DURABILITY ANALYSIS OF POROUS ASPHALT WITH ADDITION OF RECYCLED ASPHALT PAVEMENT

FINAL YEAR PROJECT UG 2018

BY

M.Talha	NUST BECE2018 - 242498
Zohaib Anwar	NUST BECE2018 - 243194
M.Faseeh	NUST BECE2018 - 242655
Faisal Hamid	NUST BECE2018 – 267640

Advisor: Dr. Arshad Hussain

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology, Islamabad,Pakistan

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This is to certify that the

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M. Talha	NUST BECE2018 - 242498
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M.Faseeh	NUST BECE2018 - 242655
Faisal Hamid	NUST BECE2018 - 267640

has been accepted towards the requirements for the undergraduate degree

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CIVIL ENGINEERING

Dr. Arshad Hussain
Assistance Professor
HOD Transportation
NUST Institute of Civil Engineering
School of Civil and Environmental Engineering
National University of Sciences and Technology, Islamabad, Pakistan

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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ABSTRACT

Transportation infrastructure plays a crucial part in the everyday life of social beings. For its design, highway agencies focus on acceptable and cost-effective design technique. For this goal, engineers are experimenting with porous pavements, and via accommodation of Recycled Asphalt Pavements the infrastructural wastes can be decreased. The usage of RAP will not only limit the consumption of our natural resources but also help in repurposing the waste materials for a beneficial purpose, meeting economic and environmental friendly needs of a country.

Pavements over time becomes damaged by rutting, fatigue, Durability Analysis render it unfit for automobiles. Therefore, it is required to have such design which are cost effective and environment friendly. The usage of Recycled Asphalt Pavement acts as a significant component in reaching national prosperity. This project is based on analysing the performance of Porous Asphalt by employing varying quantities of Recycled Asphalt Pavement as an additive in Asphalt Concrete.

NHA grade B, PARCO grade 60/70 Bitumen and RAP from the G-13 Reconstruction Project were employed in this investigation. On virgin bitumen, penetration, ductility, and temperature tests were performed. The RAP contents used were 10%, 20%, and.30%. After determining the OBC, volumetric, stability, and flow of AC mixes, performance testing was performed. Using those OBC and adding RAP as an addition in bitumen, several samples were made and tested for evaluation, and the results were compared to the performance testing results of AC mixes without RAP. Analyze Durability Porous Asphalt Pavement is tested to see how its durability compares to Porous Asphalt.

Key words

- Porous Asphalt
- Recycled Asphalt Pavement (RAP)
- Durabilty
- Raveling
- Strength

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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

PA –Porous 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

RAP – Recycled Asphalt Pavement

CHAPTER 1: INTRODUCTION

1.1 Background

The climate of the southern and western parts of Pakistan is very dry. An exceptionally large area receives an annual rainfall of less than 150 mm. Due to lack of infrastructural capacity Pakistan, most of the water during precipitation is lost as Surface runoff. This runoff is greater on paved surfaces. There it causes hydroplaning. Hydroplaning is the cause of an extensive number of accidents, where vehicles slip and lose control. Another challenge that rainfall brings to the drivers is the splashing and spraying effect on the windshields, as a courtesy from the leading vehicles. In Japan, porous asphalt technologies were introduced in accident prone areas with high amount of rainfall. The accident ration in the city of Osaka dropped from 72% in wet conditions to 61.2%. A similar approach was adopted in San Francisco and Las Angeles where the rates dropped significantly as a result of reduction in the splash and spray effect.

1.2 Problem Statement

Failure of pavement is result of severalfactors like stress because of heavy vehicles, water intrusion, seasonal temperature changes causing expansion and contraction, and sun exposure. For the residents and owner sudden failure of pavement structure can be frightening and dangerous, theformation of sinkhole and other structural problems of pavement can add to that fear. Moreover, potholes raise a question about drive safety and drive comfort. During rainfall, vehicles create a splash and spray effect that minimizes the visibility of the drivers. This leads to wet road accidents and fatal damages. These types of accidents cost the state around 1 billion rupees annually. The overall strength of the porous asphalt pavement is relatively lower than that of the hot mixed or warm mixed technologies. In order to accommodate this gap, locally available RAP can be utilized to reduce the quantity of infrastructural waste.

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 RAP (Recycled Asphalt Pavement) as an additive in PAP (Porous Asphalt Pavement). The reason of choosing RAP as an additive is because of its properties. Those properties whichare deficient in Porous Asphalt Pavement can be covered by using some optimum amount of RAP. Also because of RAP properties the road problems will be addressed and will reduce the maintenance and operational cost. We wish to examine the durability of Porous Asphalt Pavement after the addition of RAP.

1.4 Research Objective

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

- To assess Durability Analysis of Porous Asphalt Pavement with and without Recycled Asphalt Pavement(RAP).
- To Reduce maintenance costs by using RAP 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, Recycled

Asphalt,their possible use in Porous Asphalt 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 RAP in pavement andproblems associated with it. Finally, it includes research of different test methods used forDurability Analysis.

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. Futurerecommendations are also discussed.

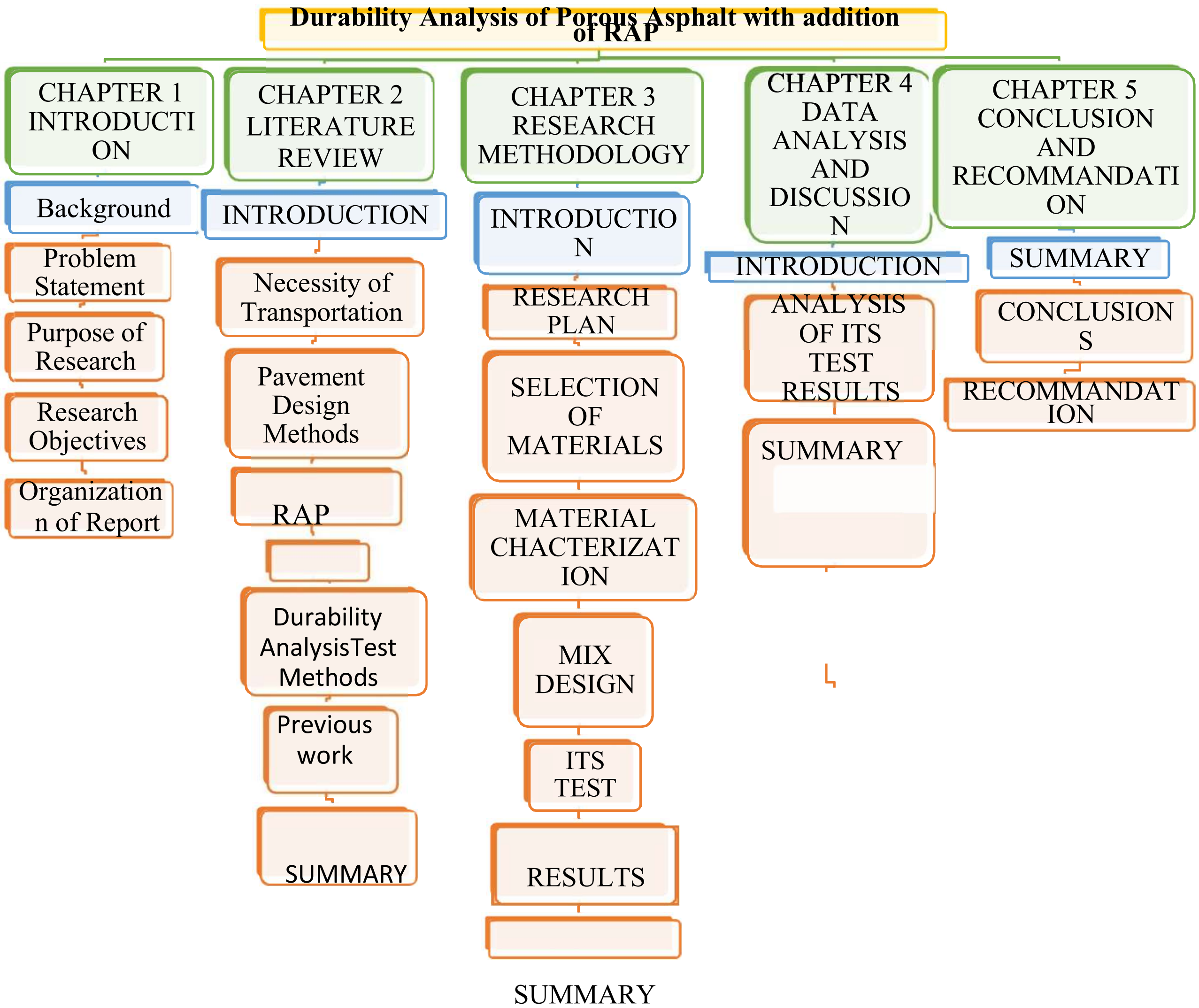


Figure 1.1: Organization of Report

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 Recycled Asphalt Pavement, previous works on incorporating it in pavement and the results of doing so. This chapter also discusses response of Porous Asphalt pavement having RAP and previous works on it. The details of Durability Analysis 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 2018-2022 Government.

2.3 Flexible Pavements

Flexible pavements have a bituminous or asphaltic surface over one or more layers of aggregates, such as unbound base courses lying over a bed of compacted granular material consisting of subgrade. Its strength is derived from the load-distributing properties of a layered system designed to eventually safeguard each underlying layer, including the subgrade, from compressive shear collapse.

The design of a flexible pavement based on the load distribution characteristics of a multilayer system is designed to ultimately protect each underlying layer, including the sublayer, from compression slippage as the magnitude of the load increases. decreases when passing from the surface to the interior. Subsoil that, via repeated layers, is more weather-resistant and environmental-resistant employed in a bituminous upper layer intended to resist fatigue failure and exhibit stability under traffic load when pavement temperature is exceeded.

Figure 2.1 Typical conventional pavement cross section

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 2 % to 4% 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 corresponds to optimal stability.
2. Bitumen content equivalent to maximum bulk specific gravity (G_m)
3. Bitumen content proportional to the median of designed limits of % air voids (V_v) in the total mix (i.e., 20%).

2.4 Recycled Asphalt Pavement

It includes Recycled Asphalt fragments, which is produced as the road is destructed and new foundation is to be laid. Sometimes, the same fragments are reused for the construction of new pavements. The thermal conductivity, moisture content, and mass density are respective to the ingredients of the primary asphalt mixture.

2.4.1 Recycled Asphalt Pavement Characteristics

The properties and characteristics of Recycled Asphalt such as strength, holding capacity of moisture or hygroscopic property and the gradient of moisture from top to bottom of growing slab. By just changing these RAP characteristics, different RAP products for different uses can be made availble in market. The already bitumen-coated aggregate allows better binding and cohesion properties.

2.4.2 Previous work

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

Pakistan has an annual rainfall of 297.5 mm (169384 billion cubic meters). Most of this rainfall ends up as surface runoff from roads and paved surfaces. In a country like Pakistan, where the reserve water capacity is 30 days. The total wastage per year is 10 trillion gallons. Porous asphalt is suitable for such situation but the strength is low.

Around the globe, Research on Recycled Asphalt Pavement as an additive is going on. Means the world is using the RAP for some beneficial purpose. This project is focused on replacing the fine aggregate with RAP to make some improve the strength.

2.4.3 Problem Statement

Failure of pavement is result of severalfactors like stress because of heavy vehicles, water intrusion, seasonal temperature changes causing expansion and contraction, and sun exposure. For the residents and owner sudden failure of pavement structure can be frightening and dangerous, the formation of sinkhole and other structural problems of pavement can add to that fear. Moreover, potholes raise a question about drive safety and drive comfort. During rainfall, vehicles create a splash and spray effect that minimizes the visibility of the drivers. This leads to wet road accidents and fatal damages. These types of accidents cost the state around 1 billion rupees annually. The overall strength of the porous asphalt pavement is relatively lower than that of the hot mixed or warm mixed technologies. In order to accommodate this gap, locally available RAP can be utilized to reduce the quantity of infrastructural waste.

2.4.4 Literature Review

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

In 2012 a durability related examination into porous asphalt was made to explore the influence of age hardening on the binder cohesive characteristics and the implications on the mixture performance. The long life in porous asphalt depends upon the degree of movement of aggregate and the association between movement of aggregate in porous asphalt and tensile strain exists and completed wheel tracking test. Three-dimensional crack studies, photography assessed by camera and water permeability test are excellent approaches to quantify the degree of damage for porous asphalt. The tensile strain of porous asphalt under wheel tracking test was created by the movement of aggregate and it was caused to a fracture in porous asphalt.

In 2019 , the study on durability of Porous Asphalt Mixtures was done to verify the ravelling resistance and the abrasion resistance of the Porous Asphalt by adding steel slag Electric arc furnace slag (EAFS) and Ladle furnace slag (LFS) (LFS). It reveals that loss in abrasion results' fulfilled the norms for the heaviest loads, but inserting the slags provided a little inferior performance than the conventional mixes, which could be attributable to the increment in porosity of the slag mixes. Steelmaking slag combinations were more porous and permeable than the usual mixtures.

In 2013, a study was carried out on how porous asphalt durability is impacted by adding percentage (15 percent) of coarse RA aggregates to the mix. Moreover, the influence of the performance of recycled porous asphalt mixtures on varied total binder contents has been investigated. 15 percent Recycled Asphalt Pavement was used to put in the mixture. Mechanical properties of the examined mixes were tested under both dry and wet conditions in order to analyse also the performance degradation owing to water damage. It was shown that the adhesion strength at the aggregate–binder interface improves in both dry and wet circumstances utilising coated aggregates emulating RA aggregates. Moreover, the loss in performance because of water suffered by the virgin aggregate is more than double what the loss encountered by the coated aggregate. In terms of water sensitivity, all the recycled combinations can perform as well as (or even better than) the reference one, except for the mixture containing low (inadequate) binder concentration (4.50 %).

In 2014, the Effect of Crumb Rubber Particle Size on the Optimal Binder Content for Open Graded Friction Course was discovered. Rubber size, rubber content, and binder content relationships in determining optimum binder content for open graded friction course (OGFC). Higher rubber content raises the viscosity of bitumen, which raises the film thickness and, as a result, lowers the vacancy in the mix. Coarser rubber crumb has a smaller window of optimum binder content selection. Higher binder and crumb rubber content can be employed as the mesh size lowers.

In 2007 , durability related investigation into porous asphalt was madeto study the effect of age hardening on the binder cohesive properties and the implications on the mixture performance. Short term aging and long term aging bitumen were considered. Upcoming conclusions can be drawn based on the interpretations of the test results. Aging has a positive influence on PA performance at intermediate and high temperatures. It minimizes possible drainage of the bituminous mortar and improves the stability of the mix. The conventional lab binder aging method does not simulate long term field aging of PA. A new aging method is crucial for PA. The relaxation potential of the binder is an important factor for enhanced performance of PA at low temperatures. Aging reduces the relaxation potential and increases the stiffness of the binding material (mastic/mortar).

High-viscosity modified asphalt mixes for double-layer porous asphalt pavement in 2021: Design optimization and assessment metrics to extend the life of the porous asphalt pavement's base asphalt binder (PG64-22). To make high-viscosity asphalt binder, modified asphalt was used. Softening point, ductility, and penetration tests were performed in this investigation. The softening point and ductility of asphalt binders rise as the dosage of high-viscosity modifier increases, whereas penetration decreases. The softening point, ductility, dynamic viscosity at 60 °C, and rotational viscosity all rise while penetration falls. The use of a high-viscosity modifier improves the rutting resistance, low-temperature performance, and moisture stability of a porous asphalt mixture significantly.

In 2020, State-of-the art of porous asphalt pavement: Experience and considerations of mixture design and its objective was to investigate the four main components of PA mixture design and analysing the influence of different contributing factors based on international experience. The mix design of PA also varies internationally. Cantabro abrasion test is performed for the abrasion performance of PA as a standard test. The Hamburg wheel tracking device (HWTD) is widely used to predict the rutting potential and moisture susceptibility of PA mixes. In Binder drain drown, the allowable drain down of PA mixture should be limited to less than 0.3 percent. Drain down testing is performed using the Beaker Method, Basket Method, and Enamel Plate Method. PA is a separate mixture type that was purposefully developed to be an open-graded structure with a high percentage of interconnecting air spaces and a coarse granular skeleton with stone-on-stone contact.

In 1990 , analysis on ten Years' Experience of Porous Asphalt in Belgium was carried out to discuss various aspects of use of PA i.e. mix design, the influence of binder type, winter behavior, acoustic properties etc. Bitumen with newly manufactured elastomers (mainly SBS), Bitumen with recycled elastomers (bitumen admixed with powdered rubber and an aromatic oil). Aggregates to be gap graded for porous asphalt to be manufactured. The order of entry into the mixer during manufacturing of PA (Porous Asphalt). The noise reduction is related to the high sound absorption. Coefficient of the material. The coefficient varies with sound frequency and is most favorable at about 1000 Hz. Other aspects include structural contribution, winter serviceability and clogging. Porous asphalt makes it possible to improve road safety in a number of critical cases and, by reducing rolling noise, contribute to the comfort of both road users and frontages.

2.5 Summary

In the above chapter, it can be established that multiple studies have been made in order to study the durability and composition of porous asphalt pavements. Some researchers are based on experiences that extend from between 10 to 14 years of experience in use of porous asphalt pavement. It also includes a durability related study on the porous asphalt. This entails Three-dimensional crack studies, camera photography, and water permeability tests are all helpful ways for determining the extent of damage in porous asphalt. The tensile strain of porous asphalt during the wheel tracking test was produced by aggregate movement, which resulted in a crack in the porous asphalt.

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 RAP. 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 RAP. Performance testing includes Durability Analysis. 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 RAP was procured from site of reconstruction IJP Road Rawalpindi. These materials were then brought to laboratory of NUST INSTITUTE OF TRANSPORTATION (NIT) and different tests of aggregate and bitumenwere 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.

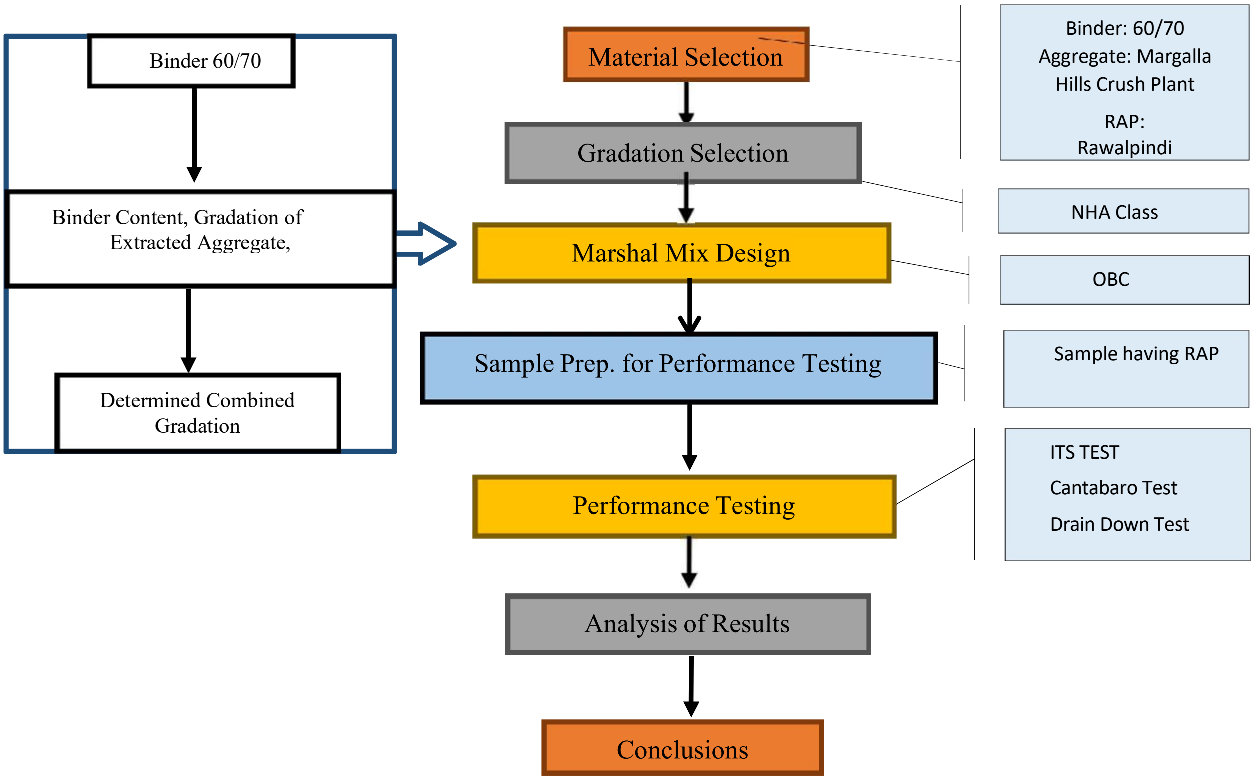


Figure 3.1: Research Methodology

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) Islamabad Collection Point.

3.3.3 Recycled Asphalt Pavement (RAP)

Recycled Asphalt is available along any road site that is undergoing reconstruction. It is abundant amounts in an infrastructurally developing country like Pakistan. Therefore, we faced minimal difficulty in its procurement. In Rawalpindi, the main IJP Road was under reconstruction. We personally visited the site and we procured around 15 kgs of RAP from there.

Figure 3.3: Recycled Asphalt Pavement

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 impacttesting 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

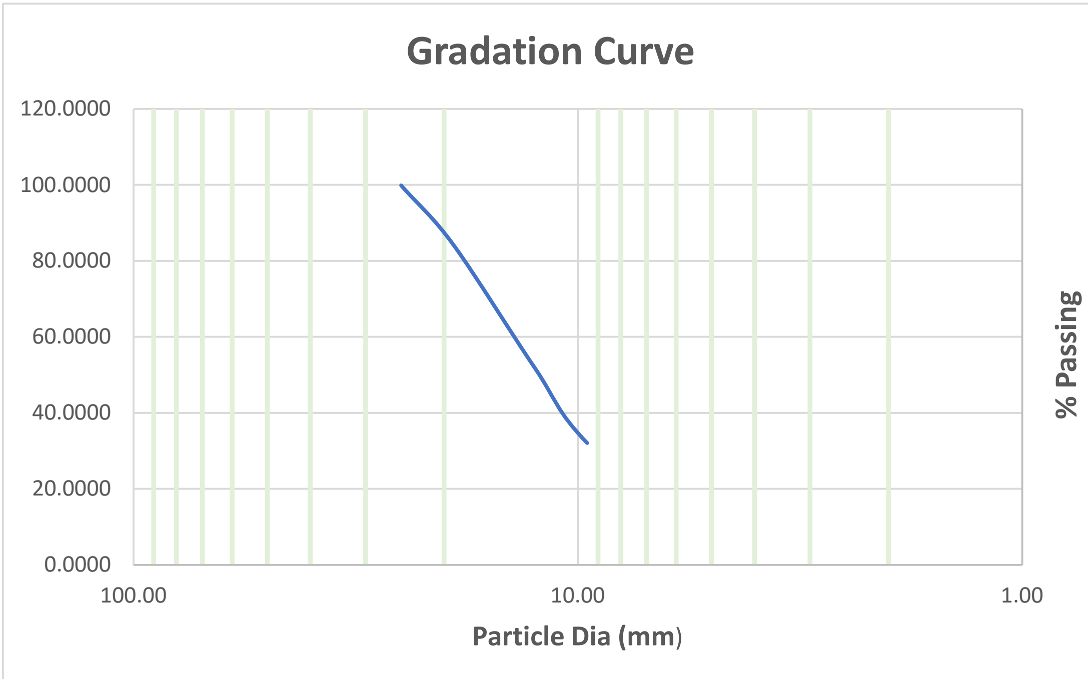
Test results of Aggregate

Table 3.1 Test results of Aggregate

TEST TYPE	STANDARD VALUE	TEST REULTS	SPECIFICATION
Elongation Test	<15%	1.8%	ASTM-D479
Flakiness Test	<15%	6.34%	ASTM-D-4791
Impact Value Test	<30%	15.21%	BS-812
Abrasion Test	<30%	20.26%	ASTM-C-131
Specific Gravity	-	2.74	ASTM-C-127

Sieve Analysis:

Sieve Number	Diameter (mm)	Mass Retained	Accumulative Retain (gm)	% Mass Retain	% Passing
1 in	25.00	21	21	0.0761	99.9239
3/4 in	19.00	4384.5	4405.5	15.9620	84.0380
1/2 in	12.50	8901.8	13307.3	48.2149	51.7851
3/8 in	9.53	5431	18738.3	67.8924	32.1076
# 4	4.75	8630	27368.3	99.1605	0.8395
Pan	0.000	231.7	27600	100.0000	0.0000
Total			27600		



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 RAP 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

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 therequired 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

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

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 ondifferent samples of bitumen.

Figure 3.9 Ductility Test

3.5.4 Flash and Fire point

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

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 measuresthe torque required to rotate an object submerged in fluid. (Asphalt in this case) and relatesit 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
Softening Point (*C)	45-55	47	ASTM-D-36
Specific Gravity	1.00-1.05	1.03	ASTM-D-70
Penetration (mm) , 25*C	60-70	63.67	ASTM-D-60
Flash Point (*C)	>230	368	ASTM-D-92
Fire Point (*C)	>250	381	ASTM-D-92
Ductility (cm) , 25*C	100	135	ASTM-113-99

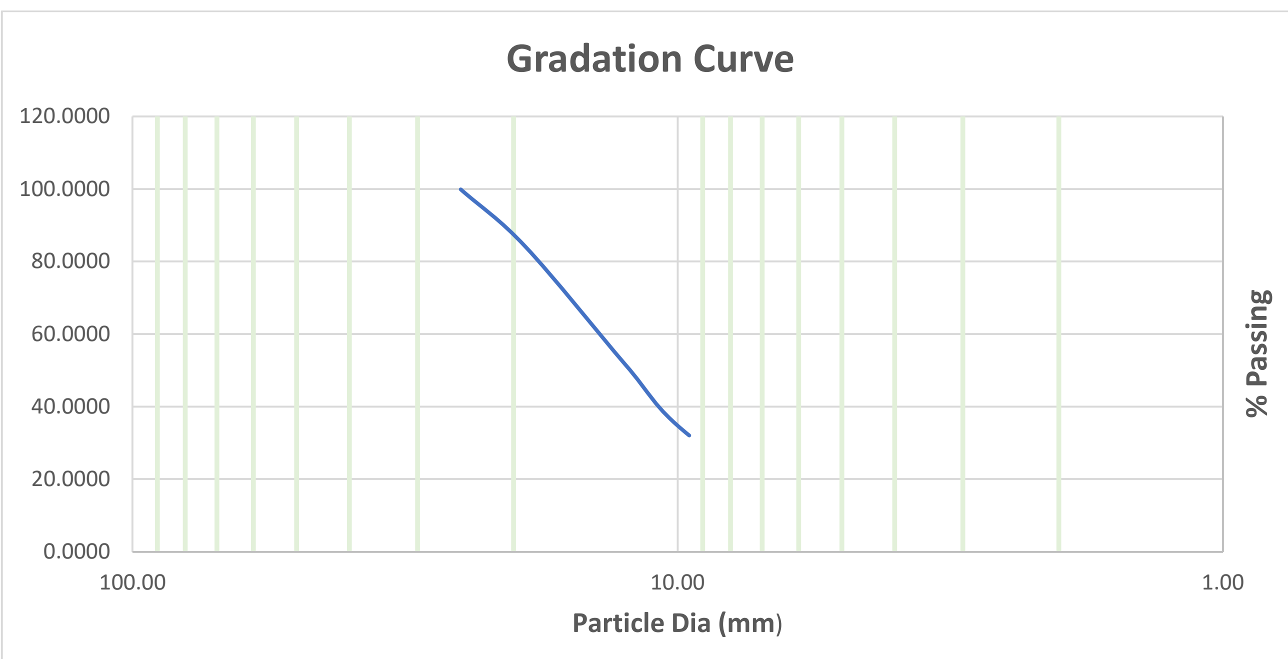
Table 3.2 Test results on Bitumen

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 passing against each sieve and corresponding gradation curve is plotted in Fig 3.16.

Sieve Number	Diameter (mm)	Mass Retained	Accumulative Retain (gm)	% Mass Retain	% Passing
1 in	25.00	21	21	0.0761	99.9239
3/4 in	19.00	4384.5	4405.5	15.9620	84.0380
2 in	12.50	8901.8	13307.3	48.2149	51.7851
3/8 in	9.53	5431	18738.3	67.8924	32.1076
# 4	4.75	8630	27368.3	99.1605	0.8395
Pan	0.000	231.7	27600	100.0000	0.0000
Total			27600		

Table 3.3 NHA Gradation



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 RAP in 10%, 20% and 30%. The specimens without RAP are prepared to determine OBC. These specimens are prepared per Marshal Mix Design Procedure. After determination of OBC, 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 2%, 2.5%, 3%, 3.5%, 4% 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 CONTENT	NUMBER OF SAMPLES
2%	3
2.5%	3
3%	3
3.5%	3
4%	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.

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 of specimen 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-D-2726 and ASTM-D-2041 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.

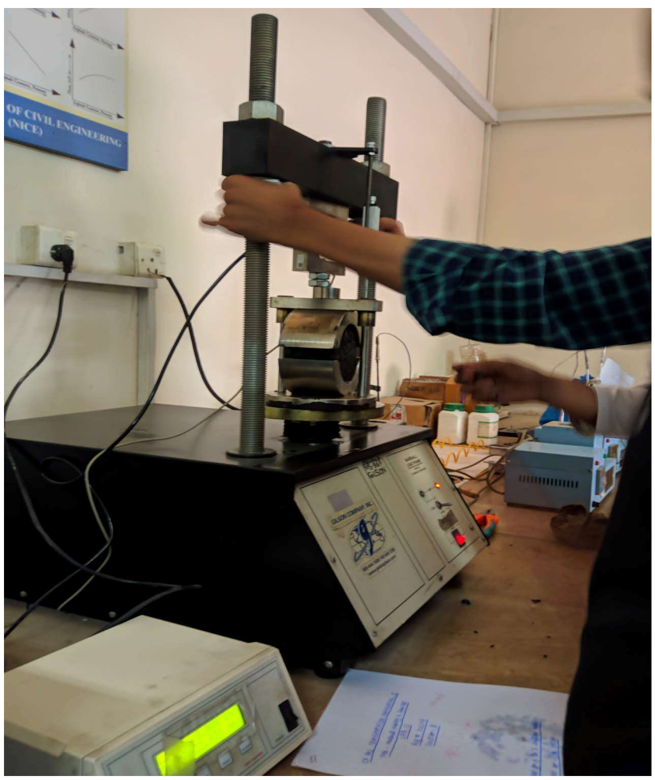


Figure 3.16 Marshall Stability and Flow Test

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 Gmm Determination

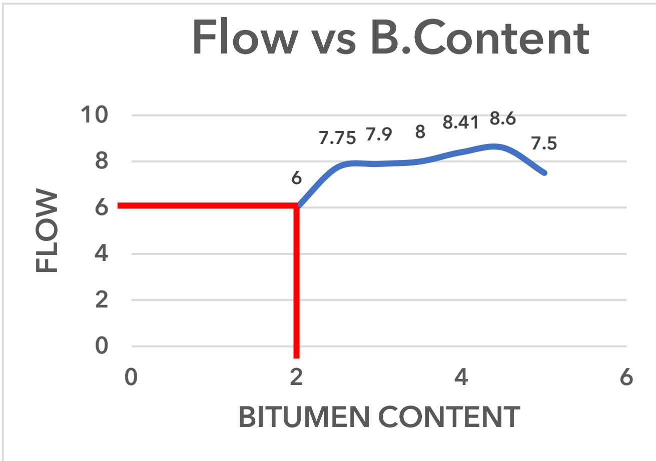
3.8.1 Volumetric properties of mix

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

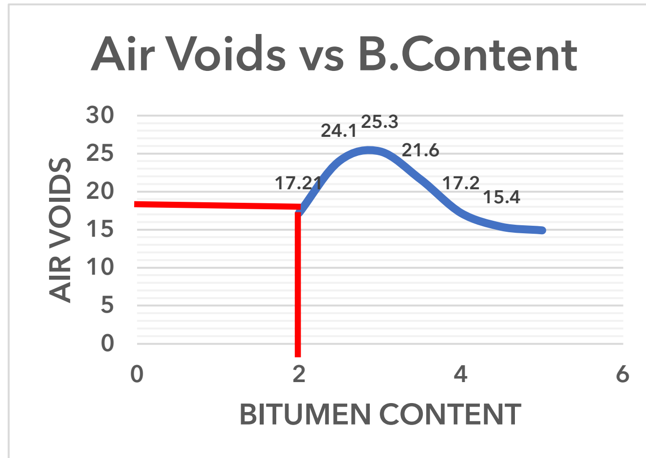
Table 3.5 Volumetric Properties

BITUMEN%	GRADE	FLOW (mm)	STABILITY (kN)
2%	**60-70**	**6**	**6.81**
2.5%	**60-70**	**7.75**	**7.04**
3%	**60-70**	**7.96**	**7.31**
3.5%	**60-70**	**8**	**8.1**
4%	**60-70**	**8.41**	**8.32**
4.5%	**60-70**	**8.6**	**8.11**

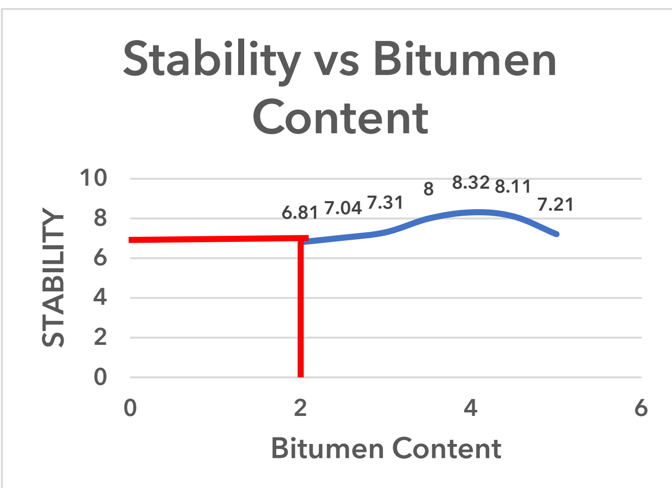
The graphs of Asphalt content verses different volumetric properties to find out OBC are shown in figure 3.18.



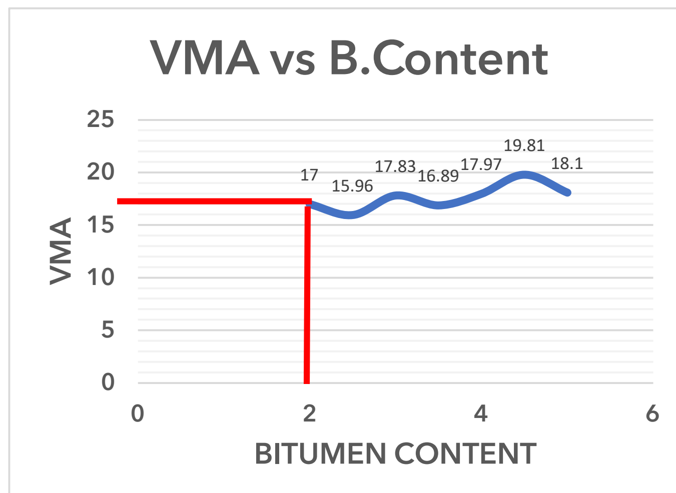
a) Flow vs Binder



b) Air Voids vs Binder



c) Stability vs Binder



d) VMA vs Binder

Figure 3.18 Marshall Volumetrics

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 Durability Analysis

The Durability Analysis 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 RAP and other containing bitumen with RAPpercentage.

Table 3.7 Test Matrix for Durability Analysis Test

BITUMEN CONTENT	NUMBER OF SAMPLES
Virgin Sample	3
2%	3
2.5%	3
3%	3
3.5%	3
4%	3

3.9.1.1 Preparation of Samples with RAP

Sample having RAP were prepared as the procedure used for preparing sample to determine OBC. As RAP is an allergic material and can cause rashes so we used it with strict precautions. Firstly, aggregate and RAP (in shredded form) were heated and dry mixed and then bitumen was added. Aggregate were first oven dried at 110 °C then mixed with RAP and bitumen at 140 °C. The compaction was achieved at 125 °C.

3.10 Durability Analysis Testing

The Durability Analysis test was performed according to ALDOT 361-88. For each percentage of RAP there were 3 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 werekept in water bath for 24 hours day at 40 °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 Recycled Asphalt for performance testing i.e., Durability Analysis. In the end ofChapter Durability Analysis methods were elaborated.

CHAPTER 4: RESULT AND ANALYSIS

4.1 Introduction

The study is based on incorporating Recycled Asphalt Pavement with percentages of 10%, 20%, 30% and their comparison with Porous Asphalt sample with 0% Recycled Asphalt Pavement and find their effect on Durability Analysis using Performance Tests. Aggregates for said Asphalt Mix development were acquired from Margalla Crush Site. The aggregate used in the Marshall Mix were graded according to porous classification. Bitumen used were provided by PARCO Oil Refineries Limited and the Recycled Asphalt Pavement used for enhancing the properties of Asphalt pavement was procured from IJP Road Reconstruction site.

In this chapter we are going to show different test results i.e., Durability Analysis. Detailed discussion about the tests were done in the previous chapter. Tests were performed on Virgin PA containing different Recycled Asphalt Pavement percentages as discussed earlier. After tests on both samples with Recycled Asphalt Pavement percentages and virgin samples, their properties against Durability Analysis were compared.

4.2 Moisture Induced Damage (TSR) Results

The methodologies provided herein for determining the water sensitivity of bituminous mixes were based on BS EN 12697-12 (BS EN, 2008). Two compressed subsets were prepared for subsequent conditioning and de-conditioning processes. The conditioned specimens were immersed in water at 25°C for 20 minutes before being vacuumed at 6.7 kPa for 10 minutes and kept under vacuum for 30 minutes. Following that, the specimens were submerged in water for another 30 minutes before being conditioned in a water bath at 40°C for 70 hours, while a similar number of specimens were left at 20°C in an incubator for a similar period. After wet conditioning, the specimens were pre-conditioned in a water bath at 20°C for four hours before testing for indirect tensile strength according to the ASTM D4123 (ASTM, 2005) procedures.

As the Dia of sample= 64 mm

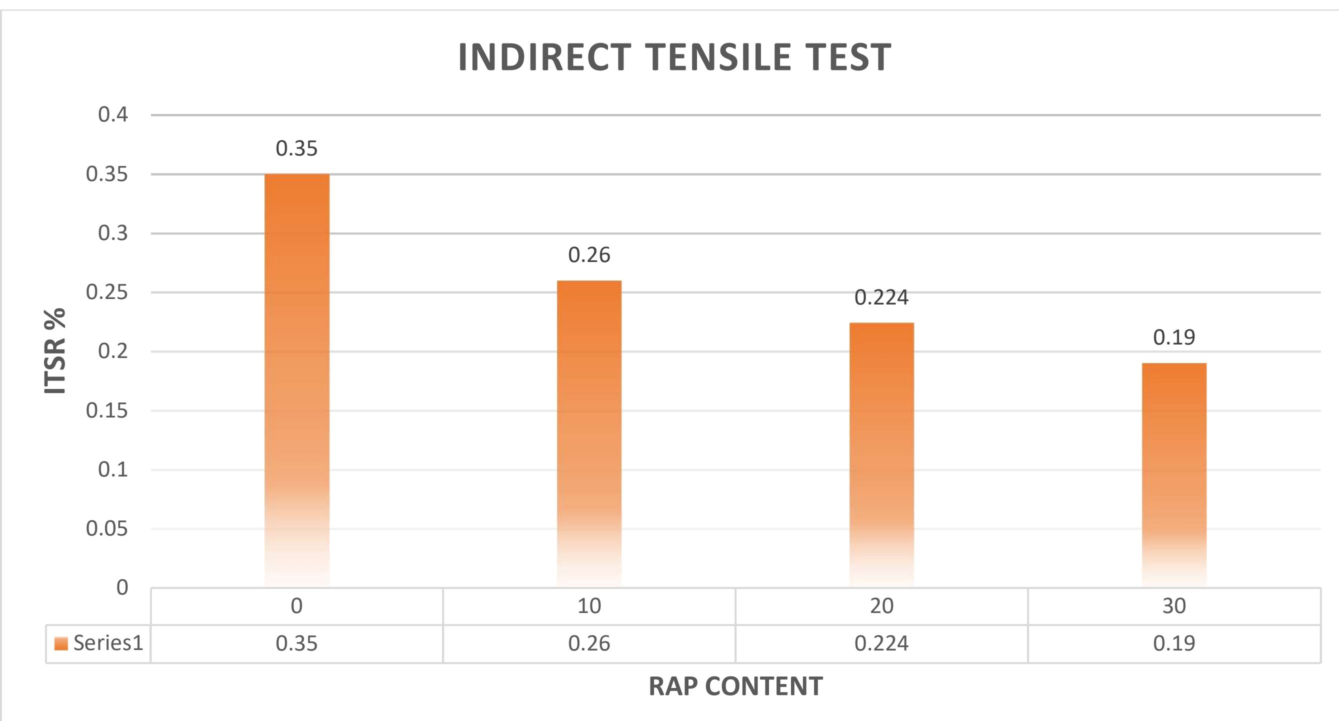
Height of the sample= 108 mm

F is the load that is (N)

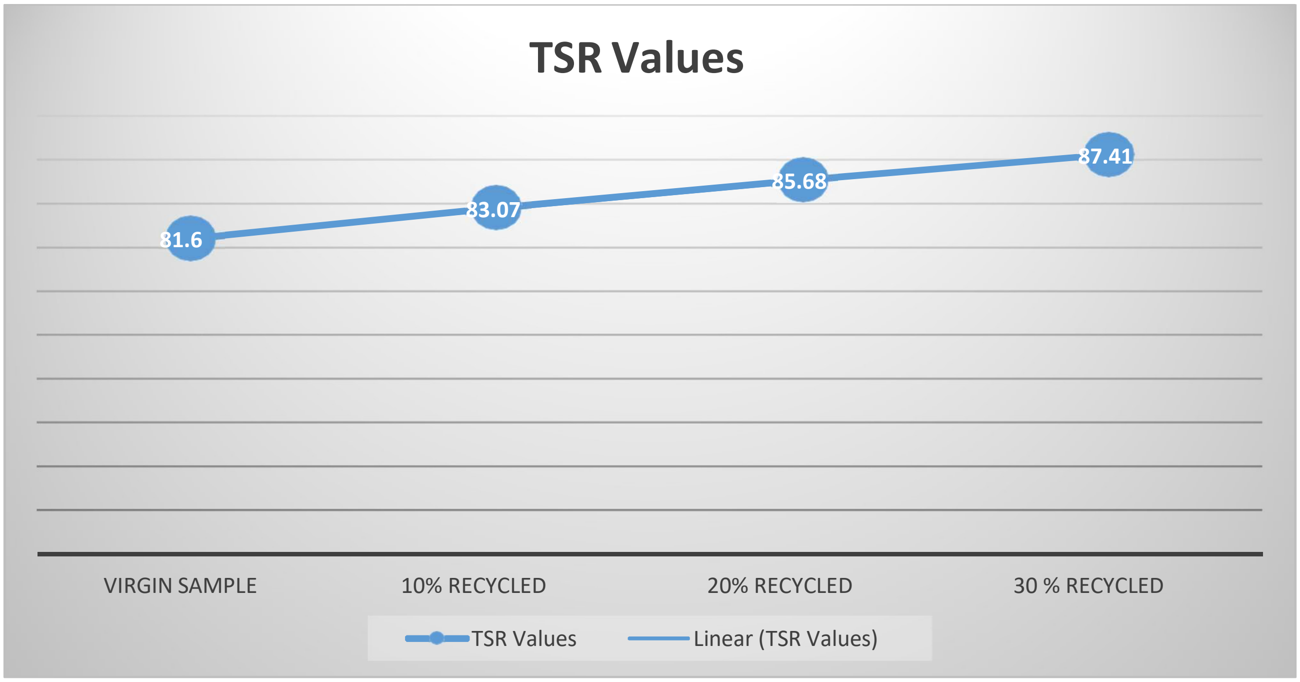
ITS = 2000 x F)/ 3.14 x D x H

Table 4.1 Tensile Strength Test Results for Porous Aspalt containing Recycled Asphalt

Samples	Load (kN)	ITS Dry Kpa	ITS Wet Kpa	ITSR %	Limits
Virgin	**4.91**	**452.45**	**359.38**	**81.6**	**> 77 %**
	3.90				
10% Rap	**5.97**	**556.13**	**446.12**	**83.07**	**> 77 %**
	4.84				
20% Rap	**5.61**	**489.37**	**397.157**	**85.68**	**> 77 %**
	4.31				
30% Rap	**5.93**	**555.67**	**457.97**	**87.41**	**> 77 %**
	4.96				



Graph 4.1 Tensile Strength Comparison



Graph 4.2 Tensile Strength Ration Trend

4.3 Cantabaro Test Results

The abrasion loss of compacted hot-mix asphalt (HMA) specimens is determined using this test procedure. Using the Los Angeles Abrasion machine, this test method determines the breakdown of compacted specimens. The % of weight loss (Cantabro loss) indicates the durability of PAP, WMA, and hot-mix cold-laid asphalt and is related to the quantity and quality of the asphalt binder. For informational purposes, this method can be performed on other HMA mixes.

Limits for Dry Condition is: < 25%

Limits for Wet Condition is: < 35%

Procedure:

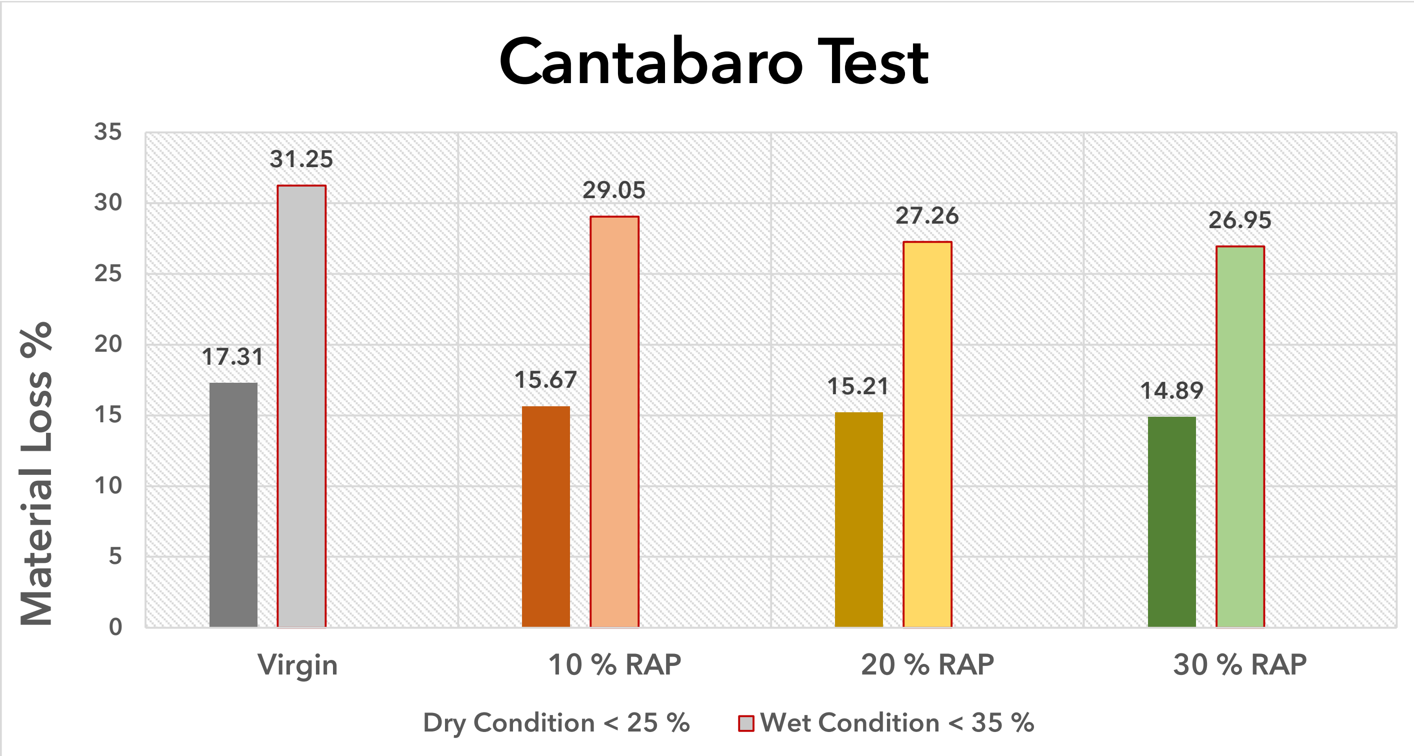
- Allow compacted specimens to cool to room temperature before weighing. Make a note of the weight and label it.
- Insert the test specimen into the testing equipment in Los Angeles. Leave out the steel balls.

- For 300 revolutions, rotate the Los Angeles machine at a pace of 30–33 revolutions per minute.

WET	Samples	Initial Wt. W1	Final Wt. W2	Material Loss %	Average Loss %	Limits
Virgin	**1**	**1063**	**726**	**31.7**	**31.25**	**< 35%**
	2	**1059.5**	**733.1**	**30.8**		**< 35%**
10 % RAP	**1**	**1052.4**	**748.3**	**28.9**	**29.05**	**< 35%**
	2	**1055.6**	**746.6**	**29.21**		**< 35%**
20 % RAP	**1**	**1064**	**770.4**	**27.6**	**27.26**	**< 35%**
	2	**1046.4**	**764.6**	**26.93**		**< 35%**
30 % RAP	**1**	**1061.5**	**772.8**	**27.2**	**26.95**	**< 35%**
	2	**1069**	**790**	**26.7**		**< 35%**

Calculations:

DRY	**Samples**	**Initial Wt. W1**	**Final Wt. W2**	**Material Loss %**	**Average Loss %**	**Limits**
Virgin	**1**	**1033**	**850**	**17.71**	**17.31**	**< 25%**
	2	**1034**	**859.2**	**16.92**		**< 25%**
10 % RAP	**1**	**1022.4**	**850**	**15.86**	**15.67**	**< 25%**
	2	**1031.6**	**876.4**	**15.48**		**< 25%**
20 % RAP	**1**	**1024**	**870.1**	**15.03**	**15.21**	**< 25%**
	2	**1018.4**	**862.6**	**15.4**		**< 25%**
30 % RAP	**1**	**1031**	**885.4**	**15.2**	**14.89**	**< 25%**
	2	**1038**	**903.4**	**15.09**		**< 25%**



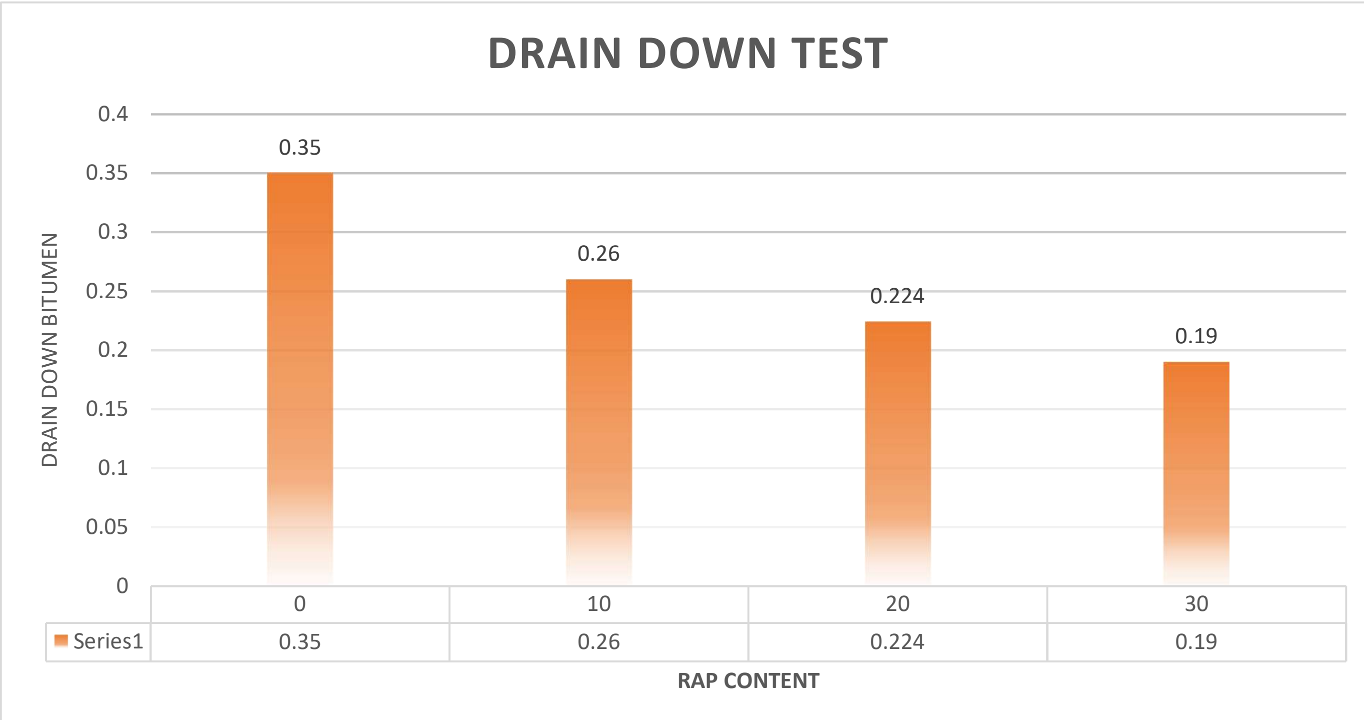
Drain Down Test:

A sample of asphalt mixture is put in a wire basket and set on a plate or other appropriate container of known weight. The sample, basket, and plate or container are placed in an oven at the production temperature for a certain period. The basket carrying the sample is withdrawn from the oven together with the plate or container at the conclusion of the heating time, and the weight of the plate or container is calculated. Drain down is defined as the quantity of material that separates from the sample as a whole and is deposited outside the wire basket. Drainage material can be made of binder or a mixture of binder and fine aggregate.

Figure: Uncompacted Porous Asphalt

RESULTS:

Sample	W_1 (g)	W_2 (g)	$(W_1-W_2)/W_1$	Avg. Value	Limits
Virgin	**1048**	**1044**	**0.381**	**0.35**	**< 0.3%**
	1046.5	**1042**	**0.43**		
10% RAP	**1038**	**1035**	**0.289**	**0.26**	**< 0.3%**
	1041	**1038**	**0.289**		
20% RAP	**1041.5**	**1039**	**0.24**	**0.224**	**< 0.3%**
	1042.5	**1040.5**	**0.246**		
30% RAP	**1036**	**1034**	**0.19**	**0.19**	**< 0.3%**



4.4 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 Durability Analysis testing with increasing Recycled Asphalt Pavement content with and without conditioned samples were presented anddiscussed in detail which shows an increase in Tensile strength value with the increasing percentage of Recycled Asphalt Pavement.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Our project was focused on to measure the Durability of Porous Asphalt Pavement by the addition of Recycled Asphalt Pavement in the proportion of 10%, 20% and 30% . Durability is the major concern which cause the pavement to damage most effectively. Recycled Asphalt Pavement is used in the pavement mix to provide it strength. In this project bitumen of grade 60/70 was provided by PARCO Oil Refineries, NHA wearing aggregate was acquired from Margalla Crushing sites. For determining Optimum Bitumen Content Marshall Mix method was utilized with varying percentages of 2%, 2.5%, 3%, 4%, and 4.5%. After the determination of Optimum Bitumen content Marshall Mix samples were made using the appropriate amount of Recycled Asphalt Pavement in samples. After that Durability Analysis was checked using performance tests and results were compared with that of PA without RAP. The key findings of performance tests, 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 20% air voids and OBC calculated was 2%. Other properties were also well within their ranges.
- From the TSR, we conclude that the with increasing Amounts of RAP the strength of the Porous Asphalt increase both in wet and dry conditions.
- In the Cantabaro test, the material loss percentage decreases with the addition of RAP in successive amount (10%, 20%, 30%).
- In the Drain Down Test, amount of bitumen drain down decreases with the addition of RAP in successive amount (10%, 20%, 30%).

- The Optimum Amount of RAP is find out it to be 30% because after this amount the Strength of Porous asphalt decreases.

5.3 Recommendations

Following recommendations are being laid considering results and conclusions:

- In the project for determination of specimen's Durability Analysis 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 Porous Asphalt concrete using RAP content.
- Study of fatigue life under strain- controlled conditions and finding the effect of different gradations on performance of Porous Asphalt using RAP.
- A comprehensive study on inter-binding of black aggregate with fresh aggregate in porous pavements.
- Chemical Analysis for the checking the effect of fresh Bitumen and the Old bitumen in RAP
- A study on the cost and benefit analysis including the cost comparison of both normal and porous pavements.
- It is also suggested to initialize a chemical study of Recycled Asphalt Pavement Asphalt Concrete sothat any agent causing improvement can be found. In this way more amount of Recycled Asphalt Pavement can be utilized enhancing the properties of Asphalt Concrete.

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