of Samples
3%	3
3.5%	3
4%	3
4.5%	3
5%	3

Table 3.4 Test Matrix for determination of OBC

3.7.2 Preparation of Aggregate and Bitumen

After sieving the Aggregate into different sizes required for the project, these aggregates were then oven dried at 110 °C. The total sample weight of Marshall mix is 1200gm.The weight of Asphalt Cement varied according to its percentage which is from 3% to 5% of mix. The aggregate then used is composed of different sizes according to gradation used.

Figure 3.12 Preparation of Aggregate

3.7.3 Mixing of Aggregate and Asphalt

For Controlled Samples, asphalt cement is first heated to around 150 °C then oven dried aggregate is mixed with it. Keep mixing until homogenous mix is formed.

Figure 3.13 Asphalt Mixing

3.7.4 Compaction of Specimen

According to Marshall Mix design, there are three criteria for compaction depending on either the surface is prepared for light, medium or heavy traffic. In this project wo have designed pavement for heavy traffic so 75 blows on each side ofspecimen are applied to achieve compaction. The loose mix obtained from heating aggregate with bitumen is transferred to mold have base plate. A filter paper was placed below and above the specimen. After achieving 75 blows on one side, specimen was inverted, and 75 blows were applied on other side of specimen. This compaction was achieved by Manual Compaction.

Figure 3.14 Marshall Samples

3.8 Determination of OBC

After the cooling of Specimen to room temperature the volumetric of specimen are calculated by determining G_{mb} and G_{mm} values. The tests for G_{mb} and G_{mm} are performed following standards ASTM D2726 and ASTM D2041 respectively. For determination of G_{mb} firstly weight in air of specimen is determined, after which its weight in water and SSD weight are determined.

After the determination of G_{mb} the specimen is transferred to water bath at 60 °C for 30minutes then analyzed for Marshall Stability and flow using Marshall Equipment. After placing the sample in Marshall Apparatus, it is loaded at constant deformation rate of 2 inch/min till the specimen fails. The maximum load that the specimen takes is its Stability value and the strain value because of maximum load is noted as flow number. According to Marshal mix design Criteria MS-2, for surface designed for heavy traffic load should have Stability value greater or equal to 8.006 KN and value of flow should lie in range of 2mm to 3.5 mm.

Figure 3.15 Marshall Samples being placed in water bath.

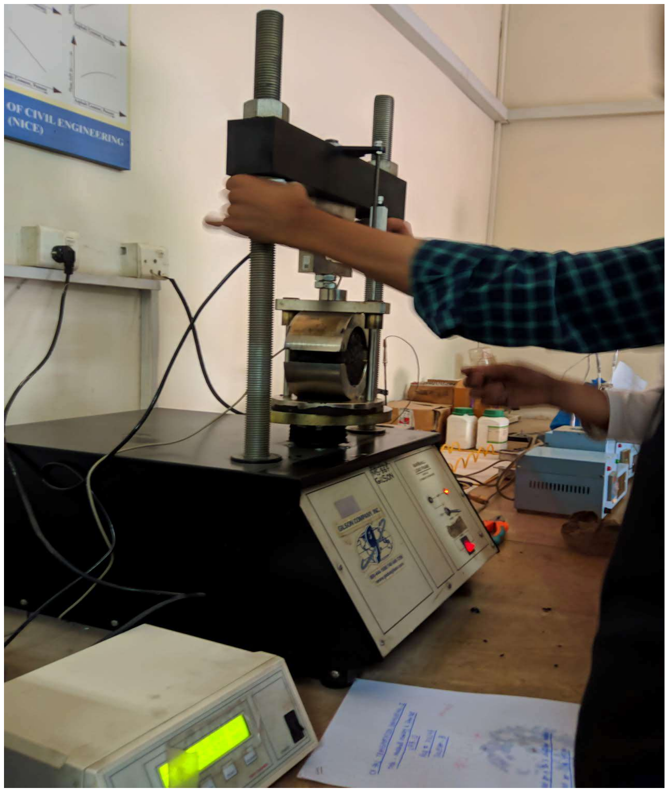


Figure 3.16 Marshall Stability and Flow Test

For G_{mm} calculation weight the loose mix, then find the calibration weight of apparatus, after that transfer the mix to apparatus and apply vacuum. After the removal of air entrapped in mix weigh again the apparatus containing mix also.

Figure 3.17 G_{mm} Determination

3.8.1 Volumetric properties of mix

The flow values and stability values of controlled mix are shown below.

Bitumen %	VA%	VMA%	VFB%	Stability (kN)	Flow (mm)
Normal Values	3-5	min 13	65-75	min 8	8-14
Optimum (4.33%)	4	14.32	71.95	8.2	12.8

Table 3.5 Volumetric Properties

The graphs of Asphalt content verses different volumetric properties to find out OBC are shown in figure 3.18.

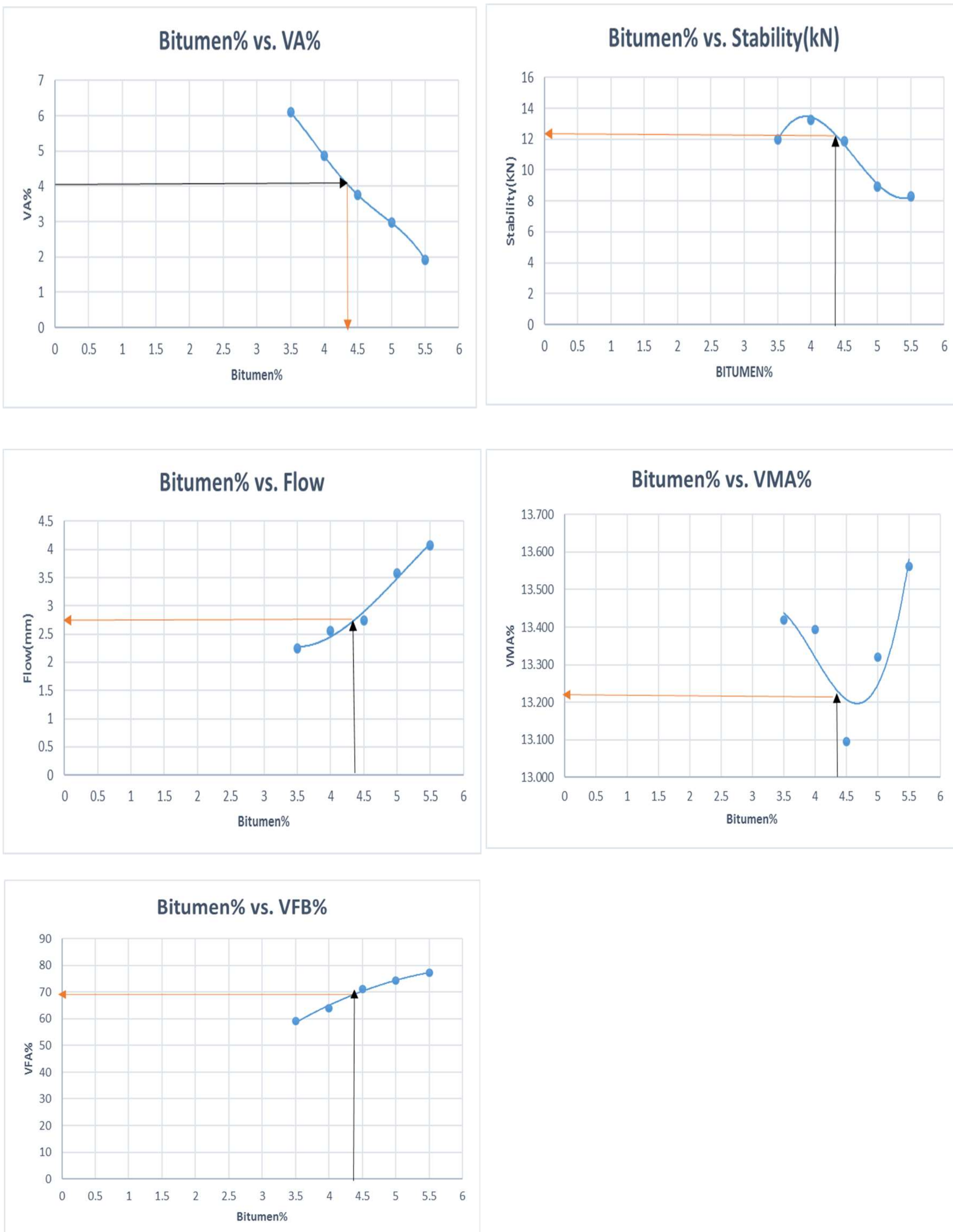


Figure 3.18 Graphs

3.9 Preparation of Sample for Performance Tests

After finding out OBC at different percentages of bitumen, performance tests samples were prepared.

3.9.1 Moisture Susceptibility

The Moisture Susceptibility test samples were prepared according to ALDOT 361, for which Marshall sample having 2.5” height and 4” diameter was prepared. These samples falls into 2 categories; one without RWF and other containing bitumen with RWF percentage.

Rock Wool %	0%	0.4%	0.6%	0.8%
Conditioned Samples	2	2	2	2
Unconditioned Samples	2	2	2	2

Table 3.7 Test Matrix for Moisture Susceptibility Test

3.9.1.1 Preparation of Samples with RWF

Sample having RWF were prepared as the procedure used for preparing sample to determine OBC. As RWF is an allergic material and can cause rashes so we used it with strict precautions. Firstly, aggregate and RWF (in shredded form) were heated and dry mixed and then bitumen was added. Aggregate were first oven dried at 110 °C then mixed with RWF and bitumen at 160 °C. The compaction was achieved at 130 °C.

3.10 Moisture Susceptibility Testing

The moisture susceptibility test was performed according to ALDOT 361-88. For each percentage of RWF there were 2 set of samples to be tested. One sample was unconditioned sample. These specimens were only kept in water bath at 25 °C for 1 hour after that test was performed. For other set namely conditioned samples, these sample were kept in water bath for 24 hours day at 60 °C and after that at 25 °C for 1 hour. Both sets of samples were then placed in machine at which load at rate of 50mm/minute is applied. The maximum load was noted at failure and tensile strength wasdetermined accordingly to the formula given below. Then the TSR ratio was determined by dividing conditioned sample's average tensile strength to that of unconditioned sample. This ratio should be minimum of 80% for satisfying the criteria of performance.

The tensile strength can be found from given Equation:

$$St = 2000P/\pi Dt$$

Here:

St. = Tensile strength

P = Maximum load

t = Specimen height before tensile test

D = Specimen diameter

TSR indicates the damage potential because of moisture to pavement, TSR is the ratio of conditioned sample tensile strength to that of unconditioned samples. TSR for each subset of specimen can determined from given TSR equation.

$$TSR = \text{Tensile Strength Ratio} = S2/S1$$

Here:

S1 = Unconditioned Sample average tensile strength, and

S2 = Conditioned Sample average tensile strength

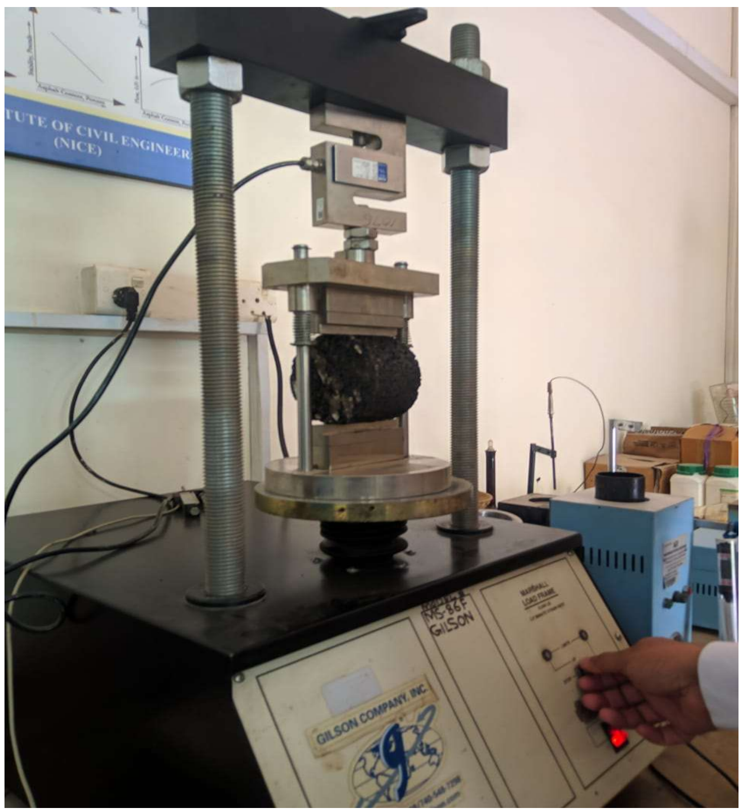


Figure 3.19 ITS testing using UTM

3.11 Summary

This chapter explains the testing of Aggregate and Bitumen. The material satisfying the criteria was then used to prepare Bituminous Mix samples. The volumetric properties of mix were calculated and OBC was determined. The OBC determined was then used to prepare samples with and without Rock Wool for performance testing i.e., Moisture Susceptibility. In the end of Chapter Moisture Susceptibility methods were elaborated.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

The study is based on incorporating Rockwool with percentages of 0.4%, 0.6%, 0.8% and their comparison with HMA sample with 0% Rockwool and find their effect on moisture susceptibility using TSR tests. Aggregates for said Asphalt Mix development were acquired from Margallah Crush Site. The aggregate used in the Marshall Mix were graded according to NHA B Classification. Bitumen used were provided by PARCO Oil Refineries LTD and the Rockwool used for enhancing the properties of Asphalt pavement was provided by INCOM ROCKWOOL LTD.

In this chapter we are going to show different test results i.e., Moisture Susceptibility. Detailed discussion about the tests were done in the previous chapter. Tests were performed on HMA containing different Rockwool percentages as discussed earlier. After tests on both samples with Rockwool percentages and virgin samples, their properties against moisture susceptibility were compared.

4.2 Moisture Induced Damage (TSR) Results

For TSR testing, samples were made and tested using standard ALDOT 361-88. For Hot Mix Asphalt having different samples containing different amount of Rockwool 2 samples were made for conditioned and for unconditioned testing 2 samples were made separately. For the unconditioned testing, samples were tested dry while the conditioned sample were tested after placing them for 24 hours in a water bath at temperature of 60°C and then for 2 hours at 25°C.

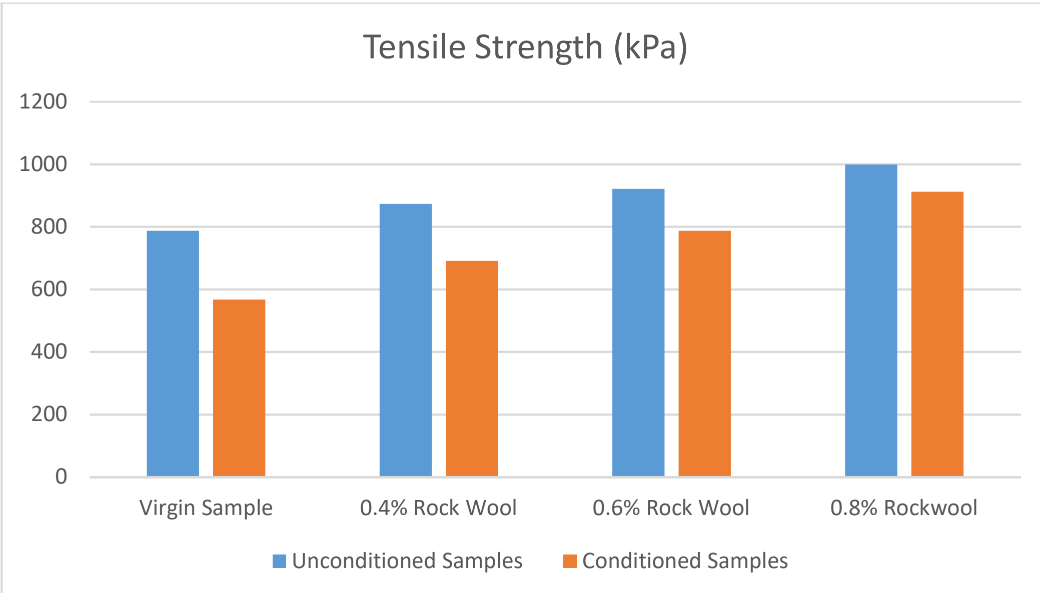
Increasing tensile strength ratio trend was observed against moisture susceptibility with increasing percentage of Rockwool. Also, the minimum value of TSR which is 0.7 is also satisfied. The trend was observed due to hardening of mix design as rockwool has bonded Asphalt and aggregate well which made it thicker with time. The sample behaves strongly under tension because increased viscosity and because of harsh moisture conditions and high temperature increased viscosity which will cause less reduction in tensile strength. Results of TSR are shown in form of table:

Rockwool (%)	Height (mm)	Mean(mm)	Diameter (mm)	Load (kN)	Mean Load(kN)	Tensile Strength (kPa)
0	64.77	65.41	101.6	8.11	8.22	786.79
	66.04			8.33		
0.4	66.04	66.04	101.6	9.42	9.21	873.41
	66.04			9.04		
0.6	66.04	66.12	101.6	9.44	9.73	921.30
	66.19			10.55		
0.8	66.04	66.04	101.6	10.22	10.53	998.98
	66.19			11.12		

Table 4.1 Tensile Strength Results for HMA containing Rock Wool (Unconditioned Sample)

Rockwool (%)	Height (mm)	Mean(mm)	Diameter (mm)	Load (kN)	Mean Load(kN)	Tensile Strength (kPa)
0	64.77	65.41	101.6	5.89	5.92	567.30
	66.04			6.32		
0.4	66.04	66.04	101.6	7.14	7.29	690.93
	66.04			7.47		
0.6	66.04	66.12	101.6	8.21	8.31	787.44
	66.19			8.52		
0.8	66.04	66.04	101.6	9.22	9.62	912.20
	66.19			10.14		

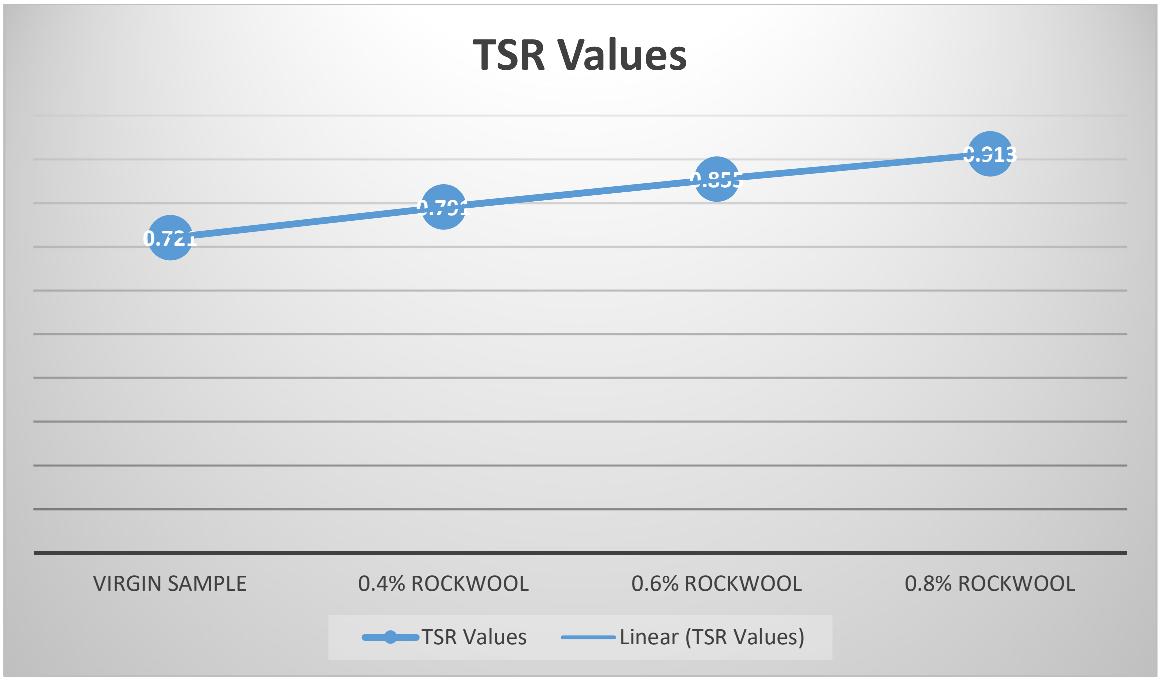
Table 4.2 Tensile Strength Results for HMA containing Rock Wool (Conditioned Sample)



Graph 4.1 Tensile Strength Comparison

Rockwool (%)	Conditioned Strength (kPA)	Unconditioned Strength (kPA)	TSR Value
0	567.3	786.79	0.721
0.4	690.93	873.41	0.791
0.6	787.44	921.3	0.855
0.8	912.2	998.98	0.913

Table 4.3Tensile Strength Test Results for HMA containing Rock Wool



Graph 4.2 Tensile Strength Ration Trend

4.3 Summary

In this chapter results were shown, and detailed analysis was done on the results of performance testing. The results obtained were discussed in reference to increase in Tensile Strength Ratio values. Table and graph were presented so we can be analyze data based on TSR testing. Comparison of lab results obtained from the Moisture Susceptibility testing with increasing Rockwool content with and without conditioned samples were presented and discussed in detail which shows an increase in Tensile strength value with the increasing percentage of Rockwool.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Our project was focused on to measure the efficiency of Rockwool in different proportions which are 0.4%, 0.6% and 0.8% in Hot Mix Asphalt. Moisture Susceptibility is the major concern which cause the pavement to damage most effectively. Rockwool is used in the pavement mix to protect it from water. In this project bitumen of grade 60/70 was provided by PARCO Oil Refineries, NHA Class-B Wearing aggregate was acquired from Margallo Crushing sites. Rockwool used in varying proportions was provided by INCOM ROCKWOOL LTD Karachi. For determining Optimum Bitumen Content Marshall Mix method was utilized with varying percentages of 3%, 3.5%, 4%, 4.5%, and 5%. After the determination of Optimum Bitumen content Marshall Mix samples were made using the appropriate amount of Rockwool in samples. After that Moisture Susceptibility was checked using TSR method and results were compared with that of virgin samples. The key findings of Tensile Strength Ratio testing, their results and conclusions are explained here.

5.2 Conclusions

After analysis of results explained in the previous chapter, we concluded that:

- Criteria for Optimum Bitumen Content was set at 4% air voids and OBC calculated was 4.33%. Other properties were also well within their ranges.
- In Unconditioned samples the Tensile strength was increased from 786.79 to 873.41 KPa using 0.4% Rockwool which is about 11%, and to about 998.98 KPa which is about 28% increase in Tensile Strength as compared to a sample having no Rockwool content.

- In Conditioned samples the tensile strength was increased from 567.30 to 787.44

KPa using 0.6% Rockwool in Marshall Mix sample which is about 39% increase and to about 912.20 KPa which is about 61% increase in Tensile Strength as compared to sample having no Rockwool content.

- The mixture reinforced with Rockwool have higher Tensile Strength as compared to sample with 0% Rockwool content. Which indicates higher loading capacity of Asphalt concrete. Thus, Asphalt Pavements thickness can be reduced.

- Asphalt Concrete containing Rockwool content depicts durability which in turn increases the life of Asphalt Pavement as well as reduces the maintenance cost of the roads.

5.3 Recommendations

Following recommendations are being laid considering results and conclusions:

- In the project for determination of specimen's moisture susceptibility Tensile Strength Ratio (TSR) tests was performed. Other tests such as Dynamic Creep Testing for Rutting, Stiffness modulus, and fatigue testing has been done in the past. It is recommended to test Asphalt concrete against Rutting and Fatigue as in the prevailing condition of Pakistan.
- Further studies are recommended for finding the increased life of Asphalt Concrete using Rockwool content. It is also recommended to study fatigue life under strain-controlled conditions and finding the effect of different gradations on performance of Asphalt Concrete using Rockwool.
- After this study it is highly recommended to study the effect of Rockwool on Asphalt Concrete by increasing the amount of Rockwool percentages i.e., 1%, 2%
- It is also suggested to initialize a chemical study of Rockwool Asphalt Concrete so that any agent causing improvement can be found. In this way more amount of rockwool can be utilized enhancing the properties of Asphalt Concrete.
- Keeping in view the results of the lab testing and study we recommended without

any doubt that Rockwool can be used in Asphalt Concrete as an additive to enhance both volumetric and performance properties.

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APPENDICES

Marshall Mix Design Report

		Mass, grams of compacted Specimen					Mass, grams of loose Mix							Stability, (KN)	
% AC by wt. of mix, Spec. No.	Spec. Height in. (mm)	In Air (A)	In Water (C)	Sat. Surface Dry in Air (B)	B-C	Bulk S.G. Specimen (Gmb)	Dry Weight (a)	Calibration Weight = wt: of Pycnometer	wt: of Sample + Water + Pycnometer and Lid	Max. S.G.	Air Voids%	% VMA	% VFA	Stability, (KN)	Flow mm
3.0-A	70.485	1185	694.4	1208.4	514	2.305	1174	6332	7046	2.55	9.67	14.57	33.64	9.80	2.01
3.0-B	66.675	1195	694	1216.6	522.6	2.287				2.55	10.33	15.27	32.35	10.40	2.03
Average											10.00	14.92	32.99	10.10	2.02
3.5-A	66.04	1179.2	695.5	1200	489	2.337	1210.3	6332	7058	2.50	6.47	13.80	53.13	11.80	2.24
3.5-B	69.85	1156	676.6	1177.1	496.4	2.310				2.5	7.61	14.83	48.65	12.40	2.25
Average											7.04	14.31	50.89	12.10	2.24
4.0-A	56	867.1	507	874	493.7	2.363	1165	6332	7025.3	2.47	4.34	13.29	67.37	10.50	2.82
4.0-B	66.04	1161.6	683	1184.9	496.2	2.314				2.47	6.30	15.06	58.18	11.49	2.86
Average											5.32	14.18	62.77	11.00	2.84
4.5-A	70.167	1230	719	1238	495.5	2.35	1196	6332	7036	2.43	3.33	14.17	76.51	9.50	3.24
4.5-B	64.8	1218	713	1235	495.9	2.35				2.43	3.29	14.17	76.76	10.30	3.65
Average											3.31	14.17	76.64	9.90	3.45
5.0-A	66.36	1206.5	689	1212	490.6	2.307	1208	6332	7030.5	2.37	1.96	16.14	87.88	8.50	3.86
5.0-B	63.5	1183.9	696	1197.3	489.5	2.362				2.37	1.77	14.14	87.45	9.13	4.13
Average											1.87	15.14	87.66	8.82	4.00

Worksheet for Volumetric Analysis of Compacted Paving Mixture

(Analysis by Weight of Total Mixture)

Sample:

Identification: Margalla

Composition of Paving Mixture

	Specific Gravity, G			Mix Composition, % by Wt. of Total Mix, P					
			Bulk		Mix or Trial Number				
					1	2	3	4	5
1. Coarse Aggregate	G1		2.632	P1	48.50	48.25	48.0	47.75	47.50
2. Fine Aggregate	G2		2.618	P2	48.50	48.25	48.0	47.75	47.50
4. Total Aggregate	G4	---	2.625	Ps	97.0	96.50	96.00	95.50	95.00
5. Asphalt Cement	G5	1.03	-----	Pb	3.0	3.5	4.0	4.5	5.0
6. Bulk Sp. Gr. (Gsb), total aggregate					2.625	2.625	2.625	2.625	2.625
7. Max. Sp. Gr. (Gmm), paving mix					2.508	2.489	2.482	2.467	2.448
8. Bulk Sp. Gr. (Gmb), compacted mix					2.355	2.369	2.389	2.395	2.401
9. Effective Sp. Gr. (Gse), total aggregate					2.646	2.645	2.659	2.663	2.661
10. Absorbed Asphalt (Pba), % by wt. total agg.					0.307	0.299	0.496	0.553	0.534
CALCULATIONS									
11. Effective Asphalt content (Pbe)					3.204	3.713	4.026	4.475	4.995
12. Voids in Mineral Aggregate, VMA (percent of bulk vol.					14.91	14.31	14.17	14.15	15.14
13. Air Voids (Va)					10.04	7.02	5.31	3.37	1.55
14. Voids Filled with Aggregate, VFA					32.71	50.92	62.5	76.21	89.78