USE OF MIXED WASTE RECYCLED PLASTIC AND GLASS AS AN AGGREGATE REPLACEMENT IN ASPHALT MIXTURE

FINAL YEAR PROJECT UG 2015

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This is to certify that

The Final Year Project Titled

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DEDICATION

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

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All praises be to ALMIGHTY ALLAH who made everything possible and easy for us to achieve in our amazing journey of NUST. We are extremely grateful to our parents who sacrificed and prayed for us to make progress in our course and research work.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

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
UTM	Universal Testing Machine
VA	Air Voids
VFA	Voids Filled with Asphalt
VMA	Voids in Mineral Aggregate
PET	Polyethylene terephthalate

ABSTRACT

Transportation infrastructure plays a key role in the everyday life of social beings. Since it requires very high quantities of construction material, any small percentage reduction in percentages in materials and replacement with alternate material makes greater impact. In this regard many countries have started research on replacing aggregate with Glass and Plastic in small percentages. Notable work is done in India (Jamshedpur), plastic is inculcated in bitumen for road construction. Same has been notices in Indonesia (Bali, Bekasi, Makassar, Solo and Tangerang), hence the plastic- Asphalt mixture is more common there. The use of Plastic not only conserve resources, but also reduce huge amount of Ocean pollution Pakistan is facing now a days. Same is the case with Glass which occupies large landfills and causes soil changes to soil in addition to cussing land pollution for decades to some. New York has conducted the greatest project in this regard where 225,000metric tons of Glass had been used in surface coarse. Their use is mainly applied to combat the growing Plastic and Glass waste which is causing great environment and Ocean Pollution. Plastic and Glass is produced at much higher pace then utilized or curbed to save the environment, hence their use in roads provide a viable option to mitigate their enormous amounts.

Furthermore, possible advantages of using the waste products would is the reduced amount of required bitumen in the mix as PET (Plastic bottle) researched concluded. The replacement of our aggregate resources and reduction in the amount of Bitumen would produce a cost-effective mix.

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 environmentally friendly. The utilization of Waste Plastic bottles (PET) and Glass (windows, bottles) acts 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 Plastic and Glass as an in place of aggregate.

- NHA gradation B, ARL grade 60/70, RAP from Islamabad
- Lahore M2 and Plastic and Glass from Timber Market dump yard of Islamabad were used in this study. Lime which is anti-stripping agent is bought from the I9 market Islamabad.
- Penetration, Ductility and Temperature testing were done on virgin bitumen.
- Plastic and Glass percentages of 0.5%, 1.5% and 2.5% were used.
- Performance testing was done after finding out the OBC, volumetric, stability and flow of Plastic and Glass containing mixtures. Using those OBC, different samples were formed and tested for evaluation and compared with the performance testing results of mixtures containing aggregate only.
- Performance testing's included indirect tensile Fatigue Test (ITFT) and Wheel Tracking apparatus
- It was noted that 1.5% Plastic and 1.5% Glass as a replacement of bitumen can be
- Used which would give better properties than control mix of virgin materials. Cost
- Estimation was also done which showed 3% reduction in cost.

CHAPTER 1

INTRODUCTION

1.1 Background

Generation and utilization of plastic and glass is expanding massively with the progression of time. These plastic bottles turn into an issue when they are disposed of as they are non-biodegradable. Same happens with Glass which goes to dump yards for several decades. This implies the waste plastic, and Glass when dumped, does not deteriorate and remains in the earth influencing the natural framework. Consumption of Plastic waste, as well, damages the earth as it discharges unsafe dioxins which are perilous to human wellbeing. It has influenced our climate by consuming as well as pitiably fizzled our drainage frameworks. The outflow of CO2 is a noteworthy sympathy toward earthy people and world group as it is an essential greenhouse gas. Pakistan, with its high populace and no legitimate reusing component, confronts this issue of plastic wastes. 6% of Pakistan Municipal waste is Glass, which is not fully recycled and there is a huge amount that can be used for Pollution control.

1.2 Problem Statement

Plastic bags being oil-based products are chemically composed of hydrogen and Carbon. Burning of these plastics produces dioxin, a highly toxic chemical. Dioxins are carcinogenic chemicals, which can affect the endocrine gland system causing hormonal, Immunol and reproduction difficulties.

Plastic burning causes production of benzo(a)pyrene (BAP) and other polyaromatic Hydrocarbons (PAHs), mostly which leads to carcinogen. Unburned parts of the plastic end up as garbage on ground or in water streams. It not only affects the marine life but is also the major factor of failure of drainage system in Pakistan and takes hundreds of years to decompose i.e. take up to 450 years to decompose (WWF Pakistan).

Glass on the other hand has decaying span of even more than a million years and in improper conditions of land fill it would take even more than as it would be safe from wind erosion. (New Hampshire Department of Environmental Services). It is dumped on landfills which contaminate the soil and surrounding areas. Using glass as replacement has the potential to reduce waste and save resources, since it takes less energy to recycle glass and produce less greenhouse emissions. Furthermore, it will minimize the transport cost associated with transporting Glass to the dump sites. Ground water contamination and ecological disruption due to Plastic bottle waste and Soil contamination from Glass waste are the reasons these wastes needed such attention. Therefore, project is, instead of dumping the used road material, recycles it and used it again with the virgin material so is the case for polythene bags.

1.3 Purpose of Research

Glass and Plastic is produced at a booming rate to meet the need of the country masses. With an aim to address the user consumption demand, there is no way slowing the production any time soon. However, comparing to production, the recycling project are not addressed that well.

Hence, environment and health hazards are the inevitable consequence of the practices. Plastic and Glass both has been extensively studied and practically applied in road construction in India, New York, Indonesia and Oman. But attention towards the new replacements is minimal here. Pakistan being a developing country is undertaking many new motorway projects to meet the booming traffic demand. 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.

If the proposed water products have the potential to enhance the road property of roads built in Pakistan, then now would be the ideal time to utilize plastic in roads and unlock its full capacity. The recent agreement of providing economic corridor to China via Pakistan involves construction of 1200 km long motorway between Peshawar and Karachi and overhauling and widening of Karakoram Highway between Rawalpindi and the Chinese border. We aimed to use Plastic and Glass as aggregate replacement is Asphalt pavements to reduce the indirect cost of construction, help environmental protection.

1.4 Research Objective

The main objective of the conducted research is to use Glass and Plastic (PET) in HMA

As a replacement of Aggregate. Further breakdown is as follows:

- Fatigue Evaluation of HMA Containing Plastic (PET) and Glass
- Rutting Evaluation of HMA containing Plastic (PET) and Glass
- To achieve these goals by not affecting the overall performance of the pavement

1.5 Organization of Report

This thesis has five chapters. The detail of each chapter is as under

Chapter 1 gives a shortly explains to problems related with generation of Plastic bottles (PET), their possible use in HMA pavement, Glass, 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 having Plastic bottles and Glass in pavement and problems associated with it. Finally, it includes research of different test methods used for Rutting and Fatigue testing.

Chapter 3 explains the methodology used in this research which consists of the collection and laboratory characterization of materials, the Marshal Mix design and performance testing.

Chapter 4 compiles the results of the experiments and presents analyses based on findings.

Chapter 5 Summarizes the conducted research, provide conclusions based on analyses and recommend future testing for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter consist of Literature references and importance of transportation, and different methods to design flexible pavement. It further elaborates impact of the selected waste products on the environment and existing research of incorporating them in roads. Lastly, it delineates Rutting and Fatigue testing on asphalt mixtures.

2.2 Transportation-need of an hour

Well defined connected routes within the country is the core aspect in country's progress. Passengers applying this means are huge. The other mobilizing facilities (Railway) is not as such up to the mark here as it is in other developed countries like China and Japan, hence focus is on the highways and motorways, which are developing at a speedy pace at current situation. A strong network of transport is essential in prosperity of the nation. Pakistan in this context has worked towards creating strong road linkages around the country. Total length covered is 4266 km (2019). Notable motorways include Lahore, Multan, and Islamabad which are providing speedy transport facilities. At present, Pakistan with the assistance of china is constructing a trade route called China Pakistan Economic Corridor (CPEC). The total budget to develop such an enormous project cost 54 billion dollars. Karachi and Lahore will be connected by a 1,100 kilometers long motorway as part of CPEC.

Another notable work is the Karakorum highway that connects Khunjerab China border with Rawalpindi is being completed and is soon to be functional. The main railway line between Karachi and Peshawar will also be upgraded to allow for train travel at up to 160 km per hour by December 2019. Despite the quick pace, the country is unable to meet the needs of the nation as the deprived areas still lack proper road networks.

Fig 2.1 Traffic congestion in Pakistan (Pakistantoday.com)

2.3 Glass: An Unreplaceable product

Glass is used in many day-to-day equipment, gadgets, building material for it unique property of transparency. Glass making process involves mixing of large amounts of silica sand with comparatively smaller amounts of lime and soda ash, and other materials to give the glass special qualities by heating the mixture in a furnace until it turns into a syrupy mass. It contains about 72% silica, 15% sodium oxide, 9% calcium oxide (lime) and 4% of another ingredient. On account of great variety of its use and properties the material has a huge market all over the world.

Glass can be durable, brittle, high heat and cooling resistant from Decoration to optic fibers, from colored to tainted glasses, from wind shields to window shields, all the uses adds value for its speedy production and uses.

2.3.1 Types of Glass:

The product is made to address different physical and chemical needs. Different types of glass require different compositions. The most common types based on composition are as follows.

Table 2.1 Types of Glass

Type	Primary components	Description	Applications
Borosilicate	SiO_2, $B2O_5$	The product is in great since it cost relatively less than the other glass types. On account of cheap manufacturing process and abundant material availability, it has acquired place in many	• Industrial equipment • Exterior Lighting • Laboratory and Kitchen glassware
Soda-lime silicate	SiO_2, Na_2O, CaO	This form of glass provides high durability, thermal shocks and can resist great amount	• Food and beverages containers • Windows

		of thermal cycling. Borosilicate glasses are commonly used for their superior durability. Main uses applyying this glass is cooking and lab testing which requires great thermal stability in the apparatus. The quality of low thermal coefficient makes it possible for the glass to absorb thermal stresses and resist cracking.	• Lamp envelops
Phosphates	P_2O_5	These type of glasses shows high resistance to HCL. However, they are otherwise not resistant to chemical attacks. They can be transformed chemically to meet the desired results.	• Bone scaffolds • Optical fibers • Heat absorbers

2.3.2 Glass use and impact in Pakistan

The Glass mostly produced in Pakistan is inexpensive (Lime containing) glass which is due to high reserves availability in the country. The industry focuses mainly focuses on creating building windows, decoration pieces, bottles (medicine and fizzy drinks), car windscreens etc. However, high quality of glass is mainly exported to meet the needs within the country. The huge amount produced does not all go to the recycling. One estimate suggests that Australia utilizes only 350,000 out 850,000tons for recycling which is only 40% of total. The rest is disposed. The Australian example is indicative of the glass waste disposal throughout the world and especially in Pakistan attention is given mainly on paper or small amount of glass recycling. Hence, large amount of glass is dumped on the landsite which takes hundreds of years to decompose.

Fig 2.2 Waste Glass dump yard

2.3.3 Previous work

Numerous researches have been carried out to out to check performance of pavement inpavement incorporating different percentages of waste recycled glass and plastic. Some important studies that discussed the use of waste recycled plastic and glass in HMA include: Nur Izzi and Md Yosaff 2018; Ghasemi and Marandi 2003; Sahar Mohsenian and Hadad Amlashi 2015; Y.Issa 2016; Modarres and Hamedi 2014; Taher Baghaee Moghaddam 2012.Airey *et al* reported that compared to control samples, the stiffness modulus of an asphalt mixture containing glass and an anti-stripping agent increases. Without the use of an anti-stripping the binding strength between glass and binder is weak.

Su and Chen recommended the addition of 2% lime to overcome this shortcoming. Arabani *et al*. indicated that glass particles with greater angularity can increase the fatigue life of an asphalt pavement because the glass asphalt creates a higher internal friction angle, improving the interlocking between different constituent particles. However, some problems can occur, such as inadequate friction and bonding strength when larger glass particles or a greater proportion of glass particles are used.

Recently, Navarro *et al*. showed that the reuse of waste glass as a substitute for the sand fraction in low dosages (8%) produced asphalt mixtures with mechanical properties that were suitable for road surfaces courses.

Study shows that incorporation of 4% waste recycled glass and 1% plastic produces best optimum results. However, glass up to 10% can be used without compromising strength and other mechanical properties. Recommended usage of waste plastic is within range of 2-3%.

2.4 Plastic: A Replacement for many products

Plastic is made up of two main products. Polyethylene and Polythene. The second of which is produced from distillation of raw oil, natural gas, coal and salt. Plastic has basically taken over thousands of products from its invention. From food plates to aluminum cans, packaging and toys, every material in such fields have plastic as their priority use. The main reason for its high usage is its ability to be molded in desired shaped easily. Furthermore, unlike wood and steel which are mostly get attacked by termite or resting, plastic is free from all such attacks. The ease of creation, cost effectiveness and a long-term usage are some reasons why Plastic is a major replacement to many products.

2.4.1 Types of Plastic

On account of its variable uses in the market, Humans have until now has produced 9.1 billion tons of Plastic until now and as the product has harmful and catastrophic results, it is imperative to categorize them to know the properties of each. Therefore, SPI aka Society of Plastic Industry has given special identification codes to each category for identification.

Table 2.2 Types of Plastics

Name	Code	Recycle/Non-Recyclable	Description	Uses
PETE/ PET	1	recyclable	The containers made from these at times absorbs the odors of the food in them. them.	• Soda bottles • Salad dressing bottles • Medicine jars • Peanut butter jars • Jelly Jars • Bean bags • Rope • Tote bags
HDPE	2	recyclable	The products made from HDPE are safe to be used in food and drink packing. However, on account of contamination risk, the product is	• Milk jugs • Juice containers • Grocery bags • Trash bags • Motor oil container

			avoided for packaging	• Shampoo and conditioner bottles • Soap bottles • Detergent containers • Bleach containers • Toys
PVE	3	Recyclable but not all	PVE is avoided from edible substances as it is highly toxic in nature. The product mostly found its place to be used in plumbing and construction uses.	• Some tote bags • Plumbing pipes • Grocery bags • Tile • Cling films • Shoes • Gutters • Window frames

				• Ducts • Sewage pipes
LDPE	4	Recyclable but not all	Being unharmful plastic, it's use in food industry is prominent. The use is further encouraged as it is flexible and durable in nature	• Cling wrap • Sandwich bags • Squeezable bottles for condiments such as honey and mustard • Grocery bags • Frozen food bags • Flexible container lids
PP	5	Non-Recyclable	Having nature of high heat	• Plastic diapers

			resistance, it has found its use food industry, where food packed in these plastics can be heated at high temperature without fear of plastic melting	• Tupperware • Kitchenware • Margarine tubs • Yogurt containers • Prescription bottles • Stadium cups • Bottle caps • Take-out containers • Disposable cups and plates
PS	6	Non-recyclable	It takes a lot of energy, which means that few places accept it.	• Disposable coffee cups • Plastic food boxes

			Therefore, it's a good idea to invest in a reusable mug for your daily caffeine fix!	• Plastic cutlery • Packing foam • Packing peanuts
OTHERS(Nylon)	7	Non-recyclable	Is used to designate miscellaneous types of plastic that are not defined by the other six codes.	• Plastic CDs and DVDs • Bottles for babies • Large water bottles with high capacity • Medical containers for storage • Eyeglasses • Exterior lighting fixtures

2.4.2 Impacts of plastic bags on Environment

The rapid increase in plastic is greatly linked with tremendous land and ocean pollution. Plastic ads up about 10% waste in the environment. Some estimates suggest that Amount of plastic will overrun fish in the sea by 2050. Some other facts and figures regarding the plastic pollution in sea are:

i. More than 8 million metric tons of plastic is finds way into oceans from industries per annum.
ii. More than 100,000 marine animals die annually by digesting or entangling in plastic bags each year.
iii. Approximately 4,600 turtles are being killed each year due to plastic pollution.

The rapid increasing industries and of plastic means that it's waste products also increasing at a faster pace. Most of which takes hundreds of years to decompose and remained in the environment to cause pollution and harm the environment and affect aquatic life. The damages have inculcated such a vast concern in some that they have committed to erase it from their use.

2.4.3 Use in Pakistan

In Pakistan the generation plastic is high. Where steel and timber are expensive material, plastic provides a cheaper alternate for production and ease for the masses to purchase. Secondly as there is no check or limit in for the production and sale of plastic. As indicated in surveys conducted in 2007, the polythene bags consumption in Pakistan have increased from 12 million in 1990 to 55 billion in 2007. Plastic mostly utilized in bottles producing beverages like Pepsi, sprite, mineral water etc.

The use is further broadened to add plastic shopping bags, which is produced and used without any government check. Therefore, the amount has coasted so much pollution that clogged drainage systems, high dumping sites, burning waste and many diseases has become norm in the country. Furthermore, the rise in temperature, abrupt climate changes and sudden irregular flood patterns are at increase in Pakistan. (pakistantoday.com.pk).

Fig 2.3 (Picture credit: Baluchistan Point)

2.4.4 Previous work

Asphalt is the main binding ingredient utilized in the construction works in Pakistan and all over the world. The binding agent mixed with standard well graded aggregate to achieve the desired road surface material. The constructed roads mostly get degraded on account of continuous us of the roads and improper maintenance.

To safeguard the existing roads and the new existing roads, techniques like design enhancement, upgraded construction practices, regular maintenance and additives are commonly utilized. Additives like Rice husk, waste engine oil, crumb rubber glass and plastic are used to produce better performing roads. This project mainly aims to incorporate Plastic and glass in mix asphalt to achieve the desired results.

2.4.5 Literature Review

Modarres and Hamedi claimed that the addition of pieces of waste plastic bottles in asphalt mixtures improves the fatigue behavior of the mixtures However the resilient modulus decreases when the amount of waste plastic bottle material added is greater than 2%. Besides that, with incorporation of waste plastic in asphaltic mixtures, the total volume of mixture will increase. The presence of 1% of plastic improves fatigue life of modified asphalt mixtures compared to virgin samples. A study done by Ahmadinia *et al*. found that the addition of recycled plastic to bitumen or asphalt mixture enhances the material rigidity and restricts the permanent deformations under heavy loading conditions particularly in upper pavement layers at higher temperatures.

CHAPTER 3

RESEARCH METHEDOLOGY AND TESTING

3.1 Introduction

This chapter mainly explains the methodology utilized to get the desired objectives of our research which consists of testing material acquisition, experiments on the acquired material, specimen preparation and experiments on the prepared samples. The study was performed on the control as well as the specimens containing 0.5% to 2.5% Plastic and Glass. Evaluation of the OBC on different percentage additives, Fatigue testing and rutting test were the main works done. The chapter further delineates equipment used, procedure to produce specimens and input parameters during various tests will be discussed in this chapter.

3.2 Research Methodology

Virgin aggregate was collected from Margalla hills crush plant site, after that Milled Plastic and Glass was collected from Timber market Islamabad. These materials were brought to laboratory of NUST INSTITUTE OF TRANSPORTATION (NIT) and several tests were conducted on aggregate. After that Marshall specimen were prepared for finding OBC of samples containing Plastic and Glass. These OBC's were then used to prepare samples to perform Performance test on samples containing Plastic and Glass and virgin Bitumen.

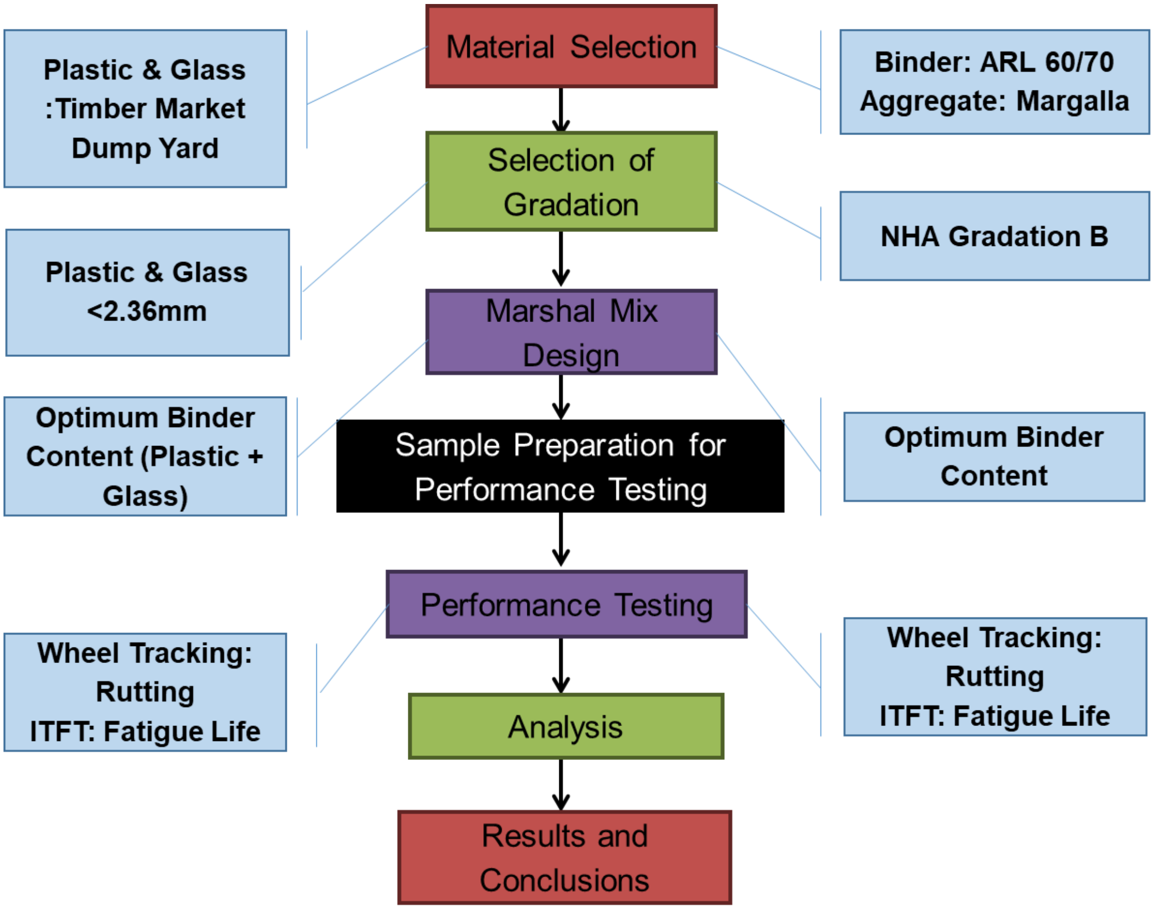


Fig 3.1 (Research Methodology)

3.2.1 Material Characterization

3.2.1.1 Aggregate Tests

Aggregate it should have sufficient strength and texture so that it can withstand its purpose in pavement. Following tests were performed on aggregate.

- Shape Test
- Specific Gravity and Water absorption Test
- Impact value of Aggregate
- Los Angles Abrasion Test

Three samples were prepared for each test and their result were compiled in the table below.

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

This test calculates the percentage of flaky and elongated particles in aggregate. Flaky particles are those having their least dimension lesser then 0.6 times their average dimension. While elongated particles are defined to be those having their greatest dimension greater than 1.8 times their average dimension. For better interlocking of aggregate, particle's Angular shape is preferred. The flakiness index should be less than 15% while elongation index should be less than 15%.

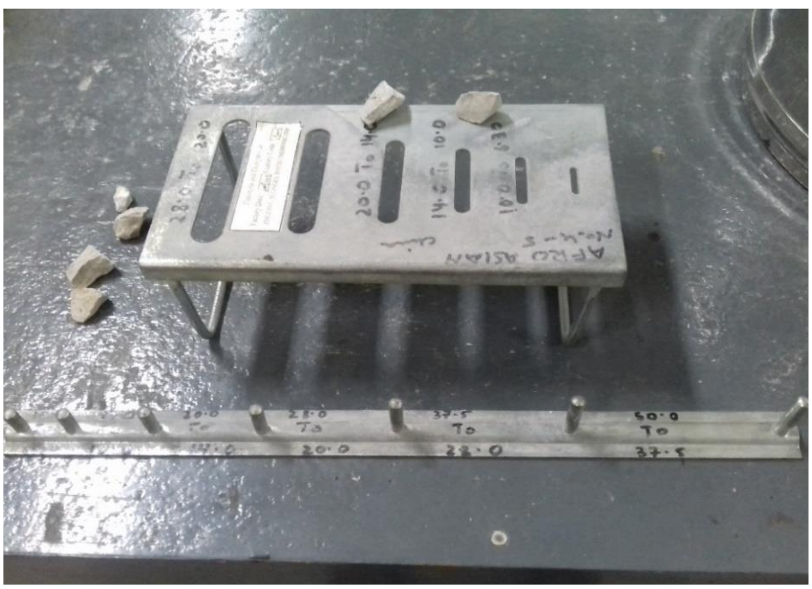


Fig 3.2 (Flakiness Index)

3.2.1.3 Specific Gravity Test (ASTM C 127 & ASTM C 128)

The specific gravity is ratio of weight of given volume of aggregate to weight of equal volume of water at 23 °C. The test was performed only on coarse aggregate per ASTM

C 127-88. Three weights were calculated for determining Specific gravity i.e. A= weight of oven dried aggregate, B=weight of aggregate completely submerged in water, and C =Saturated surface dry weight of aggregate. Specific Gravity of Fine aggregate and water absorption was determined using ASTM C 128.

Fig 3.3 (Equipment to calculate specific gravity)

3.2.1.4 Impact Value of Aggregate (BS 812)

The impact value test gives relative strength of aggregate against impact loading. The equipment included impact testing machine, temping rod, sieves of sizes 1/2”, 3/8” and #8. About 350 grams of sample passing sieve ½” and retained on 3/8” was transferred impact testing machine cup in three layers while each layer was temped 25 times with the help of temping rod. After that it was subjected to 25 blows from rammer of impact machine weighing 14 kg and free fall of 38 cm. After that material was taken out from cup and passed through sieve #8. The percent passing through sieve #8 gives impact value of aggregate. The results are summarized in table below.

Fig 3.4 (Impact Value Apparatus)

3.2.1.5 Los Angles Abrasion Test (ASTM C 535)

This test is used to check resistance of aggregate to wear and tear due to heavy traffic load. More the abrasion value of aggregate more the performance of pavement is adversely affected. The equipment used was LOS angles machines, sieve set, balance steel balls. NHA Gradation B was selected for this test. About 5000g of sample, containing 2500g retained on sieve 1⁄2" and 2500g retained on 3/8", was placed in Los Angles Machine along with 11 steel balls and drum was rotated at speed of 30-33 rpm for 500 revolutions. After that material from machine was passed through 1.7mm sieve and weight (W2) of sample passing it was noted.

The abrasion value is defined to be = W2/W1 *100.

Fig 3.5 (Los Angles Apparatus)

Table 3.1 (Test results of Aggregate)

Type of Test		**Aggregate Type**	**Test Standard**	**Specification**	**Test Results**
Shape Test	Flakiness Index	Coarse	ASTM D 4791	≤15	12.9%
	Elongation Index	Coarse		≤15	3.57%
Water Absorption		(10-20) mm	ASTM C127	≤3%	0.73%
		(5-10) mm		≤3%	2.45%
Specific Gravity Test		Coarse	ASTM C127	-	2.60

	Bulk Specific Gravity	Fine	ASTM C128	-	2.57
Impact Test (%)			ASTM D5874	30% max	15
Abrasion Test (%)			ASTM C131	≤ 40%	23

3.2.2 Asphalt Testing

3.2.2.1 Penetration Test (AASHTO T49-03)

This test is used to determine the penetration grade of bitumen by measuring the depth in tenths of a millimeter up to which a standard loaded needle will vertically penetrates the bitumen specimen under given conditions of loading, time and temperature. Softer binder gives greater values of penetration. According to AASHTO T 49-03 temperature used was 25°C, load of 100 grams, while time for the test equal 5 seconds, until unless the situations are not explicitly stated. Using two ARL 60/70 specimens, five values from each specimen were taken after performing penetration tests. All values obtained fulfilled the required criteria of penetration test as per specifications.

Fig 3.6(Penetration Test)

3.2.2.2 Softening Point (AASHTO-T-53)

The temperature at which the substance attains a degree of softening under specified condition of test is called softening point. It is usually determined by Ring and Ball test. Softening point of bitumen is the average temperature at which the two disks of bitumen soften adequate to allow the steel balls of 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.

3.2.2.3 Ductility (AASHTO T 51-00)

The property of bitumen that permits it to undergo great deformation or elongation is called ductility. It is the distance in cm, to which a standard sample of the material will be elongated without breaking with a specific speed i.e. 5 cm/min and at a specific temperature of 25 ± 0.5 °C (AASHTO T 51-00).Different samples of bitumen were tested and all gave the ductility value greater than the least limit of 100 cm.

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

The least temperature at which the bitumen momentarily flashes at specified conditions is termed as flash point. Fire Point is the temperature at which the material gets fire and burn under specific conditions. Flash and Fire point test was conducted as per D3143/D3143M-13 standards.

Table 3.2 (Bitumen Test results)

Test Type	Designation	Results	Specifications
Penetration (25°C,100g,5s) mm	ASTM D5	63	60-70
Softening point (°C)	ASTM D91	50	46-54
Flash point (°C)	ASTM D92	265	175 (min)
Fire point (°C)	ASTM D92	301	> 250
Ductility (25°C) cm	ASTM D113	> 100	> 75
Specific gravity	ASTM D70	1.03	> 0.99

3.2.3 Gradation Selection

NHA gradation B was selected for surface course mix according to NHA (1998) Specifications. The nominal Maximum size for this gradation is 19mm (3/4") according to MS2. The gradation selected is shown in table 3.7 per percent passing against each sieve and corresponding gradation curve is plotted.

Table 3.3 (NHA Gradation B)

Sr. no.	Sieve Size mm	NHA Specification Range (% Passing)	Mid gradation Selected (% Passing)	% Retained
1	**19**	**100**	**100**	0
2	**12.5**	**75-90**	**82.5**	17.50
3	**9.5**	**60-80**	**70**	12.50
4	**4.75**	**40-60**	**50**	20
5	**2.38**	**20-40**	**30**	20
6	**1.18**	**5-15**	**10**	20
7	**0.075**	**3-8**	**5.5**	4.50
8	Pan	-	-	5.50

3.2.4 Asphalt Mixture Preparation

Two types of asphalt mixtures are prepared, one is the controlled mix having only virgin having only virgin aggregate, the other having varying percentage of glass and plastic i.e. 0.5%, 1.5% and 2.5% of both. These specimens are prepared to determine OBC at each glass and plastic percentage and of controlled mix. These specimens are prepared per Marshal Mix Design Procedure. After determination of OBC, samples were prepared for Performance Testing.

3.2.4.1 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 bitumen varied according to its percentage which is from 3.5% to 5.5% of mix. The aggregate then used is composed of different sizes according to gradation used. While for preparation of sample having glass and plastic, first get the retain of sieve #4, then the amount of glass and plastic in mix is determined per its percentage used while the remaining portion of specimen is composed of virgin bitumen and virgin aggregate based on the percentage of Bitumen being used. The weight of bitumen and aggregate can be obtained by following formula:

W_T =

W_B +

W_A

W_B =

X/10

0* W_T

Where:

W_T = Mass of the Total mix

W_A=Mass of Aggregate

W_B= Mass of bitumen

X= Percentage of Bitumen

3.2.4.2 Mixing of Aggregate, Glass and Plastic and Asphalt

For Controlled Samples, bitumen is first heated to about 150 °C then oven dried aggregate is mixed with it. Keep mixing until homogenous mix is formed. For the samples having glass and plastic, first heat it up to 140 °C then mix it as the same procedure followed for controlled sample.

3.2.4.3 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. We 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 having base plate. A filter paper was placed both above and below the specimen. After achieving 75 blows on one side, specimen was inverted, and 75 blows were applied in other side of specimen. Marshall Compactor was used to achieve compaction.

Fig 3.7 (Marshall Compactor)

Fig 3.8 (Marshall Samples)

3.2.5 Determination of OBC

The volumetric properties of specimen are calculated by determining Gmb and Gmm and values after placing the specimen at room temperature. The tests for Gmb and Gmm are performed in accordance with ASTM D2726 AND ASTM D2041 respectively. For determination of Gmb firstly weight in air of specimen is determined, after which its weight in water and SSD weight are determined.

Fig 3.9 (Gmb Calculation for Marshall Samples)

Fig 3.10 (Marshall Samples being placed in Water Bath)

After the determination of Gmb, the specimen is transferred for 30-40 minutes at 60 °C then tested for Marshall Stability and flow using Marshall Equipment. After placing the sample in Marshall Apparatus, it is loaded at constant deformation rate of 5mm/minute until the specimen fails. The maximum load that the specimen takes is its **Stability** value and the strain that occurs at maximum load is recorded as **Flow number** in mm. According to Marshal Mix design Criteria MS-2, for surface designed for heavy traffic load should have Stability value not less than 8.006 KN and Flow should be between 2 to 3.5 mm.

Fig 3.11 (Marshall Stability and Flow Apparatus)

For Gmm calculation weight the loose mix, first determine 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.

Fig 3.12 (Gmm Determination)

3.2.6 Preparation of Bituminous Mixes for Marshall Mix design

There are four categories of sample in the research. OBC was determined for each for each category i.e. samples having 0%, 0.5%, and 1.5%, 2.5% glass and plastic 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.

Table 3.4 (TEST MATRIX for Marshall Mix Design)

Plastic & Glass Replaced (%)	Bitumen Content (%)	No: of Samples
Control sample	3.5	3
	4.0	3
	4.5	3

	5.0	3
	5.5	3
0.5% Plastic & 0.5% Glass	3.5	3
	4.0	3
	4.5	3
	5.0	3
	5.5	3
1.5% Plastic & 1.5% Glass	3.5	3
	4.0	3
	4.5	3
	5.0	3
	5.5	3
2.5% Plastic & 2.5% Glass	3.5	3
	4.0	3
	4.5	3
	5.0	3
	5.5	3
Total		60

3.2.7 Determination Asphalt Content in Modified Mix (ASTM D 630798)

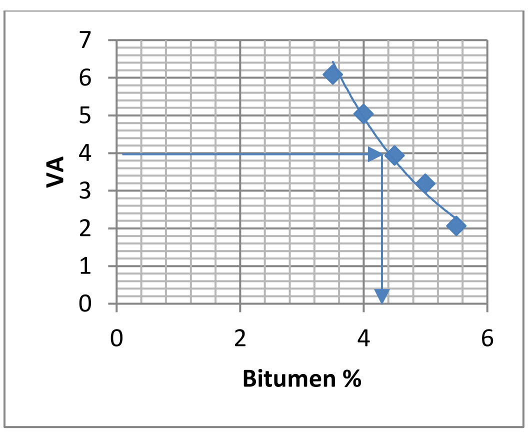
Volumetric properties of mix having 0% Plastic and 0% Glass

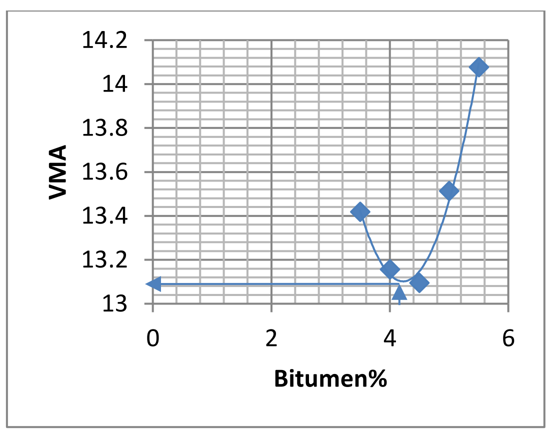
The flow and stability, volumetric properties of controlled mix are shown in table.

Table 3.5

Bitumen	%aggregate	Gmm	Gmb	VA	VMA	VFA	Stability	Flow
3.5	96.5	2.482	2.352	6.09	13.419	54.6	11.973	2.25
4	96	2.477	2.352	5.046427	13.15692	61.64432	13.276	2.55
4.5	95.5	2.463	2.366	3.938287	13.095	69.92526	11.879	2.74
5	95	2.445	2.367	3.190184	13.51346	76.39255	8.954	3.55
5.5	94.5	2.414	2.364	2.071251	14.07769	85.287	8.315	4.08

Table 3.5 Volumetric Properties of 0% Plastic and Glass the graphs between Asphalt content and different volumetric properties were plotted to find out OBC as shown in figure 3.13.





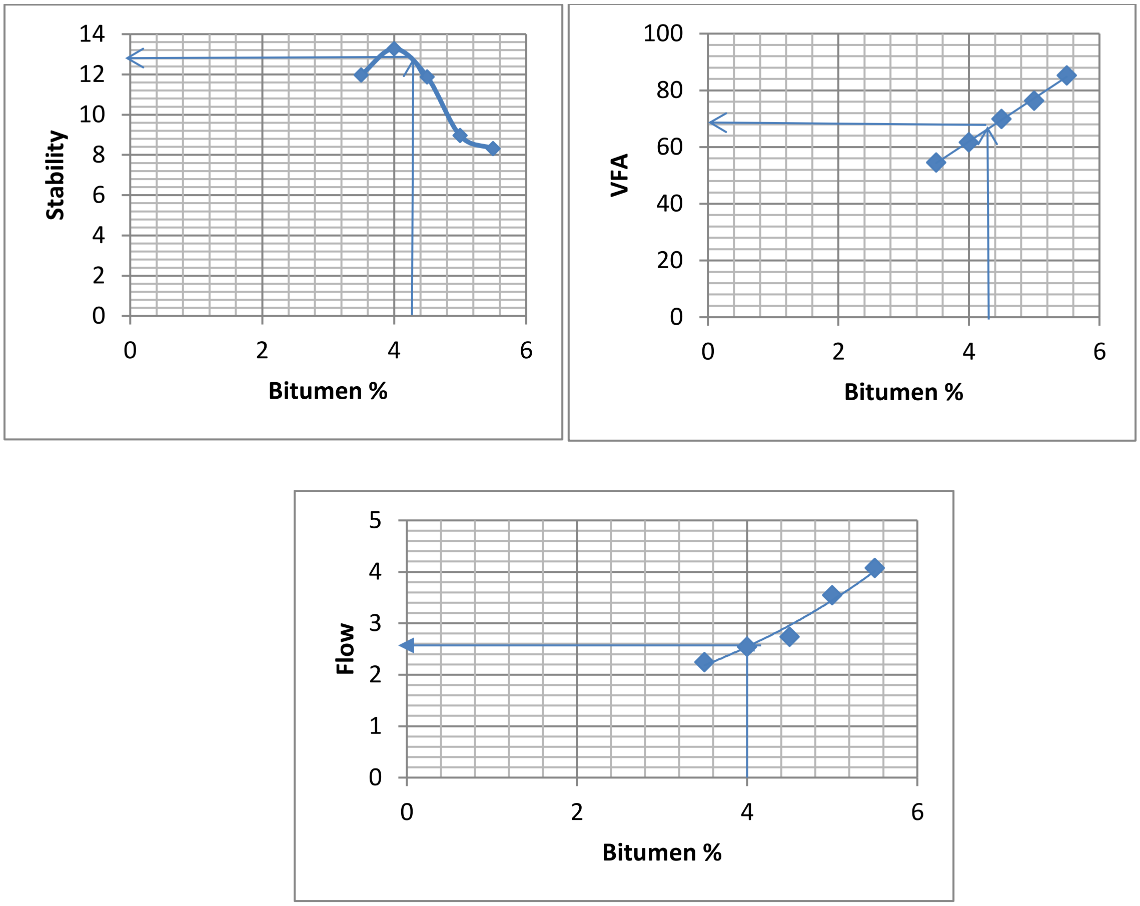


Figure 3.13 Volumetric Properties of 0% Plastic and 0% Glass Graphs

The corresponding bitumen percentage to 4% air voids is considered OBC. The OBC for the selected additive percentages is 4.38%. All other properties are checked at the selected bitumen percentage. If all the properties are within the limits specified by MS-2 then well and good otherwise OBC will have to be adjusted. According to MS-2 Criteria, the VMA value should be greater than 13% while in this case it is 13.035% i.e. within the range. VFA should be between 65-75, while the calculated value is 68%. Stability should be minimum of 8.006 KN while it is determined to be 12.85 KN in this case while flow is 2.85 mm lies within the range of 2-3.5 mm.

Table 3.6 Summary of properties 0% Plastic 0% Glass

Parameters	Value Measured	Limits	Remarks
OBC (%)	4.38	-	-
VMA (%)	13.035	≥ 13	Pass
VFA (%)	688	65-75	Pass
Stability (KN)	12.85	≥ 8.006	Pass
Flow (mm)	2.85	2-3.5	Pass

Volumetric properties of mix having 0.5% Plastic and 0.5% Glass

The flow and stability, volumetric properties of controlled mix are shown in table.

Table 3.7

Bitumen	%aggregate	Gmm	Gmb	VA	VMA	VFA	Stability	Flow
3.5	96.5	2.483	2.332	6.081	13.446	54.775	14.76	2.34
4	96	2.462	2.35	4.549	13.230	65.616	15.9	2.5
4.5	95.5	2.455	2.367	3.584	13.058	72.549	14.34	2.7
5	95	2.439	2.371	2.788	13.367	79.142	12.88	2.94
5.5	94.5	2.441	2.385	2.294	13.314	82.769	12.43	3.2

Table 3.7 Volumetric Properties of 0.5% Plastic and Glass the graphs between Asphalt content and different volumetric properties were plotted to find out OBC as shown in figure 3.14.

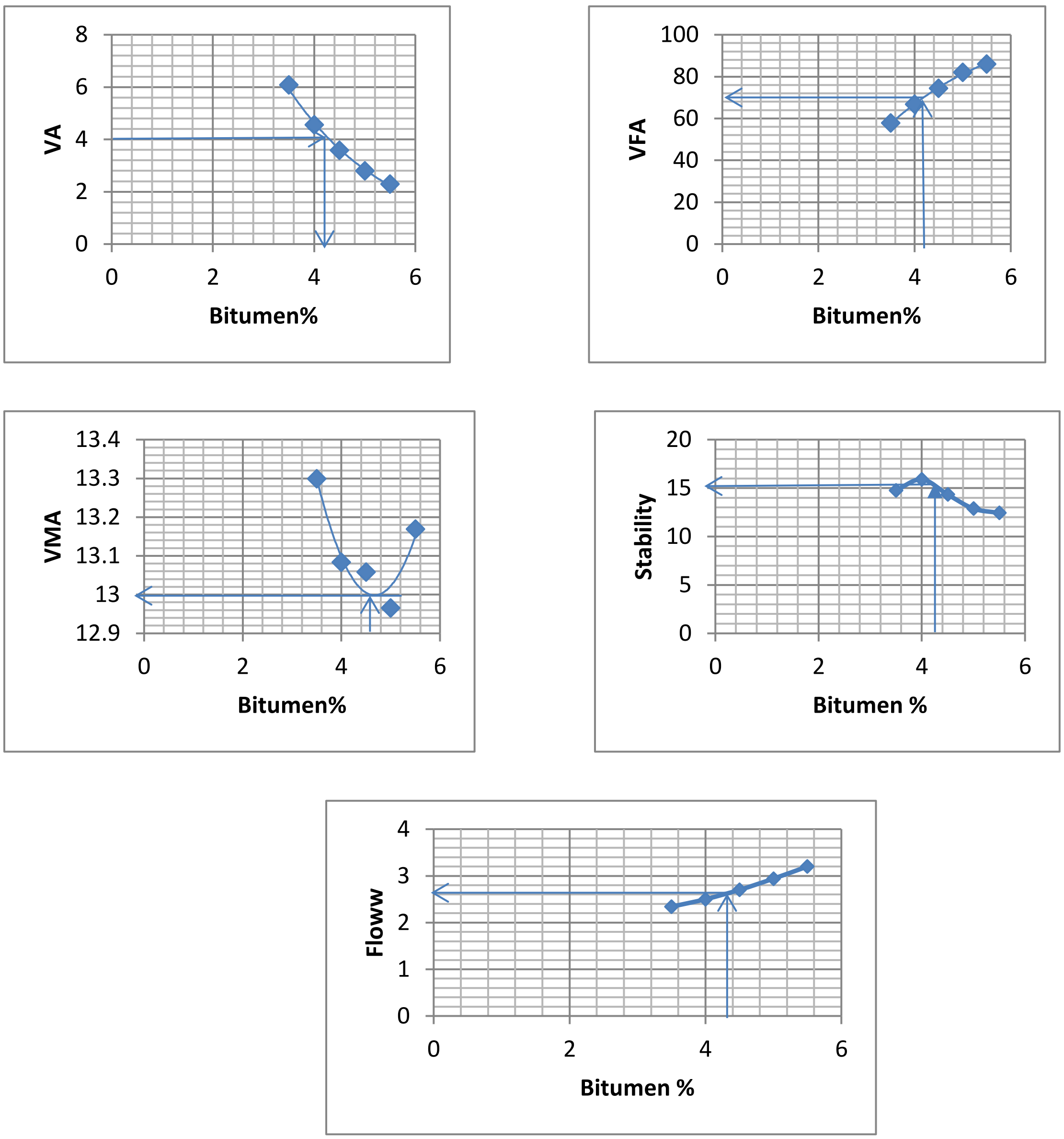


Figure 3.14 Volumetric Properties of 0.5% Plastic and 0.5% Glass Graphs

The corresponding bitumen percentage to 4% air voids is considered OBC. The OBC for the selected additive percentages is 4.28%. All other properties are checked at the selected bitumen percentage. If all the properties are within the limits specified by MS-2 then well and good otherwise OBC will have to be adjusted. According to MS-2 Criteria, the VMA value should be greater than 13% while in this case it is 13.03% i.e. within the range. VFA should be between 65-75, while the calculated value is 72.5%. Stability should be minimum of 8.006 KN while it is determined to be 14.8 KN in this case while flow is 2.62 mm lies within the range of 2-3.5 mm.

Table 3.8 Summary of properties 0.5% Plastic 0.5% Glass

Parameters	Value Measured	Limits	Remarks
OBC (%)	4.28	-	-
VMA (%)	13.03	≥ 13	Pass
VFA (%)	72.5	65-75	Pass
Stability (KN)	14.8	≥ 8.006	Pass
Flow (mm)	2.62	2-3.5	Pass

Volumetric Properties of 1.5% Plastic and 1.5% Glass Graphs

Table 3.9

Bitumen	%aggregate	Gmm	Gmb	VA	VMA	VFA	Stability	Flow
3.5	96.5	2.485	2.34	5.83501	13.15	55.6273	10.36	2.56
4	96	2.471	2.356	4.653986	13.00923	64.22551	12.48	2.78
4.5	95.5	2.457	2.366	3.703704	13.095	71.71666	11.58	2.96
5	95	2.432	2.367	2.672697	13.51346	80.22196	9.26	3.2
5.5	94.5	2.414	2.364	2.071251	14.07769	85.287	8.06	3.5

Table 3.9 Volumetric Properties of 1.5% Plastic and 1.5%Glass the graphs between Asphalt content and different volumetric properties were plotted to find out OBC as shown in **figure 3.15**

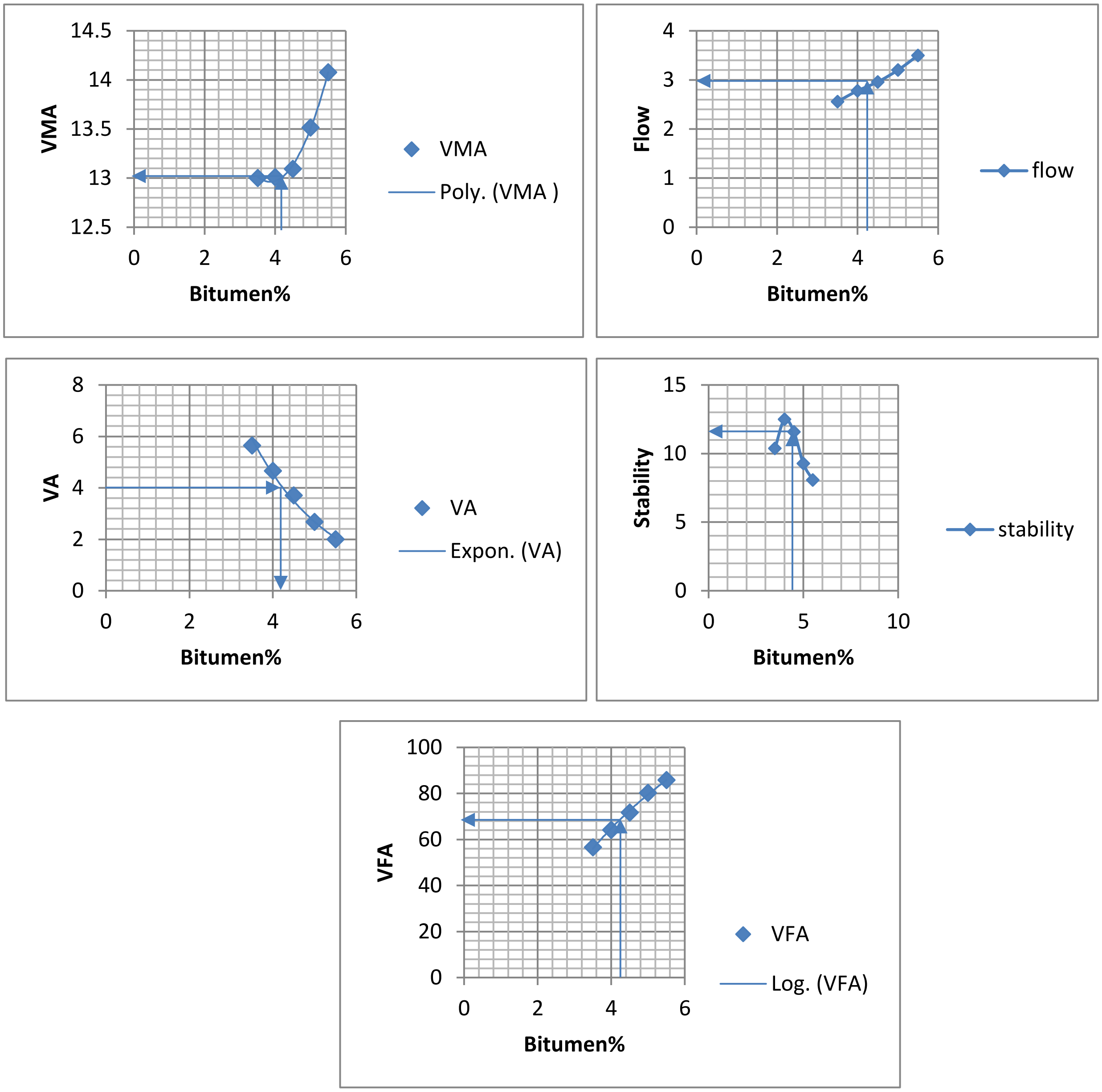


Figure 3.15 Volumetric Properties of 1.5% Plastic and 1.5% Glass Graph

The corresponding bitumen percentage to 4% air voids is considered OBC. The OBC for the selected additive percentages is 4.20%. All other properties are checked at the selected bitumen percentage. If all the properties are within the limits specified by MS-2 then well and good otherwise OBC will have to be adjusted. According to MS-2 Criteria, the VMA value should be greater than 13% while in this case it is 13.05% i.e. within the range. VFA should be between 65-75, while the calculated value is 66.5%. Stability should be minimum of 8.006 KN while it is determined to be 12.2 KN in this case while flow is 2.95 mm lies within the range of 2-3.5 mm.

Table 3.10Summary of properties 1.5% Plastic .5% Glass

Parameters	Value Measured	Limits	Remarks
OBC (%)	4.20	-	-
VMA (%)	13.05	≥ 13	Pass
VFA (%)	66.5	65-75	Pass
Stability (KN)	12.2	≥ 8.006	Pass
Flow (mm)	2.95	2-3.5	Pass

Volumetric Properties of 2.5% Plastic and 2.5% Glass Graphs

Table 3.11

Bitumen	%aggregate	Gmm	Gmb	VA	VMA	VFA	Stability	Flow
3.5	96.5	2.475	2.336	5.616162	13.29846	57.76834	9.2	2.2
4	96	2.461	2.354	4.347826	13.08308	66.76756	11.56	3.1
4.5	95.5	2.449	2.367	3.348305	13.05827	74.35873	10.26	3.9

5	95	2.439	2.382	2.337023	12.96538	81.9749	9.4	5.3
5.5	94.5	2.434	2.389	1.848809	13.16904	85.96095	8.65	5.7

Table 3.11 Volumetric Properties of 1.5% Plastic and 1.5%Glass the graphs between Asphalt content and different volumetric properties were plotted to find out OBC as shown in **figure 3.16**

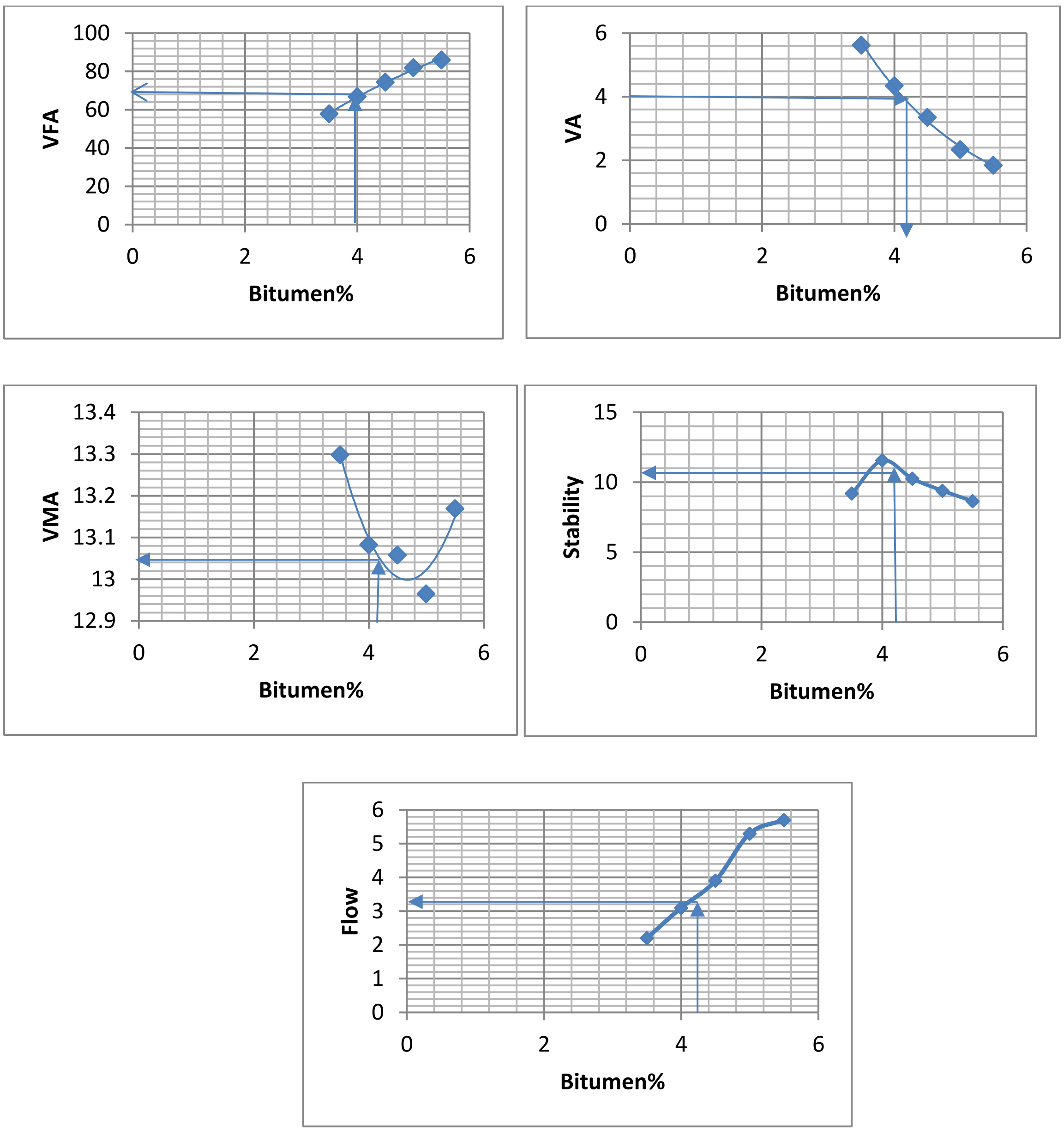


Figure 3.16 Volumetric Properties of 2.5% Plastic and 2.5% Glass Graphs

The corresponding bitumen percentage to 4% air voids is considered OBC. The OBC for the selected additive percentages is 4.15%. All other properties are checked at the selected bitumen percentage. If all the properties are within the limits specified by MS-2 then well and good otherwise OBC will have to be adjusted. According to MS-2 Criteria, the VMA value should be greater than 13% while in this case it is 13.08% i.e. within the range. VFA should be between 65-75, while the calculated value is 69.3%. Stability should be minimum of 8.006 KN while it is determined to be 11.4 KN in this case while flow is 3.40 mm lies within the range of 2-3.5 mm.

Table 3.12 Summary of properties 0.5% Plastic 0.5% Glass

Parameters	Value Measured	Limits	Remarks
OBC (%)	4.15	-	-
VMA (%)	13.08	≥ 13	Pass
VFA (%)	69.3	65-75	Pass
Stability (KN)	11.4	≥ 8.006	Pass
Flow (mm)	3.40	2-3.5	Pass

3.2.8 Preparation of Sample for Performance Tests

After finding out OBC at different percentages of Glass and Plastic, samples for performance tests were prepared i.e. for Wheel Tracking Test (Rutting) and Fatigue Tests (EN-12697-24). Samples prepared included:

- Control Samples
- Samples containing Glass and Plastic

For Fatigue tests, 12 samples were prepared at three different percentages of Glass and plastic i.e. 0.5%, 1.5% and 2.5% following the same procedure for Marshall sample preparation.

Fig 3.17 Samples for Fatigue test

For wheel tracking test, 8 samples (2 control and 6 modified) of 6kg were prepared and compacted in gyratory compactor.

Diamond Saw Cutter was used to cut the samples according to the dimensions for wheel tracking device.

Table 3.13 TEST MATRIX (for Performance Testing)

Plastic Replaced (%)	Glass Replaced (%)	ITFT By UTM	Rutting by Wheel Tracking Device	Total
0	0	3	2	5
0.5	0.5	3	2	5
1.5	1.5	3	2	5
2.5	2.5	3	2	5
Total		**12**	**8**	**20**

3.2.8.1 Fatigue Testing

After preparing the samples for fatigue testing, diamond saw cutter was used to get the samples according to the desired dimension and are then placed in UTM to perform fatigue test. The method selected is indirect tensile fatigue test. Stress controlled loading is applied. The specimen is subjected to Haversine load in vertical direction. This vertical compressive load produces tensile stress in the horizontal direction perpendicular to the load applied on the sample that's why it is known as indirect tensile fatigue test. The sample fails by splitting along vertical plane.

The fatigue life of a sample is defined as number of cycles to failure. In this research the load applied was 3500 N with a loading time of 0.1 seconds and a rest time of 0.4 seconds. The test was performed at 25 °C. Prior to testing the samples were conditioned for 4 hours at 25 °C. The test finishes once the sample is fractured. The number of cycles to failure is noted to draw conclusions.

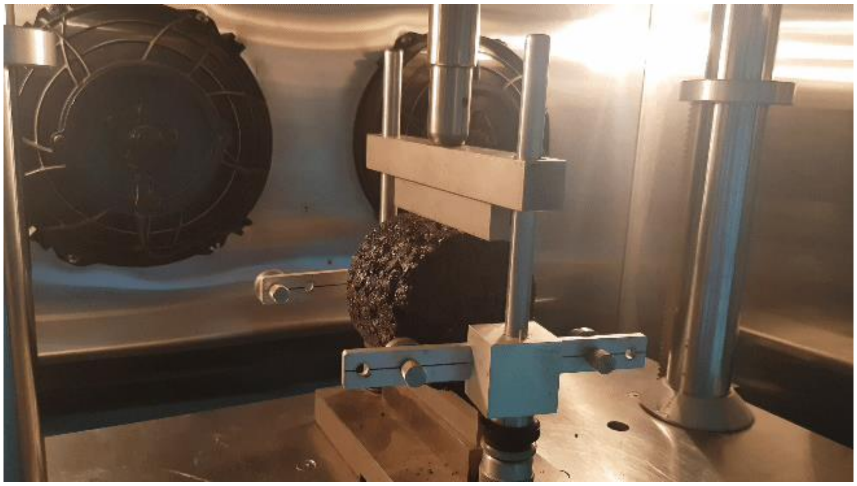


Fig 3.18 Fatigue Test Assembly

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This study is based on incorporating glass and plastic as aggregate replacement in HMA (Hot Mix Asphalt) mixture and finds their effect on fatigue life and rutting. Glass and Plastic utilized were collected from Timber Market, I-9, Islamabad. Samples for Performance testing are prepared after determining OBC at different Percentages of Glass and Plastic. The gradation used was NHA class B.

In this chapter, results are shown and analyzed for tests i.e. Wheel Tracking (Rutting) and Fatigue test. The details of these tests are already discussed in chapter 3. Glass and Plastic contents were taken to be 0.5%, 1.5% and 2.5% with 2% dry lime. The results of these tests were compared with those of control samples.

4.1.1 Fatigue (ITFT) Tests Results

Fatigue test was carried out in UTM according to the standard EN 1269724Fatigue test was carried out in UTM according to the standard EN12697-24. The test was performed in stress-controlled conditions according to which stress was held constant to increase strain within the sample. HMA samples with different Glass and Plastic contents. Samples with 50mm±1mm size with 4 hours conditioning at 25°C were tested under the loading of 3500 N. The results of which are given below.

Table 4.1 (Fatigue Test Results)

Glass and Plastic content (%)	Average no. of cycles
0%	3562
0.5%	5656
1.5%	4378
2.5%	2469

As the test was performed under stress-controlled conditions, as plastic content was increased, the stiffness is increased but up to a certain extent. The trend shows that by increasing plastic up to 1.5%, the fatigue life increases but beyond that, it decreases.

4.1.2 Wheel Tracking (Rutting) Test

Wheel tracking test was carried out in APA (Asphalt Pavement Analyzer) using rubber wheels and at room temperature 25°C. The test was performed for 5000 cycles. The final rut depths are shown below.

Table 4.2 (Rutting Test Results)

Glass and Plastic content (%)	Rut Depths (mm)
0%	0.58
0.5%	1.03
1.5%	2.48
2.5%	2.82

The results show that as the plastic and glass content is increased, the rut depths also increase. However, according to TDOT (Texas Department of Transportation), for a sample to pass the rutting test, it must have final rut depth below 12.5mm at 20,000 passes. In our case, the rut depth should be below 6.25mm for 5000 cycles or 10,000 passes. So, all the samples have performed comparatively well in rutting.

4.2 Summary

In this chapter, the results of two important tests (Fatigue and Rutting) have been discussed in detail and the reasons behind their behavior as well. The best results are obtained for the samples containing 1.5% glass and plastic as there is suitable compromise between performance and usage of waste material.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The project aimed to test the effectiveness of the Plastic bottles (PET) and Glass (Windows, bottles) as a replacement of virgin aggregate in Hot Mix Asphalt. It's efficiency in Rutting and Fatigue cracking. UTM for fatigue Asphalt Pavement Analyzer (APA) for Rutting were used. NHA class B wearing course gradation, 60/70 grade Bitumen were the material standard used. Plastic and Glass were used in equal percentages as a replacement of fine aggregate which are (0.5%,1.5% & 2.5%) with the addition of 2% lime to counter stripping due to glass. The samples were prepared to obtain OBC with virgin bitumen. Main conclusion which can be drawn from the results are as follows.

5.2 Conclusions

The conclusions drawn from the analysis of tests, conducted in the previous chapters is following below

Increasing the Plastic content specifically has led to decrease in finer particles, thereby decreasing the bitumen requirement in the mixture as compared to control specimen.

Increasing the modified content increased the stability, however, stability at 2.5% Plastic and Glass is comparatively less. This is mainly due to higher plastic content, which increases the flow of the specimen.

Bitumen remain within the range of 60/70 grade. So that other performance of pavement like low temperature cracking is not affected. More ever the virgin bitumen of grade 60/70 also act as a rejuvenating agent in reducing the stiffness.

Penetration tests and Ductility tests were performed on the LDPE contents with virgin bitumen limiting the value of LDPE to 4 % of the virgin bitumen which shows that 4% LDPE won't change the binder grade.

Results show that that increase the RAP contents with or without LDPE increases the moisture resistance. While increase in moisture resistance for sample having LDPE also, is slightly less as that of samples having RAP only.

Results shows the No. of cycles (fatigue life) of the HMA increases with increase modifier percentages in stress-controlled condition.

The Rutting resistance of the specimens reduced with increase in modifiers' contents. The result shows that the trend is closely linear.

Therefore, after analyzing the performance testing results, 1.5% Plastic and 1.5% Glass would give a suitable blend without compromising the required strength.

Using Plastic and Glass in HMA will not only reduce the indirect cost but will help us in conserving the natural resources and using of the waste materials, making the environment more sustainable.

5.3 Recommendations

In this study, Indirect Tensile Fatigue testing and rutting resistance were performed for testing performances. Other tests like moisture susceptibility, dynamic modulus, flow number and flow time were not performed. It is recommended to test the different blends of Plastic and Glass in HMA for the above-mentioned tests too, to know more about their behavior.

Further tests are required on different percentages of Glass and Plastic. It is recommended to fix the plastic percentage at 1% and increase the Glass content to 3%, 5% and 7%. Since plastic disturb the stability, specifying its percentage would increase the glass use, hence reducing waste glass amount.

Further study is recommended to check fatigue life of pavement under strain-controlled conditions and by using different gradation to see Plastic and Glass mixture performance.

It is recommended to construct a trail section to verify the blend's performance in temperature and traffic conditions of Pakistan

Based on the results of this study, it is recommended with confidence that Plastic and Glass can be used in HMA that meets the volumetric and desired performance criteria. Since it performs better than the control mixture, it has the potential to save country's resources and bring sustainability in Transportation industry of Pakistan.

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