STUDY ON CRUMB RUBBER MODIFIED POROUS BITUMEN PAVEMENT

A PROJECT

Submitted in partial fulfillment of the requirement for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"CRUMB RUBBER MODIFIED POROUS BITUMEN PAVEMENT"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Abhishek Soni (131631), Vinay Puri (131632)** and **Abhishek Verma (131680)** during a period from July 2016 to May 2017 under the supervision of **Mr. Saurabh Rawat,** Assistant Professor and **Mr. Abhilash Shukla**, Assistant Professor Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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Abstract

Pavement which allows water to percolate from its surface is called porous/pervious pavement. These type of pavements can be use in those areas where there is no proper drainage system. The water percolate through the porous pavement. We can use this type of pavement at residential area roads, parking areas and areas with low traffic

This project involves discovering how the addition of additives in plain bitumen VG40 grade affects its properties. The properties include overall Strength of the pavement, softening point ,viscosity , ductility , penetration values of the modified bitumen. The goal of the project is to show that the addition of additives in plain bitumen significantly improves its properties and can be used in casting porous bitumen pavement. This has been done by performing numerous experiments and casting marshall mix design of the pavement. The additive used were crumb rubber which is obtained from tires. Upon experimenting on these , we have found that porosity ,Ductility Softening point as well as strength, i.e Compressive strength has improved significantly.

We can thus conclude that Crumb rubber modified bitumen increase the adhesive force between the aggregates and bitumen and keep the aggregates attached to each other and impart impact resistance to Crumb rubber modified porous bitumen pavement. The softening point of the bitumen changes from 48℃ to 60℃ and Ductility reduced upto 25% and these characteristics in turn improve the porosity and strength properties of the Crumb rubber modified bitumen porous pavement.

Keywords- Porous , Drainage, Additives, Modified, Crumb, Bitumen

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Chapter1

Introduction

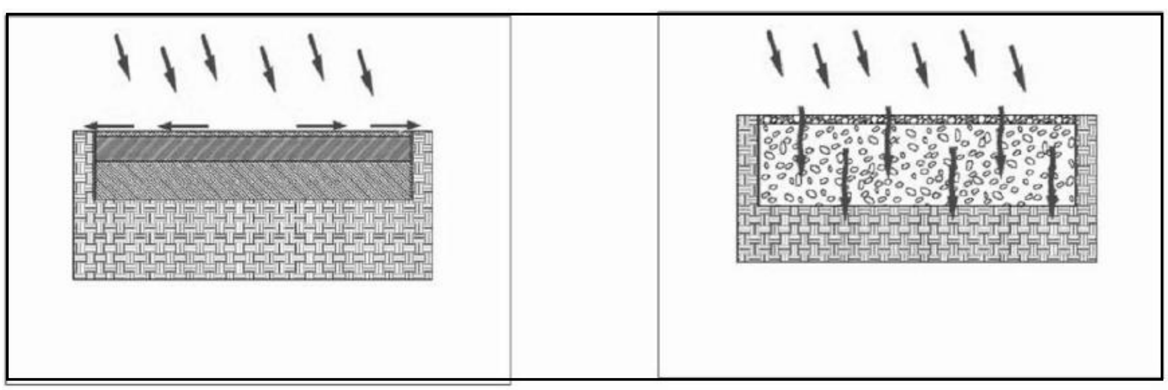
General

The accompanying part gives a prologue to and foundation into permeable asphalts concerning black-top and solid asphalt structures and in addition to create efficient binding of solid pavements. Our report hereby provides an insight into the objective, significance and future prospects of the subject. This dissertation provides the basic framework of the proposal.

Background

In recent years researchers, designers and builders searching for as good as ever approaches toensure nature is protected in the best ways available. One such developing innovation is the 'Penetrable bitumen pavement' that enable water to penetrate through surfaces that would regularly be impermeable, for example, the thick reviewed adaptable asphalts or the unbending solid asphalts.Permeable asphalts are of different sorts which incorporate permeableasphalt, pervious concrete, inter-locking concrete block pavers, turf reinforcing grids.

Porous pavements allow rain water to percolate through the pavement surface into a stone recharge bed and infiltrate into the soil below the pavement or collected in under pavement drain pipes. With the most ideal outline and establishment, permeable asphalt can give storm-water admistration frameworks that propel attack, upgrade water quality. The guideline purpose of the permeable asphalt is to manage wealth storm water overflow and allow continous movement stream without water logging condition.



(a) (b)

Figure 1:a) Precipitation on Traditional Bitumen Pavement b) precipitation on Porous Pavement
Source: Yalchinkaya et al.,2012

Common applications of Porous Bitumen Pavements are parking lots, side-walks, shoulders, drains, noise barriers, friction course for highway pavements, permeable sub base under the conventional flexible or rigid pavements and low volume roads.

The Economic Benefits incorporates:- lessening in tempest water spillover, including decrease of temperature, aggregate water volume, and stream rate, increment in groundwater invasion and revive, gives neighborhood surge control. The gathered water can likewise be utilized for road washing which will decrease the road tidy.

Permeable black-top comprises of a high rate of interconnected air voids (>15%). Subsequently of a high measure of air voids in penetrable asphalt, developing resistance of the fastener end up noticeably significant. In view of developing bituminous material winds up evidently harder and more frail, accordingly growing peril of black-top dissatisfaction. Crumb Rubber Modified Bitumen enhances the rutting resistance, flexibility modulus, and weariness breaking resistance of asphaltic mixes. This occurs mainly due to the change of the property of the bituminous folio to the degree of the consistency, softening point, misfortune modulus, and capacity modulus. This difference is brought by the concerted action of elastic particles and their swelling mechanism with bitumen. Flexible Crumbs absorb the fluid section of bitumen and can swell up to 3 to 5 times. This left a higher degree of dark top in the latch, along these lines growing its thickness.Crumb elastic enhances rutting resistance as well as condition cordial as Crumb elastic is gotten by reused procedure of waste tire.

Purpose/Motivation

With the increase in population number of vehicles per Km also rises due to this, there is need to widen the roads. But in cities limited right of way available , due to which there is need to paved the unpaved area (called shoulder of road used for drainage), which leads to improper drainage and water logging condition and thus traffic jam. So there is need such a system which will provide good drainage to storm water and continous flow to traffic.

The point of this exploration was to examine the potential utilization of a developing tempest water administration innovation as it applies to the Indian atmosphere. With expanding ecological mindfulness and an advancing outlook change in tempest water administration systems, this exploration plans to give direction to Indian specialists, contractual workers, and government organizations in managing permeable porous bitumen as a storm water controlling technique. The main objective of this examination is to be inclined towards the basic outline and suggestion for the porous bitumen mixes and execution measure.

Figure 1.2: water logging condition on roads

1.3 Objective of the study:

1. To modify the properties of Bitumen by the addition of Crmb Rubber of size 40 mesh.
2. To decide the Optimum Bitumen substance of Porous asphalt by utilizing Marshall Mix Design.
3. To decide the porousness of permeable asphalt by falling flat Head Permeability Test
4. Improving the strength of the porous pavement by changingCrumb Rubber content or by changing the gradation of the mix.

Finally based on the experimental results, propose tentative mix design guidelines for 'Porous Asphalt Pavement'.

1.4 Scope of Study:

1. Determination of optimum bitumen content of porous pavement by varying Crmb rubber size.
2. Improving the strength and Permeability of the of porous pavement with the use of other additives such as Polyethylene (PE), Ethylene Vinyl Acetate (EVA) etc.
3. Hydrological design of Porous Pavement-underground drain pipes.

1.5 Constituents of Thesis

1. Chapter One - gives an idea and introduction to the survey performed till date. It gives a general foundation and gives the degree and targets of the project.

2. Chapter Two - gives a written assessmentof the permeable or penetrable asphalt innovation.

3. Chapter Three - depicts the exploratory philosophy used to lead this examination.

4. Chapter four - gives the permeable black-top execution test comes about.

5. Chapter five - gives the examination conclusions and degree for future work

Figure 1.3 Porous Pavement Sample

Chapter 2

Literature Review

2.1 Introduction

Various research papers are accessible on the subject of crumb rubber modification. Probably the most essential research papers with regards to crumb rubber modification have been looked here in the present review.

2.2 Flexible Pavements

According to the Transportation Association of Canada (TAC) a flexible pavement is an asphalt structure mainly comprised of layers of bitumen solid constructed on unbound aggregates or stabilized bases. Of the many types of bitumen concrete mixtures the following are accepted traditional bitumen mixtures.

Porous Pavements

Prior to the finish of 1960's, research into another kind of asphalt structure was done in EPA labs in United States. With their assistance and help a permeable asphalt composition structure which was introduced in different parking lots.

There are a few weaknesses of this sort of asphalt. When all is said in done there is low specialized aptitude in these sorts of asphalts especially in frosty atmospheres. Blockage potential is of worry because of the open structure or the permeable nature of the asphalt.

There is a potential damage to groundwater fouling and a probability for harmful chemicals to spill into the framework.

Permeable asphalts are not as of now intended to treat pollutants waste. At last, there is a potential for anaerobic conditions to create in fundamental soils if the frameworks can't dry out between tempest occasions

Figure 2.3 presents an example of a typical porous section (for parking lots and low traffic areas with light weight vehicles) that was provided in an Environmental Protection Agency study.

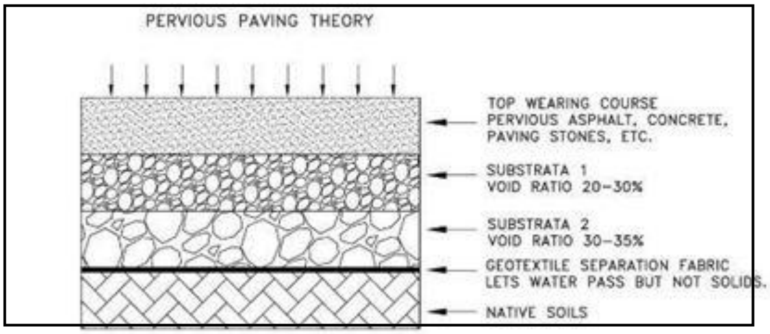


Figure 2.4representation of Section paved by porous bitumen

Two main types of permeable asphalts have been recognized by EPA: permeable bitumen and pervious cement.

The writing demonstrates that permeable asphalt may likewise be alluded to as pervious or penetrable asphalt.

2.3 Offered Benefits And Advantages

The offered advantages of permeable asphalts run from key ecological advantages to wellbeing benefits. A portion of the advantages related with permeable asphalt incorporate yet are not constrained to: usage of innovation to give extra tempest water administration measures. Moreover best practices, lessening in clamor levels, offering more convenince to drivers and people on foot , and decreased potential for dark ice.This diminishing of ice may likewise prompt decreased requirements for certain winter upkeep exercises. The ACI has additional advantages as it decreases the water-retention areas thereby increasing parking facility areas and creating additional lift to the aircraft during takeoff due to the cooling effect, and allowing air water

1. Managementof Storm water

This section can be quotes as "The ambition of porous pavement is to enhance and use the natural capacity of soil to absorb runoff and to refill the earth with it".
In contrast with a conventional dense-graded pavement, permeablepavement is commonly introduced as a urban "Best Management Practices" (BMPs) within government organisationsfor getting an another practice to storm water management and run-off control.
Permeable pavement offers the likelihood to accumulate or conceivably direct the rate of continues running off from various invulnerable surfaces. The EPA moreover says that porous pavements can outfit the many points of interest with respect to tempest water organization: reduction of pollutants thereby clearing water, reduce the necessity for checking and storm sewers, and restore neighborhood water bodies..

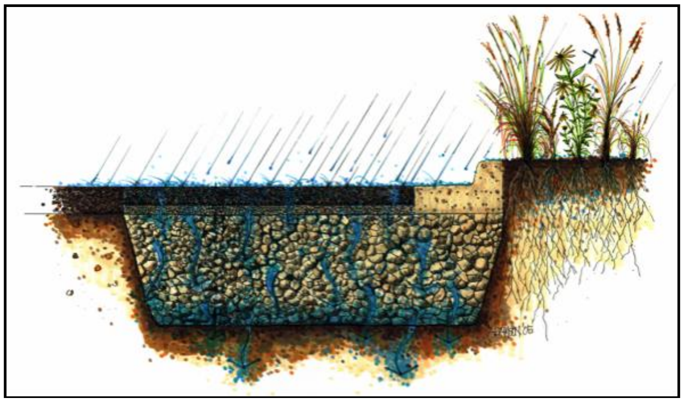


Figure 2.5: Storm water infiltration

Source:https://limestone.org/wpcontent/uploads/2016/01/Asphalt-1200x700.jpg

2. Quality of water

Permeable pavements are useful in reduction of waste. 82% to 95% of sediment, 65% of phosphorusand 80% to 85% of entire nitrogen was eliminated according to the study . As far as possible and profitability of the structure is dependent on the level of blockage inside the porous system. With legitimate support the permeable framework ought to have the capacity to successfully evacuate pollutants\waste.

3. Safety

Permeable pavement has an advantage in street security to both travellers be it the ones on foot or in the vehicles because of the potential for skid resistance particularly when there are substantial rains.Since the surface course of permeable bitumen shows comparable properties to open-evaluated contact courses, appropriately working permeable bitumen surfaces may counteract hydroplaning on roadway surfaces as water is permitted to permeate through the framework. As the still water is disposed of from the surface shower and sprinkle is diminished hence enhancing driverperceivability.

4. Noise Attenuation

Same as open-graded friction course, permeable pavements can help with diminishing the commotion produced by the tyre and street contact. Permeable bitumen tests in UK in the mid 1980's onclude that when a permeable surface course was puta diminishment of somewhere close to 5.5 and 4 decibels (dB(A)) for dry conditions was seen. In France, toward the finish of 1980's, scientists delineated that permeable bitumen was 1 to 6 dB(A) superior to thick reviewed bitumen because of the retentive capacities of permeable bitumen.

5. Durability and Strength

One of the significant worries with permeable asphalt frameworks especially the surface course is solidness and quality attributes. Snow furrow presentation, the potential for blockage because of winter support applications and the likelihood of deplete down of the bitumen.

2.4 Disadvantages

Aging and Stripping

Though a bit of hindrances Albeit permeable bitumen has many points of interest. A champion among the most standard figures the execution of bituminous mixes is the slant of the folio film on the surface of the aggregate to be unendingly exhibited to oxygen, sunlight, water et cetera. This outcomes in folio solidifying and a diminishing in asphalt benefit life (Hoban et al.,1985). At the point when bitumen solidifies, totals can be stripped effectively from the bitumen blends.
Sometimes the water remains in the structure keeping the bitumen in wet condition for a long time which may cause stripping.

Shorter Service Life

The service life of porous bitumen surface is shorter than that of dense mix layers. In addition, it depends on the binder content and type, aggregate gradation, traffic load and climate. Also as these play a major role so the effects like safety cannot be ignored.

2.5Porous Bitumen: Structure, Properties, and Design

According to the U.S Department of Transportation and the Federal Highway Administration (FHWA) permeable asphalt structures comprise of three parts: a surface course, a channel course, and a repository course, all built on a penetrable subgrade base. A 50-100 mm (2-4 inches) of an open-reviewed bitumen blend is made of surface course. 25-50 mm (1-2 inches) comprising of squashed total that gives sifting abilities and in addition give an appropriate stage to clearing is in the channel course. A 40 – 80 mm (1.5 – 3 inches) normally built as a store facility comes under repository course.

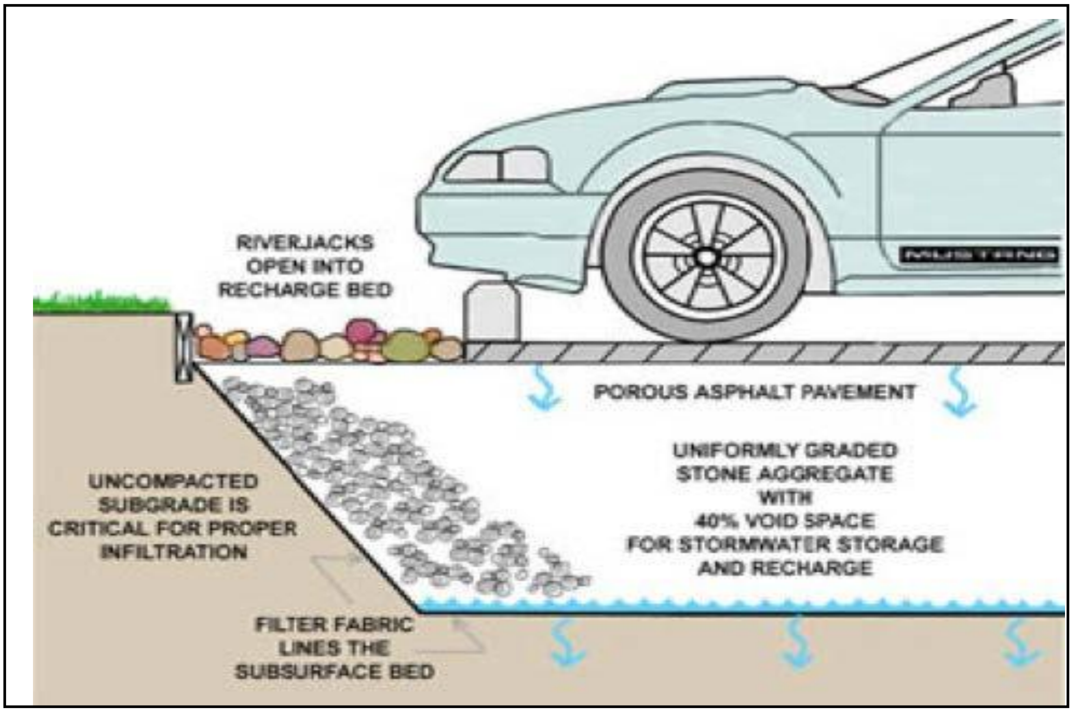


Figure 2.6 Porous pavement Cross section

Source

https://www.clemson.edu/extension/hgic/water/resources_stormwater/images/302intro_to_porous_pavement_fig1.jpg

2.6 Characteristics of Surface Course Material

Bitumen binder is the main constituent of Porous bitumen and traditional dense-graded bitumen surface courses, Various coarse and fine aggregate gradations. Surface course gives a stacking stage, ride quality and wellbeing to travellers. At present the design rules for surface courses for permeable bitumen are proportional to the rules prescribed for an open-reviewed rubbing (surface) course [NAPA 2003].

2.7 Requirements for air void

Porous pavements are highly permeable and have infiltration property of the structure. The permeability of the pavement is important for the functionality of the structure.In traditional dense-graded bitumen mix designs, a typical in-place air void percentage is 3% to 8%,percentages < 3% have resulted in rutting and percentages> 8% can lead to oxidization of the bitumen binder resulting in cracking.

2.9 Aggregates and Grading

To attain the proper air voids in the mix grading and properties of the aggregates used in the surface course are important components of the mix design.In order to provide a greater air void percentage, a greater proportion of coarse aggregate and few fine aggregates are required.

Table 1: National BitumenPavement Associations Recommended Design Gradations for Porous BitumenSurface Course (After Kumar et al., 2014)

Sieve Size (mm)	Percentage Passing %
19	100
12.5	85-100
9.5	55-75
4.5	10-25
2.36	5-10
0.075	2-4

Source: Kumar et al,, 2014

the percent passing on a 4.75 mm sieve ranges between 10-35% with a small proportion of fine aggregates in the mix accorthe National Asphalt Pavement Association

2.11 Maintenance

the prevention of blockage is the main aim for upkeep of the product. The structure annally is vaccumedto ensure that void structure is clear of dirt and debris. maintenance schedule is provided by ACI

Table 2: Maintenance Activities for Pervious Concrete

Care Activities	Frequency
- cleanliness of pavement area from debris -cleanliness of area	Monthly
-Seed bare upland areas -Vacuum cleaning	As needed
-Inspection of surfacedecandence	Yearly

Source: Lebens et al, 2012

2.12 Designing of pavement Theory

Theories like experience based, empirical, and the Mechanistic-Empirical Pavement Design Guide (MEPDG) have been connected with pavement design.
According to the National Cooperative Highway Research Program (NCHRP), the objective was obtained through the following [NCHRP 2004]:

1. The Design Guide itself, uses existing mechanistic-empirical technologies based on complete pavement design step
2. User-friendly computational software and documentation based on the Design Guide steps.

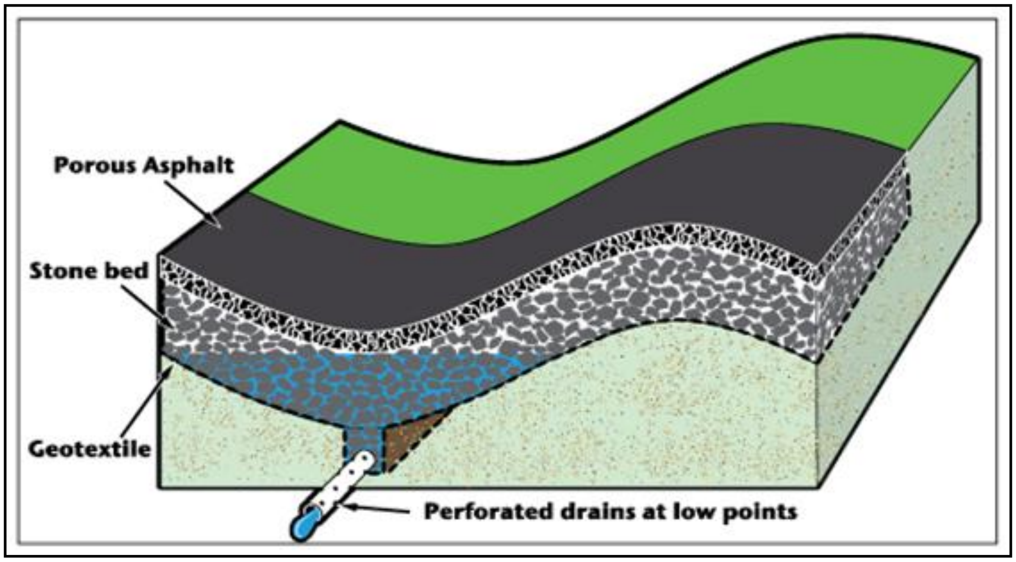


Figure 2.7: Conventional Porous Bitumen pavement

Summary

This part comprises a writing audit of permeable asphalts concerning bitumen, interlocking pavers, and thrown set up solid asphalt structures. These asphalts are intended to permit free depleting through the structure. Permeable asphalts are for the most part intended for stopping ranges or streets with lighter movement. By enabling fluids to go openly through the structure it diminishes or controls running off from the encompassing region These specific sorts of asphalts may likewise bring about a diminishing in the measure of pollutants\waste entering the ground water by separating the spillover. Some more benefits may include a decrease in noise, improved safety measures for drivers.

Porous bitumen pavement structures encompasses a porous bitumen surface course and a reservoir course all placed on the subgrade material.High porosity is the main determinant of functionality. Typical dense-graded bitumen mix designs have an in-place air void percentage is between 3% and 8%.

At the end chapter summaries with a brief conclusion of the theories associated with pavement design including experience based, and experimental Pavement Design.

Table 3: Difference between Normal Pavement and Porous Pavement

Normal Pavement	Crmb Rubber Modified Porous Pavement
Low quality	High quality
High abrasion	Low abrasion
Less maintenance required	More maintenance required
Less resistant against freezing and thawing	More resistant against freezing and thawing
Cannot control floods	Can control floods
No storage benefits	Storage benefits
More volume of mix required	Volume reduction
Less skid resistance	More skid resistance

Figure 2.8 Porous Pavement (left) and Normal Pavement (Right)

Source:
https://www.google.co.in/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwjzn4rb8cLTAhWMu48KHf21AS0QjRwIBw&url=http%3A%2F%2Fe4research.org%2Fprojects.html&psig=AFQjCNFZs4NFSsxQwXVDRfMTbG4fTSM4cw&ust=1493322429084610

Chapter 3

Material and Methods

3.1. General

The aim of this chapter is to present the research methods employed in this study.

The experimental methodology for this research was divided into three parts.

- Part one mainly dealt with the alteration of the properties of bitumen by utilizing CRMB rubber.
- Part two was to determine a suitable mix for porous pavement and to examine the performance of the mix by Marshall Stability Test.
- Part three was to determine the permeability of porous pavement.

3.2. Selection of Material

3.2.1 CRMB Rubber Modified Bitumen

The greater CRMB rubber content was said to produce high viscosity at 135°C and improve the rutting properties (Lee et al.,2008).

It is trusted that a physicochemical collaboration that happens between the bitumen and the CRMB elastic modifies the viable size and physical properties of the elastic molecule, in this manner affecting asphalt execution.

The advantages of modified bitumen can include one or more of the following for road works.

- Lower susceptibility to daily & seasonal temperature variations.
- Higher resistance to deformation.
- Better age resistance properties..
- Better adhesion between aggregates & binder.
- Overall improved performance in extreme climatic conditions & under heavy traffic conditions.

3.2.2 CRMB Rubber- Environment friendly product

The worn-out tires,scrap tires are very serious ecological issue mainly to nations with land problems.they also generate a lot of waste.One of the methodologies of reusing waste tires is to utilize CRMB rubber from the tires as a part in bitumen asphalt blends. The CRMB rubber is mixes with bitumen to improve the performance of bitumen pavements. The substantial scale utilization of CRMB rubber from waste tires in bitumen blends has all the earmarks of being more practical option as far as engineering applications and ecological thought.Changed bitumen asphalts can limit ecological effect and boost the protection of common assets.

Figure 3.9: CRMB Rubber 40 mesh

The ability of CRMB rubber to improve the bitumen performance depends on various factors such as the mixing methods, reaction time and size of the rubber. There are two different processes of mixing CRMB rubber with bitumen, a dry process and a wet process. In the wet process, the finer CRMB rubber is mixed with bitumen at high temperature (180˚C-220˚C). In the dry process, the CRMB rubber is combined with the totals preceding the expansion to the bitumen. During dry process in which the CRMB rubber is utilized as a total, the compound
response between CRMB rubber and bitumen is very constrained40 mesh size of the CRMB rubber are used through out the study.

3.2.3 Mixing of CRUMB Rubber with Bitumen

250 g of the bitumen was heated at 180˚c, to fluid condition in a 1 liter limit metal container to set it up.For mixing of CRMB rubber with bitumen, it was heated to a temperature of (180 °C - 220˚C) and after that CRMB rubber was added. For every blend test (5-20%) of CRMB rubber by weight of various sizes were used. The blend wasmixed physically or with mechanical stirrer or the stirrer which have low speed . The mix was then heated to 160-180 °C and the whole mass was blended using a mechanical stirrer for around 50 minutes to 60 minutes. Care is taken to keep up the temperature between 160 °C to 180 C.

.

Figure 3.10: Mechanical Mixing of CRMB rubber with bitumen

3.2.4. Testing on Modified Bitumen

Ductility Test.

Heated the modified bitumen to a liquid state and then poured it in the mould assembly and placed it on a brass plate this prevented the bitumen from sticking, coated the surface of the plate and inside surfaces of the sides of the shape with mercury or by a blend of equivalent amounts of glycerine and dextrine. Kept the plate gathering alongside the specimen in a water shower at 27° C for 60 minutes.Took out example from water bath after 30 min and expeled the specimen from mould. Now specimen was fixed in ductility testing machine. Adjusted the pointer to zero. Started the machine and pull clips horizontally at a speed of 5 cm per minute. Note down the distance at which the bitumen thread of specimen breaks.

Figure 3.11: Ductility Test

Softening Point of bitumen

Heat the sample to liquid state for 10-15 min. Apply glycerine and dextrine to rings and plate. Fill the modified bitumen in it and cool it for 30 minutes. Arranged the apparatus with the rings, thermometer and ball guides in position. Filled the beaker with water and put the beaker on hot plate. The beaker was heated until the material softens and allowed the ball to pass through the ring. The temperature was recorded at which the ball touches the bottom, which is nothing but the softening point.

Figure 3.12: Softening Point Test

Penetration test

Penetration value is a measure of hardness or consistency of bituminous material. Pour the bitumen in container and allow it to cool in air for 30 min. Now mould is put in water bath for 60 min. Presently kept the container on the remain of the penetration apparatus and set the needle to reach the surface of the specimen. With the assistance of the clock, discharged the needle for precisely 5 seconds.Recorded the dial gauge reading.

Figure3.13: Penetration Test

3.4 MARHALL MIX DESIGN

3.4.1. Overview

optimum bitumen content is determined by by Marshall Stability Test.

3.4.2. Marshall Mix Design

The Marshall Stability and flow test gives the measure of execution to the Marshall Mix design technique. The stability bit of the test measures the most extreme load conveyed by the compacted test specimen at a stacking/loading rate of 5.8 cm/minute. Load is connected to the specimen till failure, and the most extreme load is called as stability. The deformation at maximum load shown by the electrical gauge is the flow value. Theprocedure of marshal mix design are summarized as:

1.Specimen Preparation

- Approximately 1kg of total aggregates are heated to a temperature of 150˚C−190˚C.

- Modified Bitumen is heated to a temperature of 120˚C − 125˚C with the main trial rate of bitumen (say 4% by weight of the mineral aggregates).

- The heated total aggregates and bitumen are altogether blended at a temperature of 154˚C − 160˚C.

- The blend is put in a preheated mould and compacted by a rammer with 75 blows on either side.

- Keep the blend in the mould for 24 hours and after that remove the specimen from the mould with the assistance of test extractor.

- Measure the weight of the specimen in air and water also.

- Keep the specimen in water bath at 60˚C for 30 minutes.

- Sample is prepared for the testing now.

- The weight of blended aggegates taken for the making of the specimen might be reasonably changed to get a compacted thickness of 63.5+/ - 3 mm.

- Vary the bitumen content in the following trial by +0.5% and rehash the above methodology.

2. Loading Machine: A digital meter is connected with the loading frame which gives the flow value and stability value. The load jack produces a uniform vertical moment of 5 cm per minute.

CRUSHING TEST

One of the model in which pavement material can compound is by pounding under compressive anxiety. A test is institutionalized by **IS: 2386 section IV** and used to decide the devastating quality of totals. The total squashing esteem gives a relative measure of imperviousness to pulverizing under bit by bit connected pounding load.

The test comprises of subjecting the example of aggregate in standard form to a pressure test under standard load conditions. Dry aggregates going through 12.5 mm screen and held 10 mm strainers are filled in a barrel/cylinder shaped measure of 11.5 mm breadth and 18 cm height in three layers. Each layer is pressed together 25 times with at standard tamping rod. The test is weighed and put in the test chamber in three layers each layer being stuffed once more. The specimen is subjected to a compressive load of 40 tons step by step connected at the rate of 4 tons/minute . At that point squashed aggregates are then sieved through 2.36 mm screen and weight of passing material **(W2)** is expressed as percentage of the weight of the total sample **(W1)** which is the sum of crushing value.

Aggregate crushing value = (W1/W2)*100

Results are shown in (Annexure A)

ABRASION TEST

Abrasion test is helped out through the hardness property of aggregates and to choose whether they are reasonable for various asphalt development works. Los Angeles abrasion test is a favored one for doing the hardness property and has been institutionalized in India (**IS: 2386 part-IV**).

The standard of Los Angeles abrasion test is to discover the rate wear because of relative rubbing activity between the aggregate and steel balls utilized as grating charge.

Los Angeles machine comprises of a round drum of inner diameter 700 mm and length 520 mm continued even pivot empowering it to be turned. A grating charge comprising of cast iron round chunks of 48 mm diameters and weight 340-445 g is set in the barrel alongside the aggregates. The quantity of the grating circles shifts as per the evaluating of the example. The amount of aggregates that will be utilized relies on the degree of taking after aggregates and as a rule ranges from 5-10 kg. The chamber is then bolted and pivoted at the speed of 30-33 rpm for a sum of 500 - 1000 transformations relying on the degree of aggregates

After determined gyrations, the material is sieved through 1.7 mm strainer and passed part is communicated as rate aggregate weight of the specimen. This value is called Los Angeles abrasion value.

Results are shown in (Annexure A)

3.3.1 Testing of Aggregates

IMPACT TEST

The aggregate impact test is done to assess the imperviousness to impact of aggregates. Aggregates passing 12.5 mm strainer and held on 10 mm sifter is filled in a round and hollow steel measure (cylinder) of inward width 10.2 mm and profundity 5 cm which is joined to a metal base of impact testing machine. The material is filled in 3 layers where each layer is packed for 25 quantities of blows. Metal sledge of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical aides and the test specimen is subjected to 15 quantities of blows. The crushed aggregate is permitted to go through 2.36 mm IS strainer. Also, the impact esteem is measured as rate of aggregates passing sifter **(W2)** to the aggregate weight of the example **(W1)**.

Aggregate impact value = (W1/W2)*100

Aggregates to be used **for wearing course,** the impact value **shouldn't exceed 30 percent.** For **bituminous macadam** the **maximum** permissible value is **35 percent**. For **Water boundmacadam** base courses the maximum permissible value defined by IRC is **40 percent.**

Results are shown in (Annexure A)

SPECIFIC GRAVITY

The specific gravity and water absorption of aggregates are essential properties that are required for the design of concrete and bituminous mix. The specific gravity of a strong is the proportion of its mass to that of an equivalent volume of refined water at a predefined temperature. Since the aggregates may contain water-pervious voids, so two measures of specific gravity of aggregates are utilized:

1. Apparent specific gravity and
2. Bulk specific gravity.

Apparent Specific Gravity, "G_{app}, is given by

$$G_{app} = [(M_D/V_N)]/W$$

M_D is the dry mass of the aggregate,

V_N is the net volume of the aggregates excluding the volume of the absorbed matter,

W is the density of water.

Bulk Specific Gravity "(G_{bulk},) is given by

$$G_{bulk} = [(M_D/V_B)]/W$$

Chapter 4
Porous Bitumen Performance Test Results

4.1 Crumb Rubber Modified Bitumen

1).Effect of Crumb rubber on Ductility

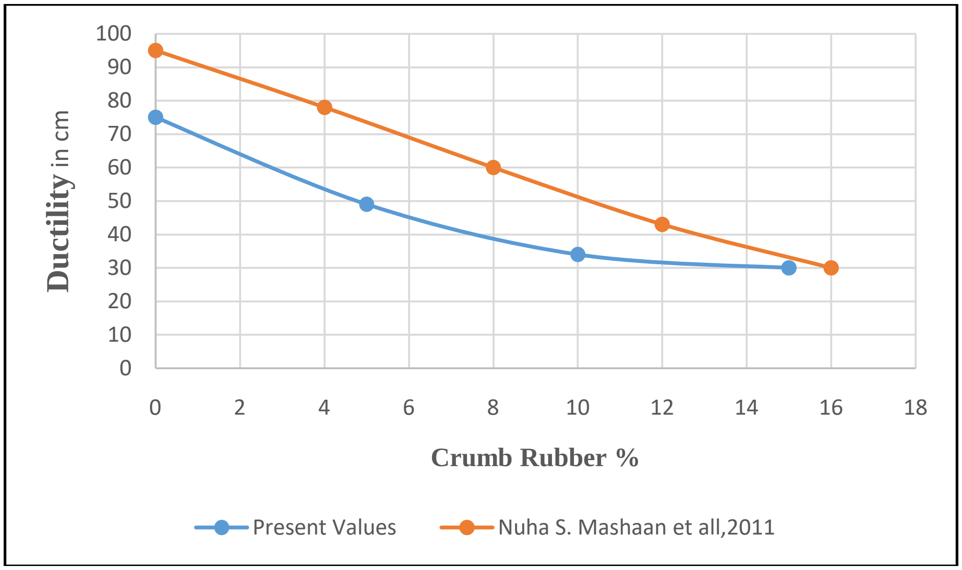


Figure4.14: Effect of Crumb rubber on Ductility

From the fig.4.14, the decrease in ductility of modified bitumen samples compared with unmodified bitumen were about (35 and 60%) for Crumb rubber content of 5% and 15% respectively.

Accordingly, an increase in binder mass could make the binder more elastic, stiff and highly resistant to pavement rutting. Meanwhile, the decrease in ductility value could be attributed to the oily part of the bitumen absorbed into the rubber powder and the increase in mass of the rubber particles. In effect, the modified binder became thicker compared with the unmodified bitumen Samples.

2) Effect of Crumb Rubber on Penetration

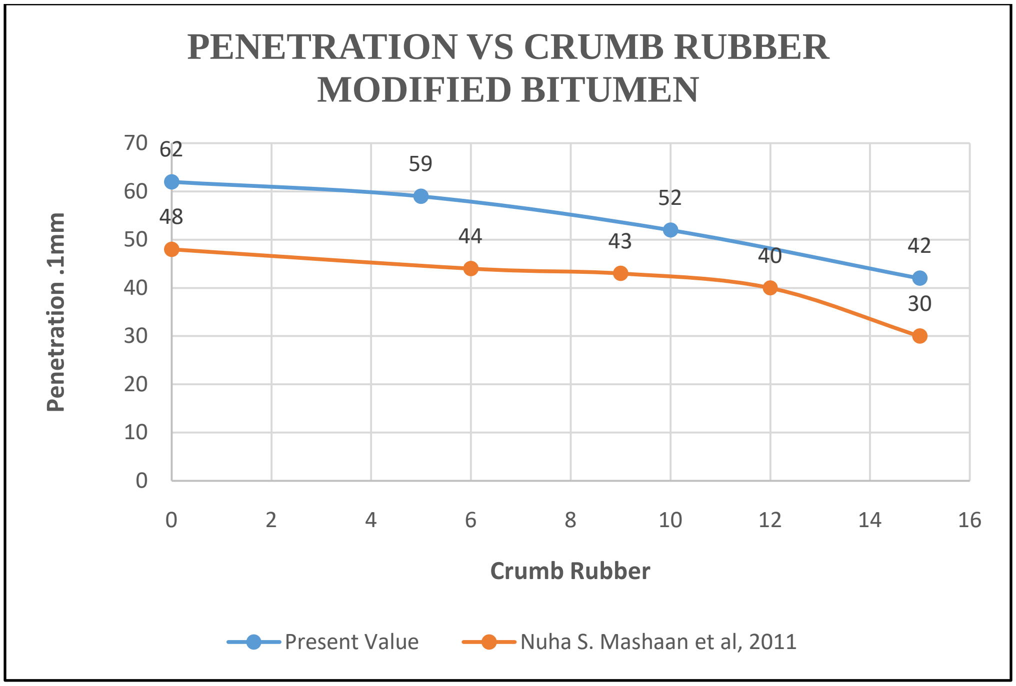


Figure4.15:Effect of Crumb Rubber on Penetration

From the fig.4.15, the penetration decreased as the amount of Crumb rubber increases. It shows that CRM content has a significant effect on penetration value. The Crumb rubber content has a strong effect on reducing the penetration value by increasing the stiffness of Crumb rubber modified bitumen, thus, would make the binder less temperature susceptible and lead to high resistance to permanent deformation like rutting as mentioned by (Liu et al., 2009). The average reduction in penetration value of modified binder was between 5% and 32% for Crumb rubber content ranging between 5 and 15% respectively.

This is because the addition Crumb rubber make bitumen more viscous. This increase in rubber content lead to enhanced the particle size of the rubber. This was due to the swelling of the rubber particle into the bitumen during the blending process, which led to the decrease in the penetration of rubberized bitumen. Thus, indicate that the rubberized bitumen binder will be less susceptible to high temperature change and more resistance to rutting.

3) Effect of Crumb Rubber on Softening Point.

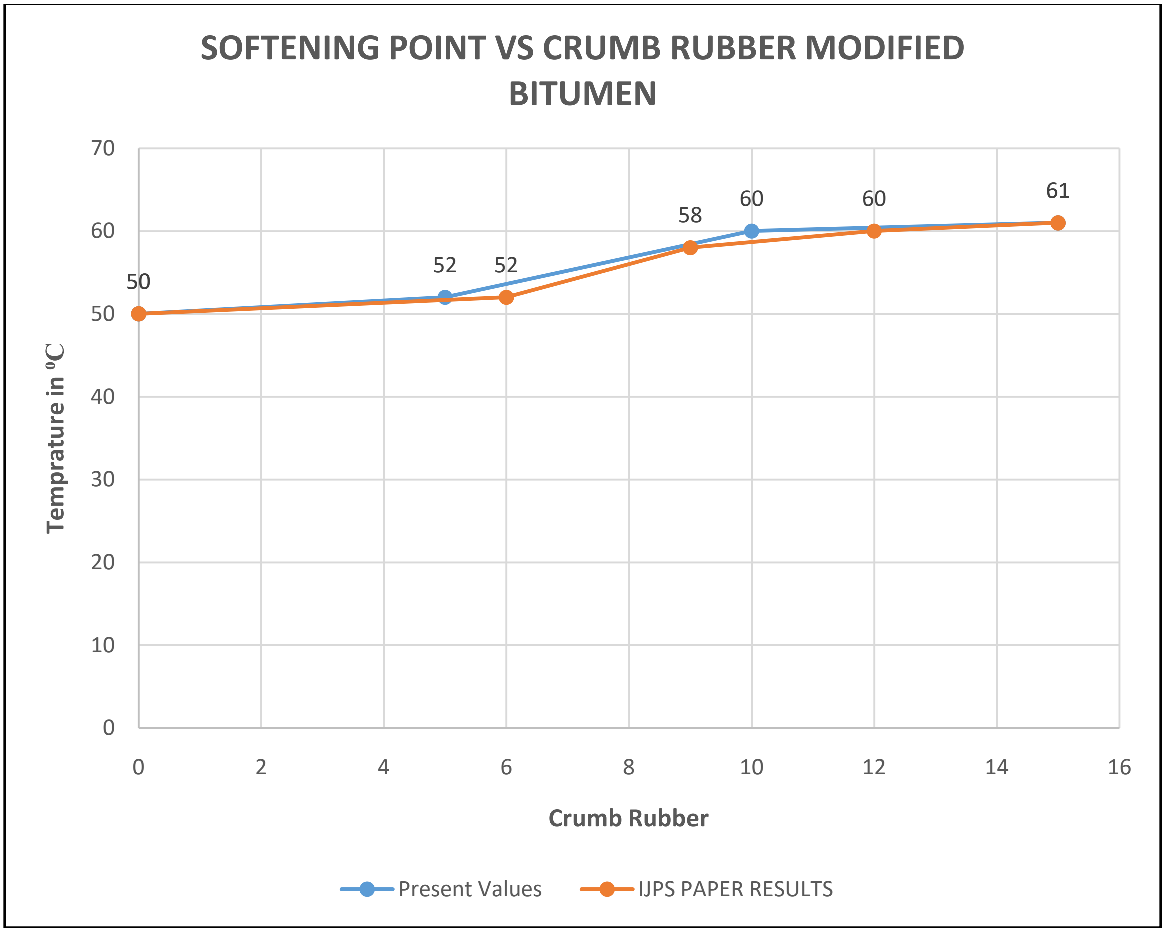


Figure 4.16: Effect of Crumb Rubber on Softening Point.

From the fig.4.16, with the increase in Crumb rubber content softening point of bitumen increases. It shows that CRM content has significant effect on softening point by increasing the viscosity. The average increase in softening value of modified binder was between 14% and 22% for Crumb rubber content ranging between 5 and 15% respectively. This behavior is justified because bitumen with higher viscosity will generally have a higher failure temperature and therefore have a longer service life due to higher temperature stability.

Marshall Mix Design

1). Marshall Stability Vs Bitumen Content

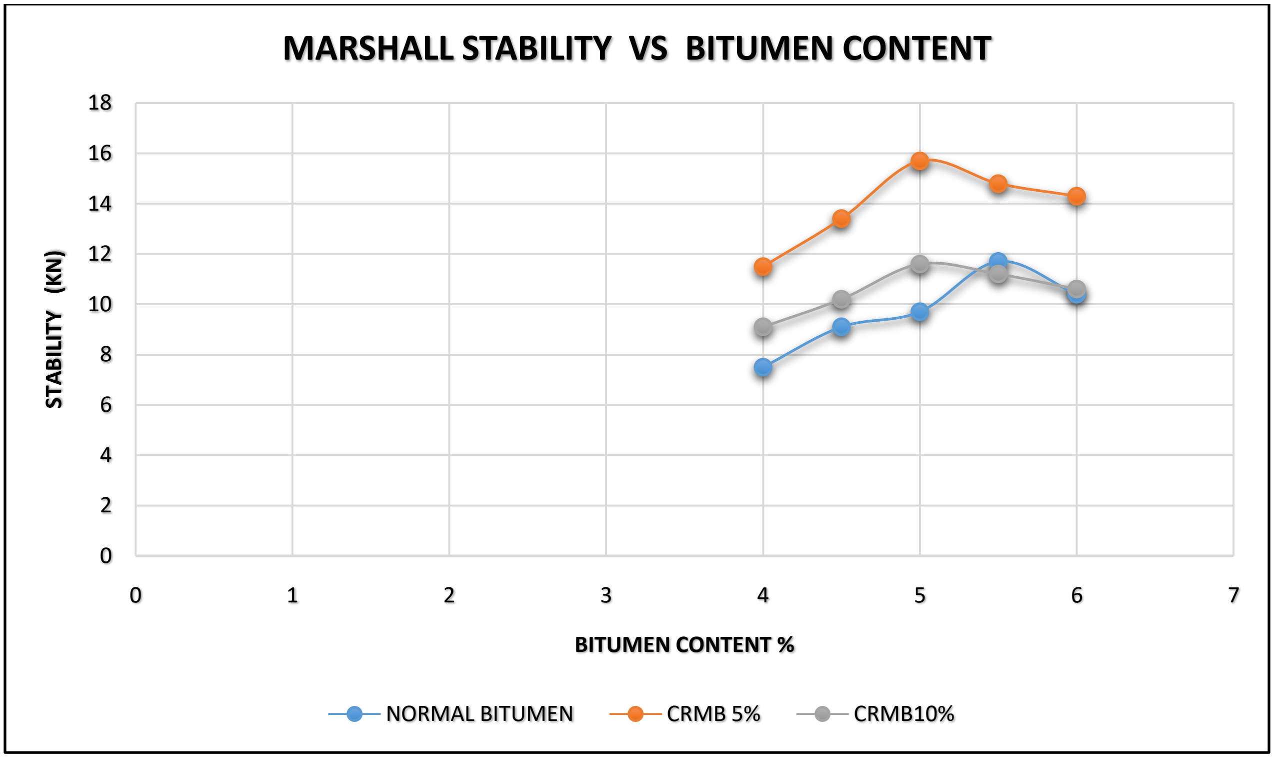


Figure4. 17: Marshall Stability Vs Bitumen Content

As shown in Fig.4.17**,** with increase in bitumen content Marshall Stability increases but up to certain content after it starts decreasing. This trend is because initially bitumen act as binder between aggregate and thus increases the strength but after a certain content voids are filled by bitumen and thus Hydraulic Load does not transferred leads to decrease in strength.

The decrease in stability value with the increase in rubber content because higher percentage of Crumb rubber makes bitumen more viscous and less ductile. Due to increase in viscosity of binder , there is lack of bonding between aggregates. Thus strength of Mix is higher at 5% rubber content as compared to 10% rubber content.

2). Flow Value Vs Bitumen Content

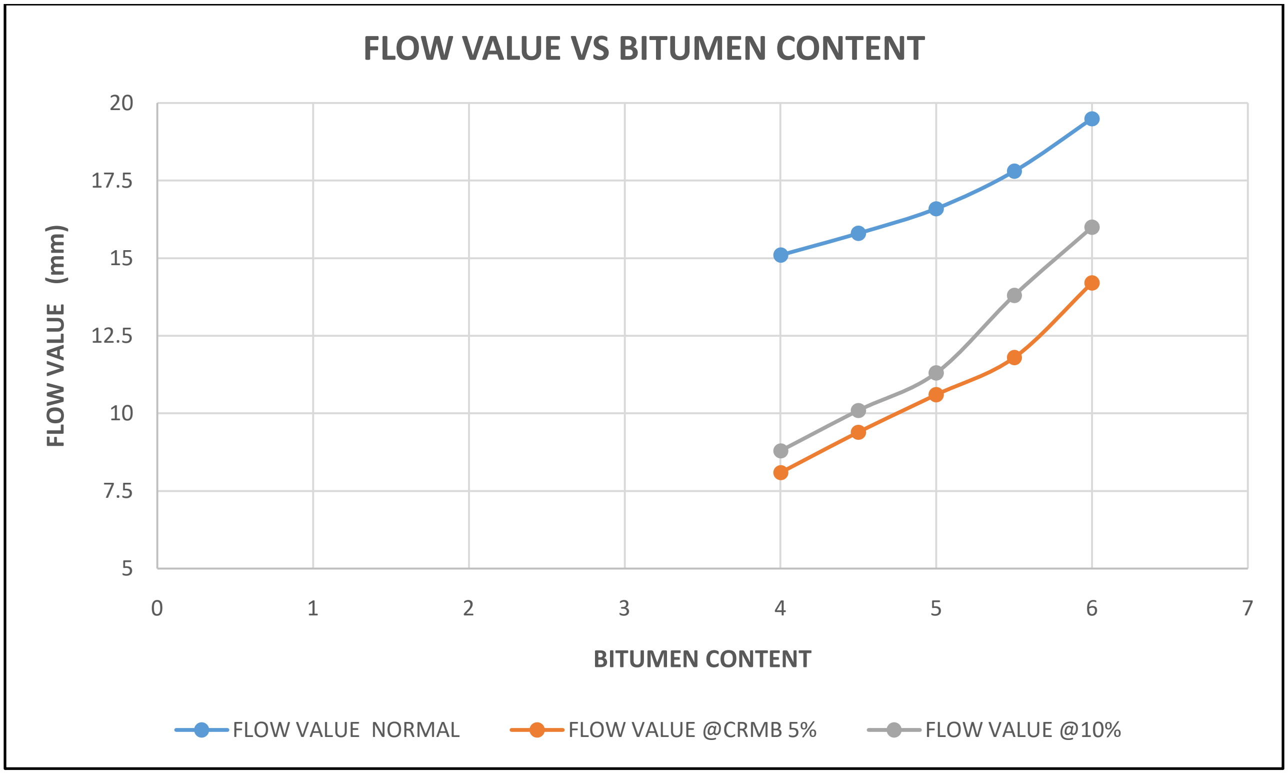


Figure 3.18:Flow Value Vs Bitumen Content

As shown in fig.11, with increase in bitumen content deformation increases as the Interfacial Transition Zone between the two aggregate which is filled with the bitumen widens. Larger the Interfacial Transition Zone lager will be the deformation thus larger will be the flow value.

Porous Mix with Normal bitumen shows larger flow value as compared to the Mix with Crumb rubber modified bitumen. This is because binder becomes more viscous an thus leads to increase in bond between aggregates and thus less flow value or less deformation. But with the increase in rubber content the binder becomes so viscous and less ductile that leads to improper binding with the aggregates and thus shows larger deformation upon loading.

3).Voids Filled with BitumenVs Bitumen content

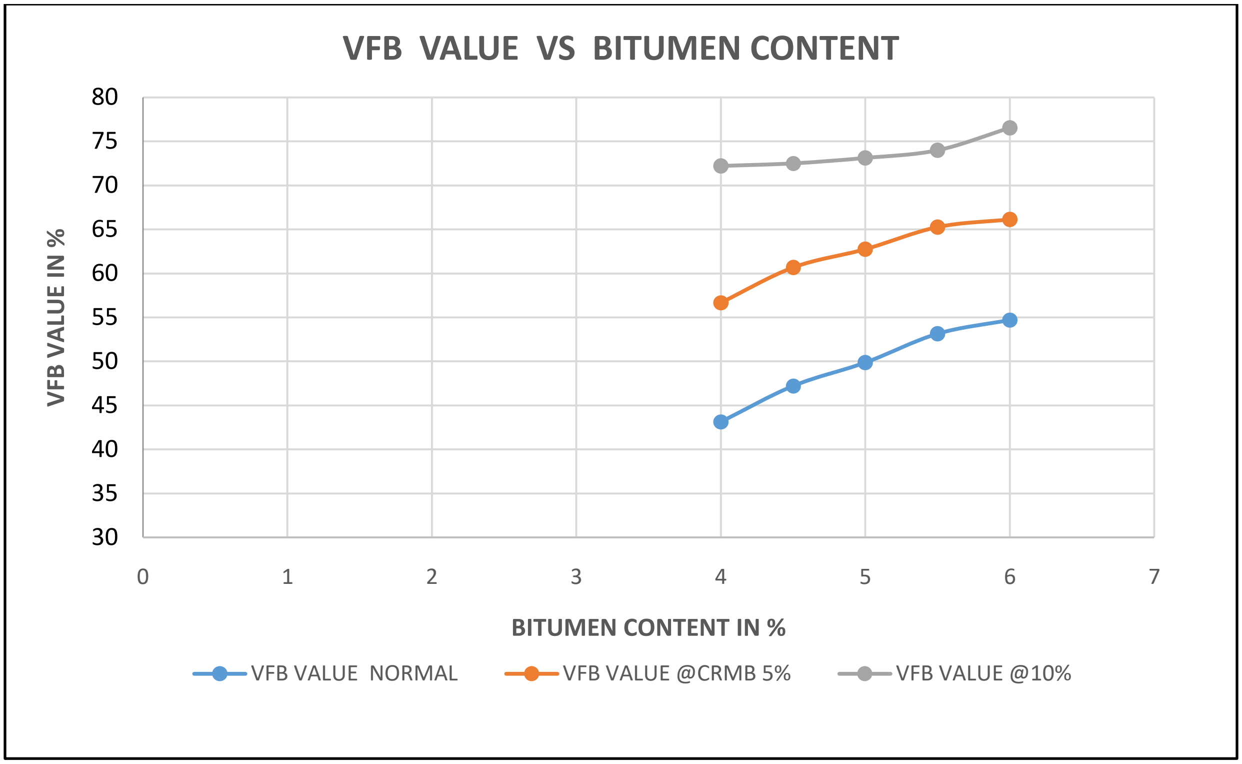


Figure 4.19:Voids Filled with Bitumen Vs Bitumen content

As shown in the fig13, as the bitumen content increases the total air void from the mix decreases or the Voids filled with bitumen in the mix increases. But after certain content it remains constant as it is not practically possible to achieve 100% compaction of mix as certain percentage of voids always remain in the mix due different shape and texture of the aggregate.

As the rubber content increases, viscosity of bitumen increases and thus voids filled by bitumen decreases.

4.) Air Voids Vs Bitumen Content

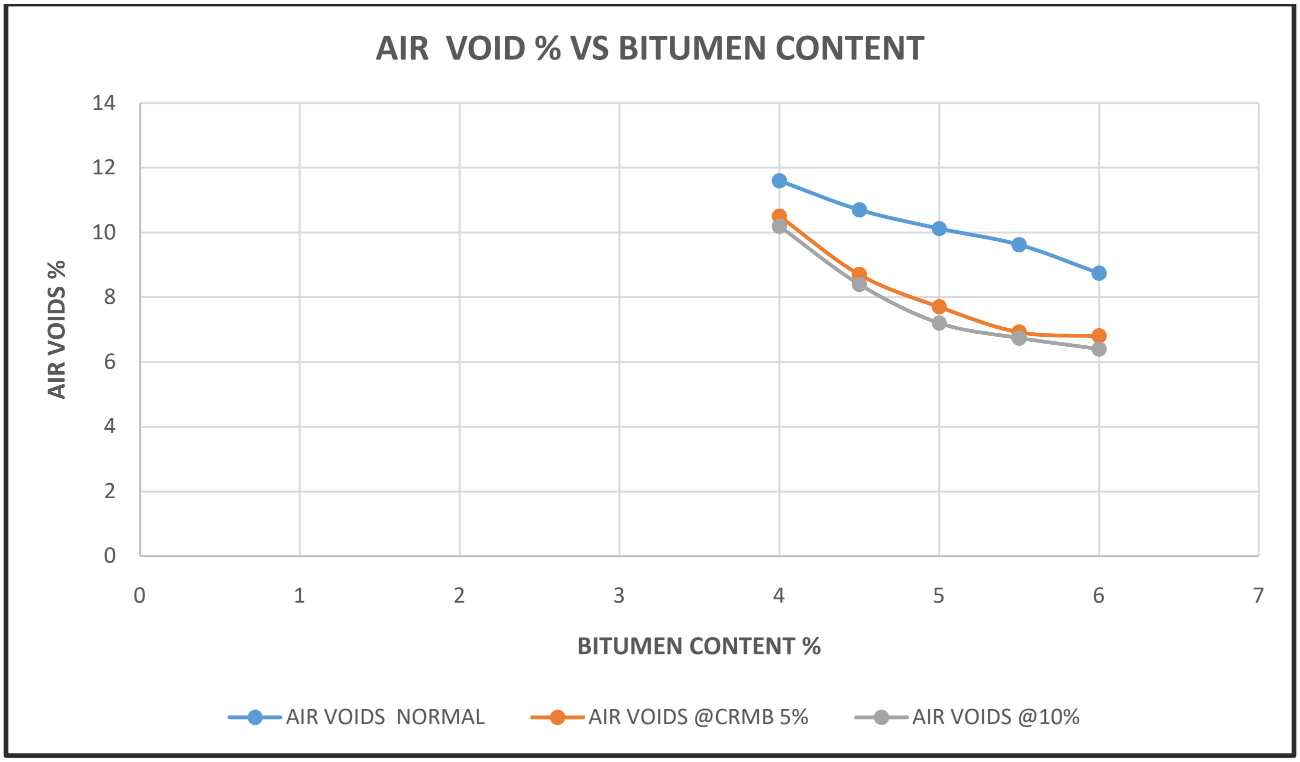


Figure 4. 20: Air Voids Vs Bitumen Content

As shown in the fig14, with the increase in bitumen content Air Void Decreases as the voids are filled by bitumen which leads to the reduction in volume of air void in the mix.

5.) Bulk Unit Weight Vs Bitumen Content

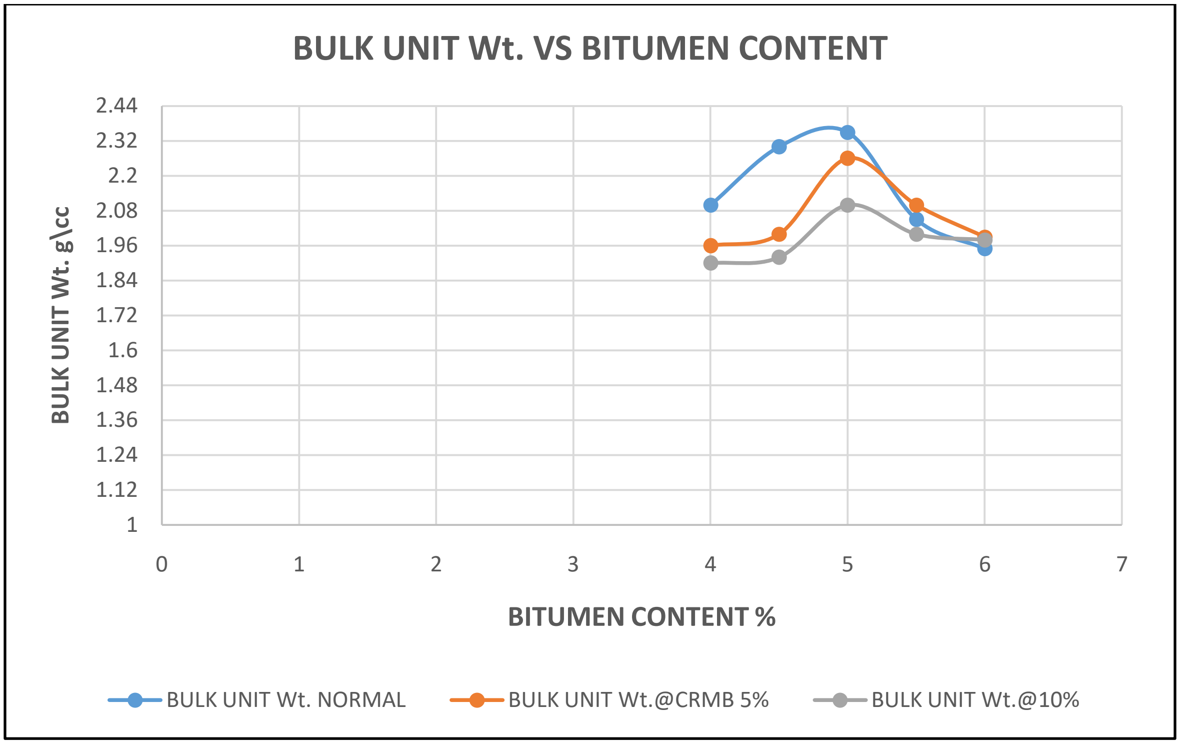


Figure 21: Bulk Unit Weight Vs Bitumen Content

As shown in fig.12,with increase in bitumen content bulk unit weight increases upto optimum bitumen content. After optimum bitumen content it starts decreasing because now the bitumen starts displacing the aggregates or bitumen takes place of aggregate and thus leads to reduction in overall weight of the specimen. Thus bulk unit weight decreases.

CHAPTER 5
Conclusion

5.1. General

Crumb rubber modified bitumen had enhance the properties of bitumen binder such as the viscosity, softening point, penetration value. This subsequently improves the rutting resistance, resilience, and improving fatigue cracking resistance of bitumen mixes. To get optimum CRUMB in term of high and low temperature properties, factors such as the mixing time, temperature, characteristics, and source of the Crumb rubber and bitumen type must be considered since these are the factors that govern the resulting performance of bitumen mixes.

Mix design for porous bitumen pavement requires aggregate gradation with maximum size 12mm and 90% of the aggregate retained on 4.75mm sieve. In order to improve bonding between aggregates and improve rutting resistance of pavement Crumb rubber modified bitumen had shown significant results.

Conclusions

Based on the observations made on various tests results, the following concluding remarks may be derived:-

1. Mixing of Crumb Rubber with plain Bitumen shows significant changes in the properties of bitumen such as decrease in ductility, penetration value and increase in softening value. The percentage change in value of bitumen properties is 15% - 26% .

2. The aggregate gradation consists of 100 percent of 19 mm down sized aggregates but requires less than 10 % of the aggregate fraction passing 4.75 mm, so that the compacted mix becomes permeable and provide adequate permeability.

3. In order to improve the strength of Porous Bitumen Pavements, Crumb Rubber Modified Bitumen has been shown to have the ability to improve the rutting resistance of pavement and aggregate bonding. The percentage increase in strength of modified bitumen Porous Pavement and Normal bitumen Porous pavement is 19% - 30%.

4. For the Pavement to be permeable, minimum air voids content should be 18% or more.

5. Permeability of porous pavement varies from 0.24 cm/s to 0.21 cm/s with the increase in bitumen content.

6. Strength of Porous Pavement is different at different Crumb rubber content. Maximum strength of pavement was obtained at 5% Crumb rubber content by weight of bitumen followed by 10% Crumb rubber content and then Normal pavement.

5.2 Applications

- Low Volume traffic roads.
- Parking lots
- Pedestrian walkways
- Shoulders of runway

5.3 Benefits

- Storm water management
- Noise reduction
- Increase in Ground water level
- Improved Skid Resistance
- Street dust control.

5.4 Scope

- Further performance testing should continue on porous bitumen including resilient modulus, beam fatigue, and detailed freeze-thaw testing.

- Greater the porosity greater will be the clogging. If pores of the pavement get jammed then the whole system will not work up to the mark and excess runoff water may collected on the surface which will be dangerous to th driver . more research work need to be done on clogging.

- Hydrological design of porous pavement such as design of under pave drain pipes and collection tank.

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Annexure A

Mix Design Calculations	**Various Tests-** Crushing, Abrasion, Impact, Specific Gravity	**A**

A.1 Aggregate Test results

Table 4 Aggregate Test Results

Test	Paper value	Present value
Crushing Value Test	<30%	26%
Abrasion Test	<35%	33%
Impact Test	25-35%	30%
Specific Gravity	2.12-2.65	2.2-2.62

A.2 Porous pavement gradation

Table 5 porous pavement Gradation

Sieve Size (mm)	NAPA recommendations (% passing)	Present Value (%passing)	Present Value (%Retained)	Composition of 1kg mix (g)
19	100	100	0	0
12.5	85-100	90	10	100
9.5	55-75	70	25	250
4.75	10-25	20	44	440
2.36	05-10	7	14	140
0.075	02-04	3	7	70

Annexure B

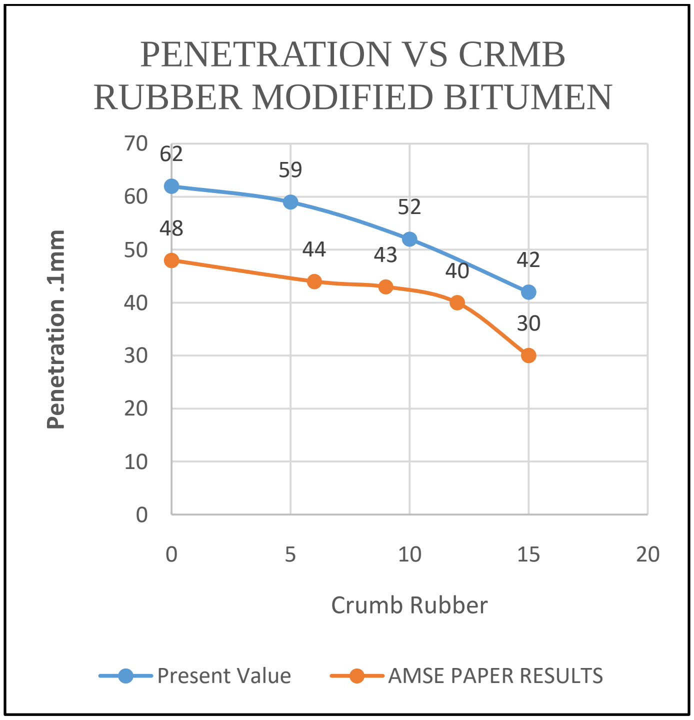
CRMB Rubber Modified bitumen	B
Test: Penetration, Ductility, Softening	
B1.1-B1.3 Effect of Crumb rubber on properties of bitumen	

B1.1

EFFECT OF CRMB RUBBER ON PENETRATION OF BITUMEN

Table 6 Efect of Crmb rubber on Penetration

CRUMB RUBBER CONTENT	PENETRATION	REFRENCE
0	62	48
5	59	--
6	--	44
9	--	43
10	52	--
12	--	40
15	42	30

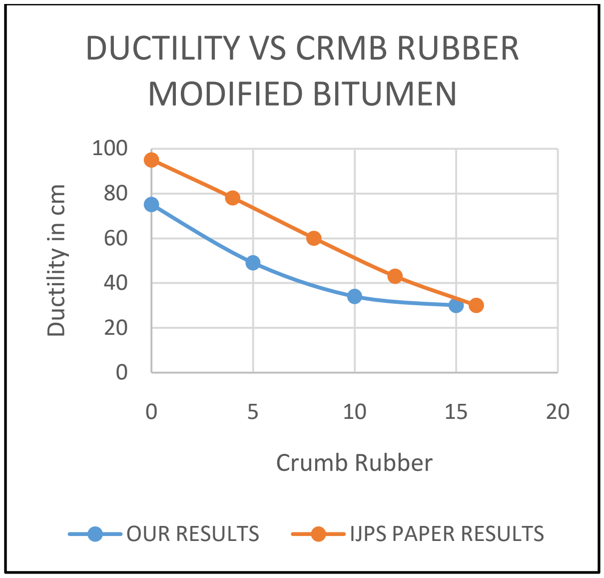


B1.2

EFFECT OF CRMB RUBBER ON DUCTILITY OF BITUMEN

CRMB	DUCTILITY	REFRENCE
0	75	95
4	---	78
5	49	---
8	---	60
10	34	---
12	---	43
15	30	---
16	---	30

Table 7 Effect of Crmb rubber on Ductiliy of Bitumen

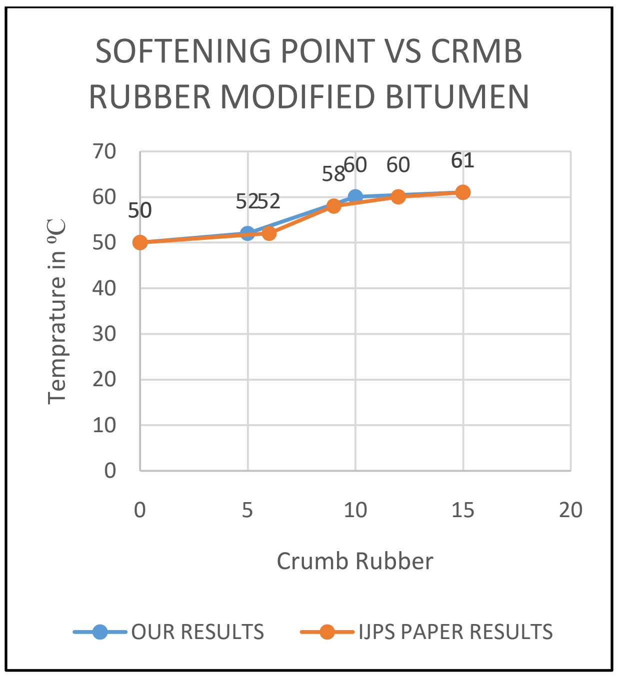


B1.3

EFFECT OF CRMB RUBBER ON SOFTENING POINT OF BITUMEN

CRMB	SOFTENING	REFFRAL
0	50	50
5	52	--
6	--	52
9	--	58
10	60	--
12	--	60
15	61	61

Table 8 Effect of Crmb Rubber on Softening point of bitumen



Annexure M

Test Name: MARHSALL STABILITY	Normal Mix ———	M1
M1.1-M1.3 Mix design Calculations	CRMB @5% ———	
M2.1-M2.5 Marshall Mix Graphs	CRMB @10% ———	

Mix Design Calculation of Normal Bitumen

Table 9 Mix Design Calculation of Normal Bitumen

Bitumen content (%)	Weight in Air (g)	Weight in Water (g)	Volume Of Sample cm^3	Theoretical Specific Gravity	Mass Specific Gravity
4	1082	580	545	2.49	2.33
4.5	1065	572	550	2.45	2.31
5	1039	570	525	2.44	2.28
5.5	1035	572	532	2.41	2.24
6	1029	565	560	2.4	2.17

Mix Design Calculations CRMB @5%

Table 10 Mix Design Calculations CRMB @5%

Bitumen content (%)	Weight in Air (g)	Weight in Water (g)	Volume Of Sample cm^3	Theoretical Specific Gravity	Mass Specific Gravity
4	1032	610	532	2.49	2.24
4.5	1022	590	545	2.45	2.23
5	1015	590	532	2.44	2.23
5.5	1035	595	550	2.41	2.18
6	1044	615	562	2.4	2.131

Mix Design Calculations CRMB@10%

Table 11 Mix Design Calculations CRMB@10%

Bitumen content (%)	Weight in Air (g)	Weight in Water (g)	Volume Of Sample cm^3	Theoretical Specific Gravity	Mass Specific Gravity
4	1087	630	550	2.457	2.37
4.5	1089	595	550	2.44	2.34
5	1044	575	532	2.42	2.32
5.5	1091	598	550	2.4	2.29
6	1097	610	560	2.392	2.26

Table 12 Stability Values of Marshall Test

BITUMEN CONTENT	STABILITY NORMAL	STABILITY @CRMB 5%	STABILITY @CRMB10%
4	7.5	11.5	9.1
4.5	9.1	13.4	10.2
5	9.7	15.7	11.6
5.5	11.7	14.8	11.2
6	10.4	14.3	10.6

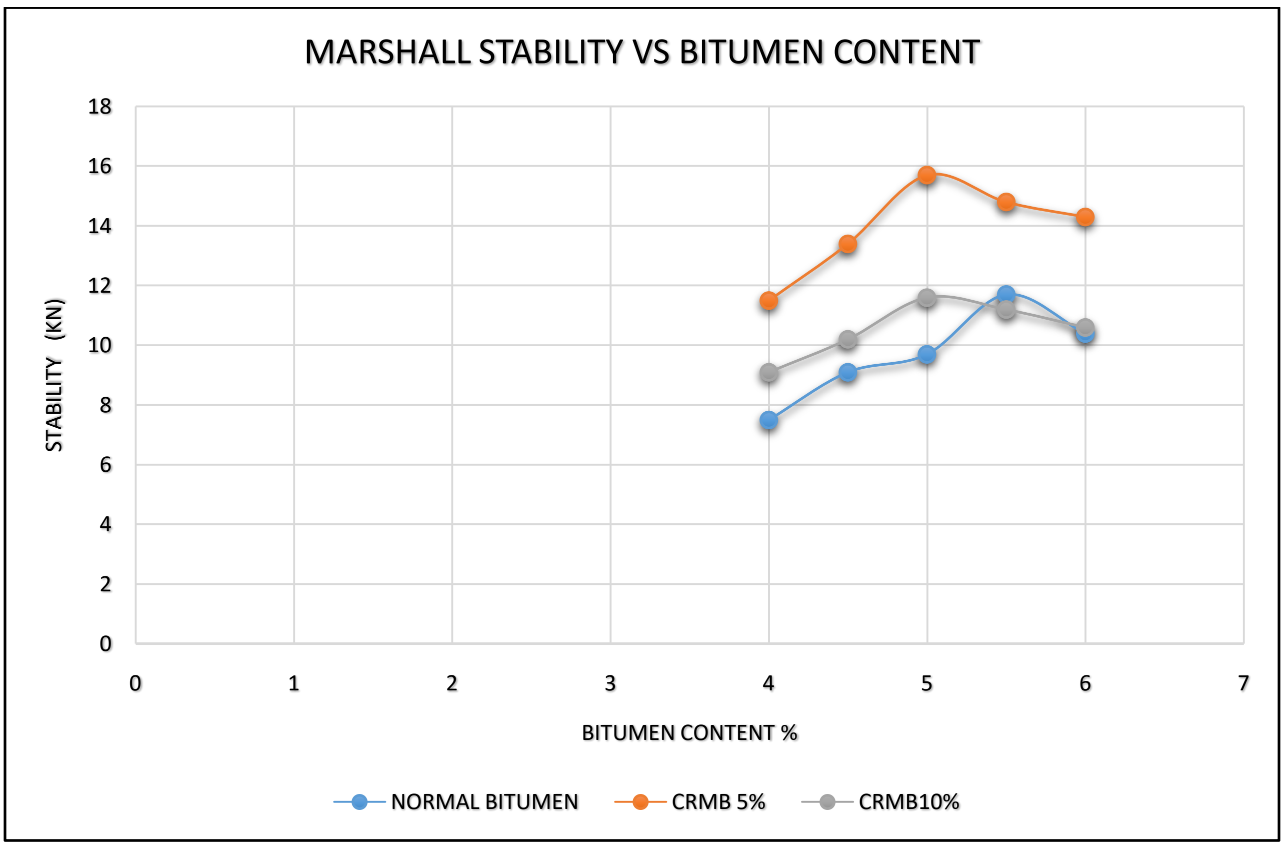


Figure 22 Marshall Stability Vs Bitumen Content

Table 13 VFB Content VS Bitumen Content

BITUMEN CONTENT	VFB VALUE NORMAL	VFB VALUE @CRMB 5%	VFB VALUE @10%
4	43.15	56.68	72.2
4.5	47.23	60.67	72.5
5	49.86	62.74	73.1
5.5	53.15	65.26	73.98
6	54.72	66.12	76.52

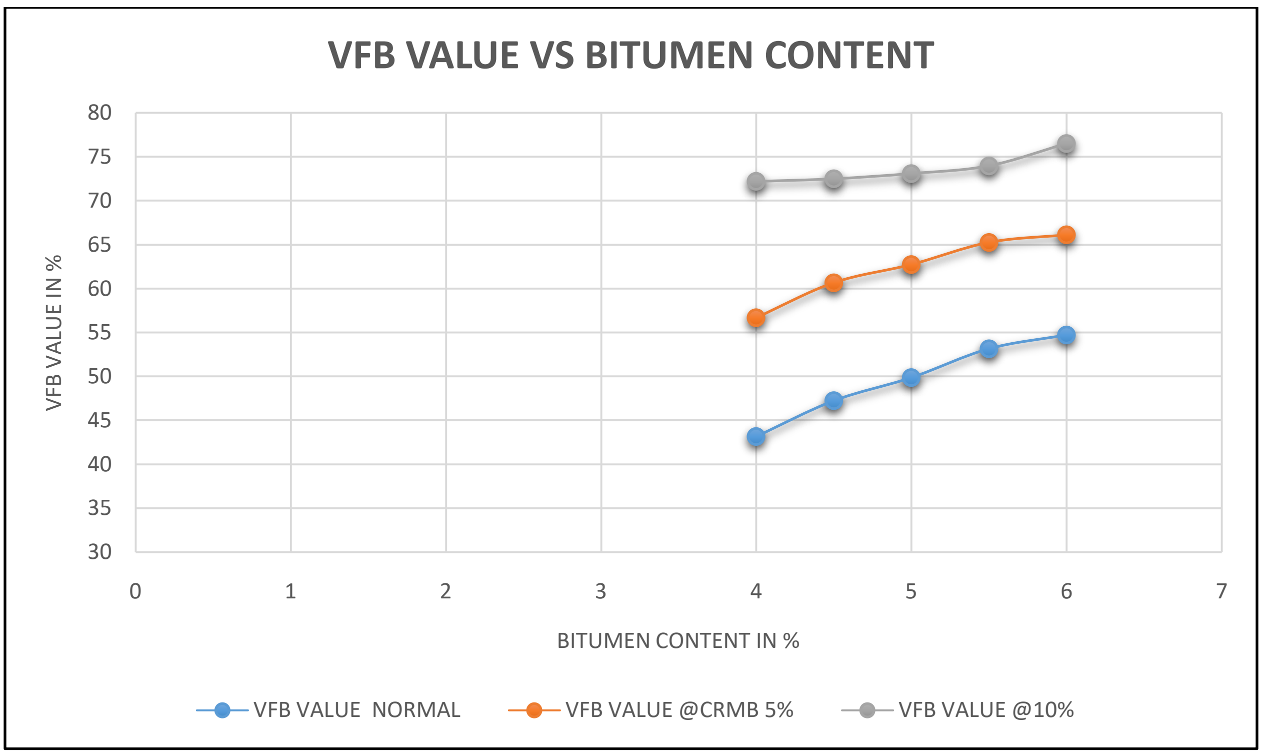


Figure 23 VFB Value VS Bitumen Content

Table 14 Flow Value Values of Marshall Test

BITUMEN CONTENT	FLOW VALUE NORMAL	FLOW VALUE @CRMB 5%	FLOW VALUE @10%
4	15.1	8.1	8.8
4.5	15.8	9.4	10.1
5	16.6	10.6	11.3
5.5	17.8	11.8	13.8
6	19.5	14.2	16

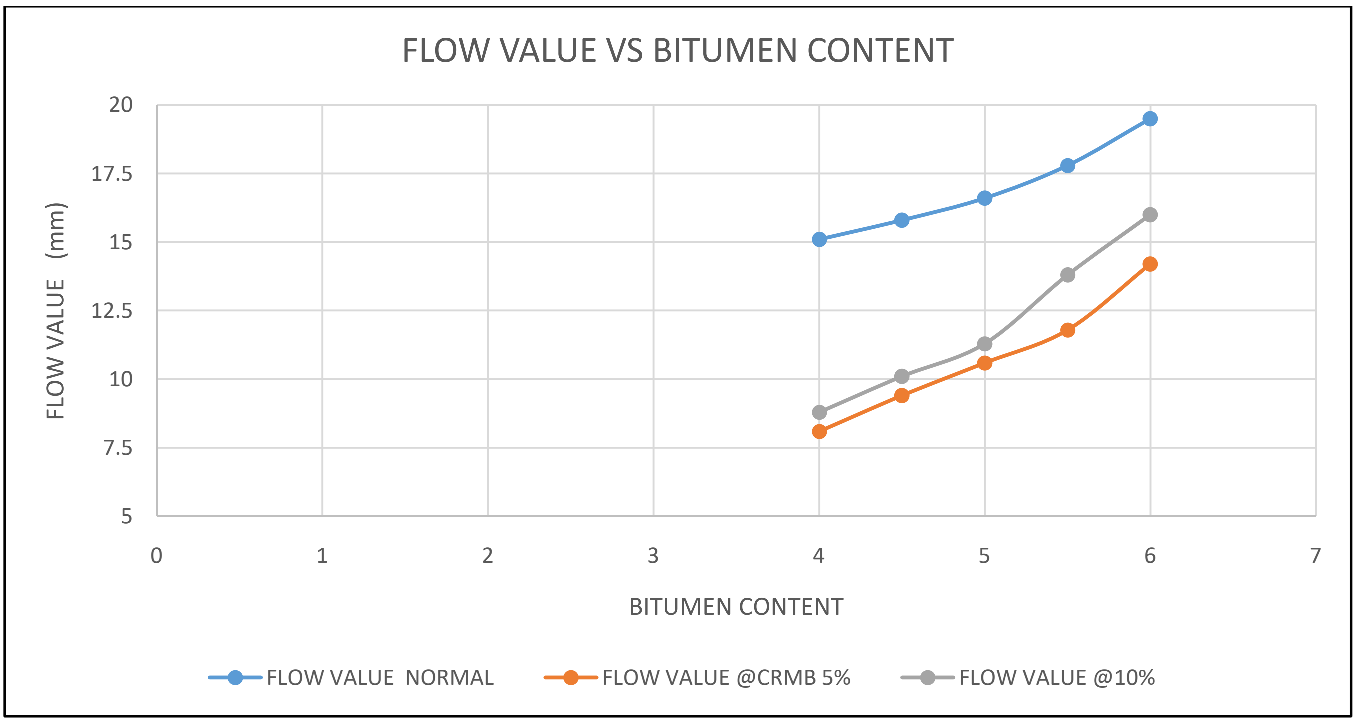


Figure 24 Flow Value VS Bitumen Content

Table 15 Value of Air Voids in Marshall Test

BITUMEN CONTENT	AIR VOIDS NORMAL	AIR VOIDS @CRMB 5%	AIR VOIDS @10%
4	11.6	10.5	10.2
4.5	10.7	8.7	8.4
5	10.12	7.7	7.2
5.5	9.62	6.92	6.74
6	8.74	6.8	6.4

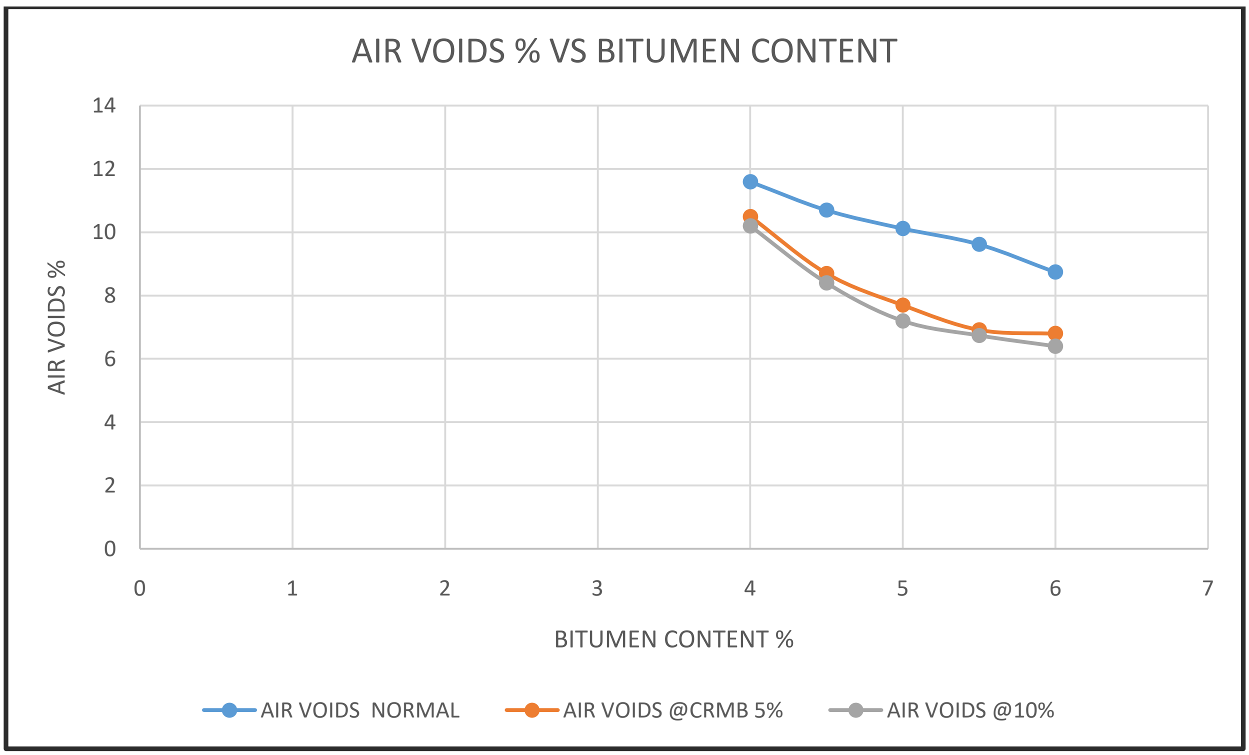


Figure 25 Air Voids VS Bitumen Content

Table 16 Value of Bulk Unit Wt. of Marshall test

BITUMEN CONTENT	BULK UNIT Wt. NORMAL	BULK UNIT Wt.@CRMB 5%	BULK UNIT Wt.@10%
4	2.1	1.96	1.9
4.5	2.3	2	1.92
5	2.35	2.26	2.1
5.5	2.05	2.1	2
6	1.95	1.99	1.98

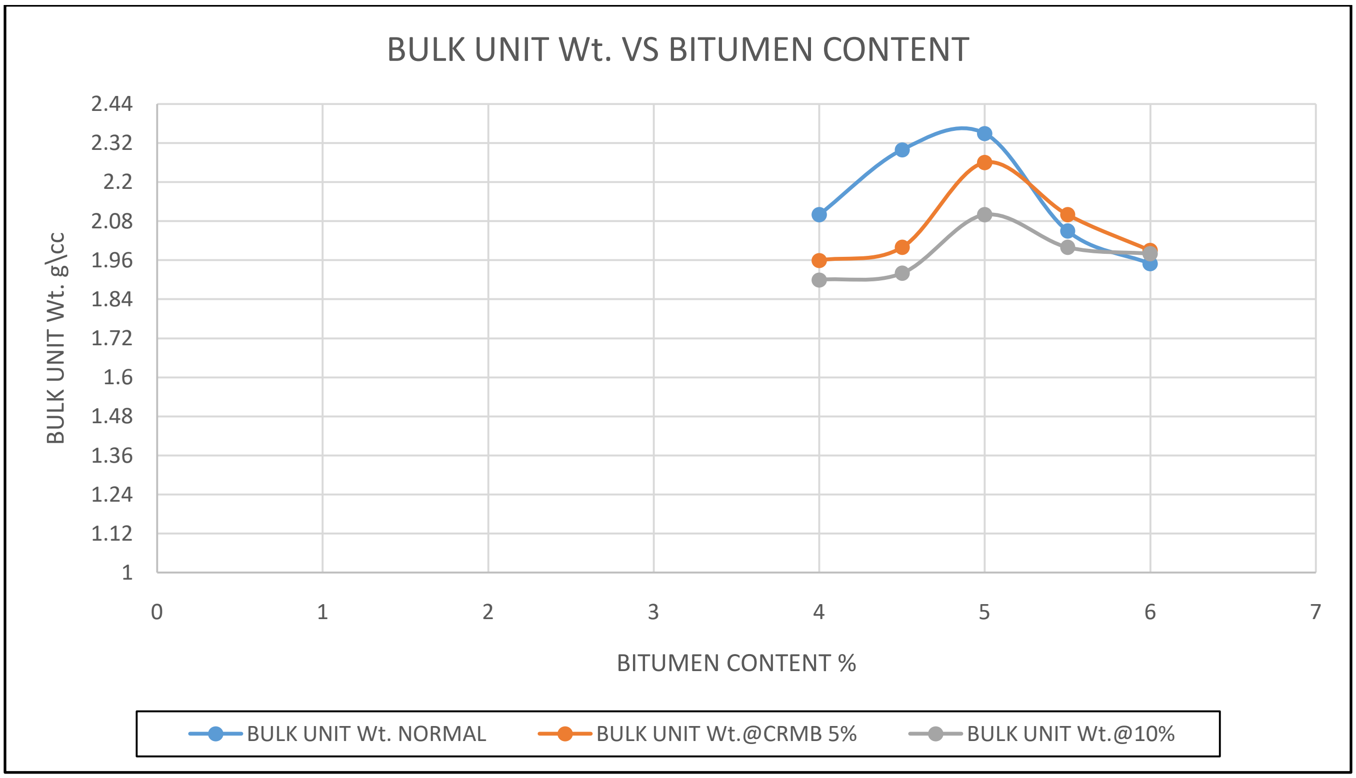


Figure 26 Bulk Unit Wt. VS Bitumen Content

Photos from Marshall Test

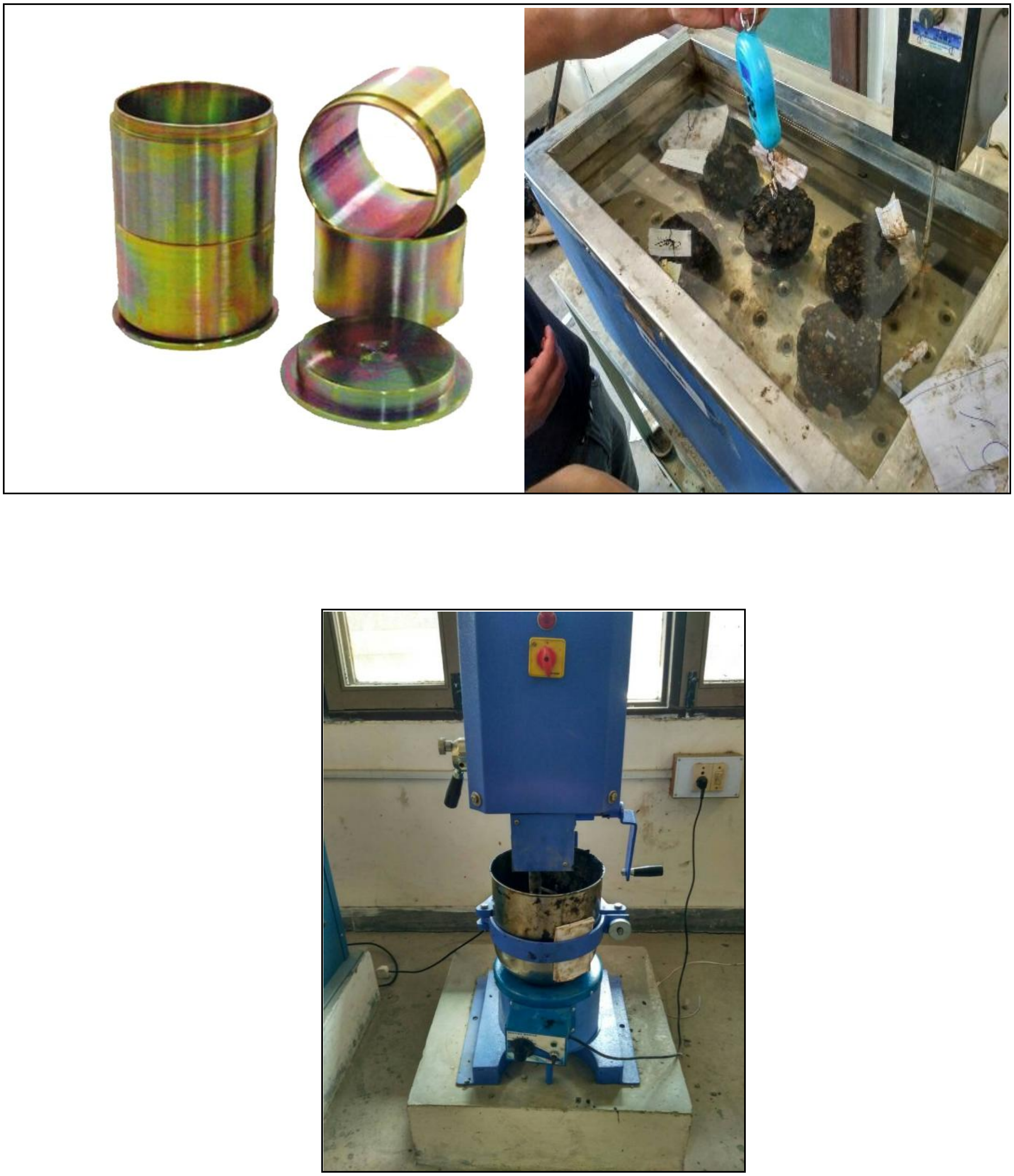


Figure 27 Lab photos