# DESIGN OF POROUS PAVEMENT USING EPOXY PLASTIC MODIFIED BITUMEN

PROJECT REPORT SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

**BACHELOR OF TECHNOLOGY**

IN

**CIVIL ENGINEERING**

UNDER THE SUPERVISION OF

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TO


DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY,

WAKNAGHAT, SOLAN-173234, HIMACHAL PRADESH


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# CERTIFICATE

I hereby declare that the work presented in this report entitled **"Design Of Porous Pavements Using Epoxy Resins Modified Bitumen "** in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology** in **Civil Engineering** submitted in the department of **Civil Engineering,** Jaypee University of Information Technology Waknaghat is an authentic record of work carried out over a period from August 2016 to May 2017 under the supervision of **Niraj Singh Parihar** (Asst. Professor ,Civil Engineering Dept.).This report is submitted in partial fulfilment of the Project for the award of B-Tech at Jaypee University of Information Technology

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This is to certify that the above statement made by the candidate is true to the best of my knowledge.

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# ABSTRACT

The Porous Pavement can also be used as rain water harvesting, for recharging the ground water. Multi-storied commercial and residential buildings, which significantly increase the demand for water supply, are increasingly being constructed in urban India. In many states of India such as Bihar, Delhi, Gujarat, Haryana, Punjab, Rajasthan and Tamilnadu, the ground water is plunging at an alarming rate.

This project is focused on designing a porous pavement by modifying the bitumen by "Epoxy Plastic" and investigating the various physical and mechanical properties of bitumen by conducting various laboratory test -Ductility Test, Penetration Test, Specific Gravity, Softening Point Test and finally determining the optimum bitumen content by Marshall Stability Test.

The deterioration of the flexible pavement due to extreme climatic conditions prevailing in the country in addition to the heavy traffic. The Epoxy Plastic modification of the bitumen can improve the quality of binders and enhance the properties of binders used for the construction of pavements. The properties of bitumen mainly depend on the age of bitumen. Therefore, there is a need to study the properties of modified bitumen before and after ageing.

In this project, the physical and mechanical properties of Epoxy Plastic modified bitumen is discussed, optimum dose is determined and design of porous pavement is done using the optimum dosage of bitumen. The usage of porous pavement for recharging the ground water and rain water harvesting is also discussed. It was concluded in this study that introduction of Epoxy Resin to bitumen can improve the anti-aging property, rutting performance and rheological properties of bitumen binder.

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# CHAPTER 1

## INTRODUCTION

## 1.1. General

In recent years' researchers, designers and builders are always looking for new and enhanced ways to protect the environment in the most effective ways. One such developing technology is the "Permeable pavements" that allow water to infiltrate through surfaces that would normally be impermeable, such as the dense graded flexible pavements or the rigid concrete pavements. Permeable pavements are of various types which include porous asphalt, pervious concrete, inter-locking concrete block pavers, turf reinforcing grids, decks, open graded aggregates. Porous pavements allow water to drain through the pavement surface into a stone recharge bed and infiltrate into the soils below the pavement. With the proper design and installation, porous pavement can provide storm-water management systems that promote infiltration, improve water quality, and many times eliminate the need for detention basin. During a storm, runoff flows over impervious pavement, picking up pollutants such as dirt, grease and oil, and transports these contaminants to watercourses and storm sewer systems. In response to this issue, porous pavement allows runoff to pass through the pavement into a stone base, then into the soil below to recharge the groundwater supply. With proper installation and maintenance, porous paving allows for infiltration of up to 80% of annual runoff volume. Many studies on "Filtration effect of porous pavement", indicate that porous paving systems can remove between 65 and 85 percent of undissolved nutrients from runoff and up to 95% of sediment from runoff.

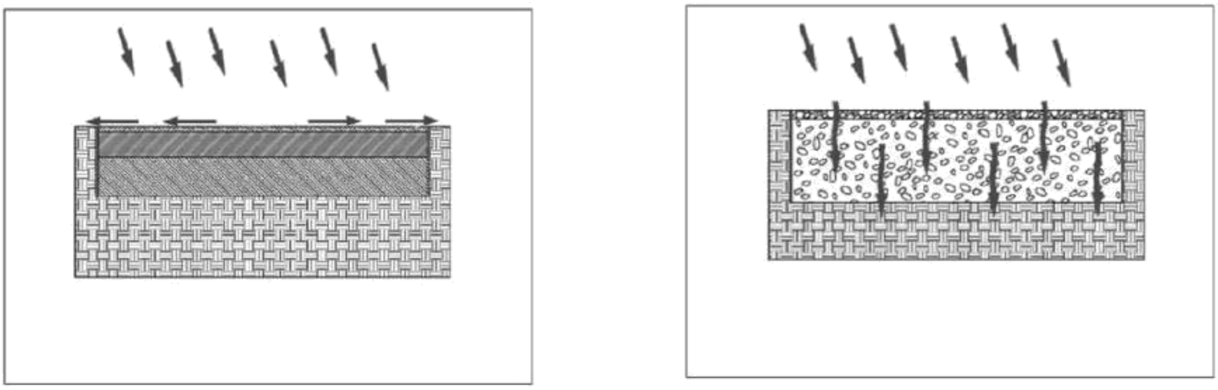


Fig 1.1: - Rain on Traditional Bitumen Pavement (Left) and rain on Porous Pavement

Porous asphalt or Bitumen consists of a high percentage of interconnected air voids (>15%). Because of a high amount of air voids in porous bitumen, aging resistance of the binder becomes crucial. Void content in bitumen mix determines the rate of aging by controlling oxygen access to the binder. Higher air voids would facilitate the oxidative aging of the binder even deeper in asphalt pavement. Aging makes bituminous materials harder and more brittle, thus increasing risk of pavement failure.

The ability of modified bituminous binders to reduce rutting at high temperatures and thermal cracking/fracture at low temperatures has made them popular in the recent past. The quality of bituminous road surfacing and its performance depends upon the properties of bitumen and these are controlled by composition of bitumen.

Hence, properties of bitumen may be modified by certain binders such as polymer, crumb rubber, Sulphur, Epoxy Resin etc. Addition of Epoxy Resin in bitumen increases the life span of the road pavement considerably. The purpose of bitumen modification using Epoxy Resin is to achieve desired engineering. This modification results in improvement of one or more properties of binder and (hence the mix) viz. fatigue resistance, stiffness modulus, rutting resistance, stripping potential, temperature susceptibility etc.

In the last few decades Porous Asphalt mixtures have been placed in many European countries, Japan, the United States, China, and other countries, mainly to improve pavement surface drainage during raining to reduce the risk of hydroplaning. Due to their high air-void contents, these mixtures have also the potential of reducing tire/pavement noise. In recent years, several research efforts have been spent to revise the current porous mix designs, which are primarily aimed at high surface drainage, to specifically incorporate the needs of noise reduction, surface smoothness, and durability.

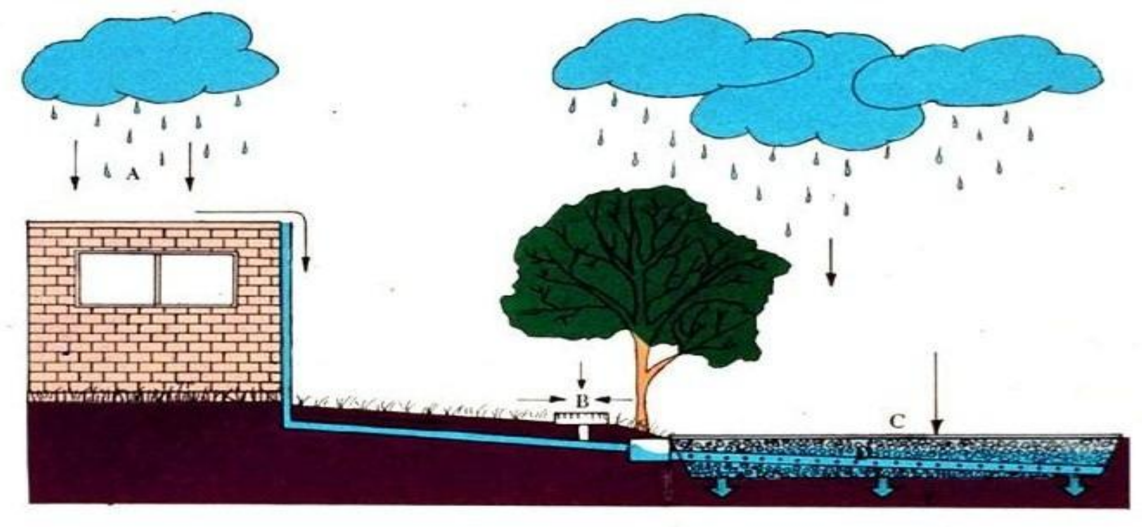
Binder modification is aiming to produce new binders with better rheological and mechanical properties

## 1.2. Rain Water Harvesting Integrated with Porous Pavement

Rainwater harvesting systems of the buildings can be integrated into the porous pavement. A typical rooftop rainwater harvesting system for buildings consists of the following elements:

1. Vertical down pipes for carrying the water from the roof to ground level and a horizontal pipe system for connecting all down pipes.
2. A silting pit fitted with a steel screen

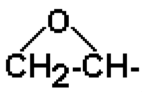
The water from the rooftop is carried directly to the stone water reservoir and dispersed there through a series of perforated water pipes. This way, the stone reservoir does not experience any localized flooding. This system also means no soaking well or bore hole which involves considerable cost. Water from the roof top of the buildings on the street can all be diverted to the stone water reservoir course. Another major advantage of this technology is that the water recharging the underground water is mostly free of contaminants.




## 1.3. Material

### 1.3.1. Epoxy Resin

An epoxy resin is defined as a molecule with more than one epoxy group, which can be hardened into a usable plastic. The epoxy group is also called the glycidyl group.


*Epoxy group*

What one sees is an oxygen atom on the outside of the carbon chain. Epi means "on the outside of" and the second part of the word comes from oxygen.

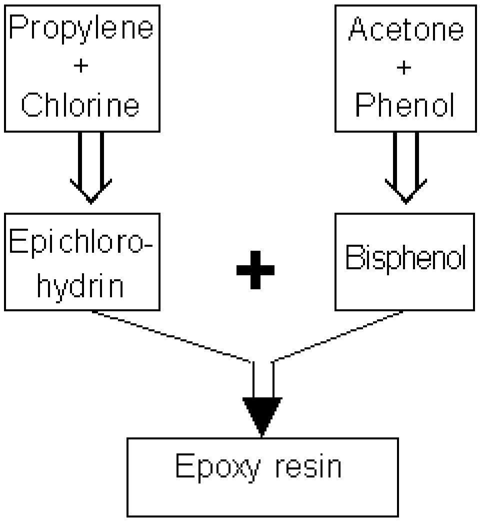
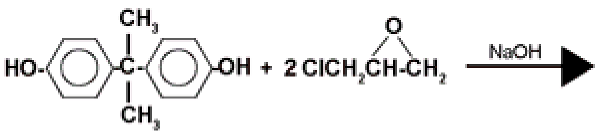
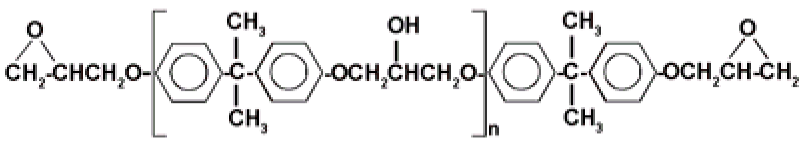



Fig.1.3: - Formation of Epoxy Resin

With the help of chemical formulas, the last stage out is as follows:




Bisphenol A + Epichlorohydrin



Diglycidylether Bisphenol A (DGEBA) epoxy resin

By varying the relationship between bisphenol A and epichlorohydrin, various molecular weights are obtained for the completed epoxy resin. The lowest molecular weight an epoxy resin of the DGEBA type can have is 340, but if two elements together can form different molecular weights when they react, the epoxy resin will contain a mixture of epoxy molecules of varying lengths. One therefore does not refer to the epoxy resins' molecular weight, but rather to their mean molecular weight.

Epoxy resin with a mean molecular weight of over 700 is called high molecular, and epoxy resin with a mean molecular weight of under 700 low molecular.

### 1.3.2. Hardener

To convert epoxy resin to epoxy plastic, a reaction with a suitable substance is required. Such a substance in this context is called a "Hardener".

For hardening at room temperature, amines and amides are primarily used, and to a certain extent mercaptans. The other hardener types generally require temperatures above +150°C to react with the epoxy

As hardener for the epoxy resin, primarily diamines and polyamines are used.

A schematic of the epoxy plastic then looks like this:

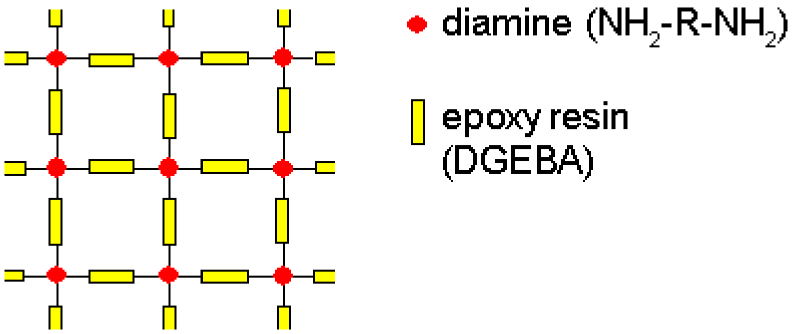



Fig.1.3.1: - Epoxy Plastic Structure

### 1.3.3. Material used in Project

The Epoxy resin and hardener used in 2:1 Proportion and have following properties:

**HARDENER:**

Hardener used in this Project is "LATENT HARDNER"

These types of hardeners React with Epoxy Resin at Elevated Temperature

**EPOXY RESIN:**

The main two compound of Epoxy resin are bisphenol A - Bis A - (or bisphenol F -Bis F)

This is basically used in Artificial Jewelry Industry and Sports Industry


Fig.1.3.2: - Hardener

Fig.1.3.3: - Epoxy

## 1.4. Epoxy Plastic's Characteristic Basic Properties

**ADHESION**

One of epoxy plastic's most characteristic properties is the capacity to adhere to most substrates. The reason for this is the presence of polar hydroxyl groups, and the ether bonds. The negligible shrinkage also entails that contact between the epoxy plastic and the substrate is not disturbed by tensions. The epoxy plastic's surface tension is most often below the critical surface energy for most materials.

**MECHANICAL STRENGTH**

No other hard plastic can display as high mechanical strength as correctly formulated epoxy plastic. Again, it is largely because of the minimal shrinkage that built-in tensions are avoided. The tensile strength of Epoxy Plastic can exceed 80 MPa.

**CHEMICAL RESISTANCE**

The possibility of varying the epoxy plastics' properties, one can make epoxy plastic resistant to most chemicals. In general, epoxy plastic is very resistant to alkali, which is of importance in surface-treating.

**SHRINKAGE**

The epoxy plastics have very slight shrinkage during hardening. This is because the epoxy molecule has a rather small reorientation during the hardening process compared with, for example, polyester and methylmetacrylate.

**HEAT RESISTANCE**

The room temperature hardened epoxy plastic differs very little from heat hardened thus epoxy resin have high heat resistance.

## 1.5. ADVANTAGES OF POROUS PAVEMENT

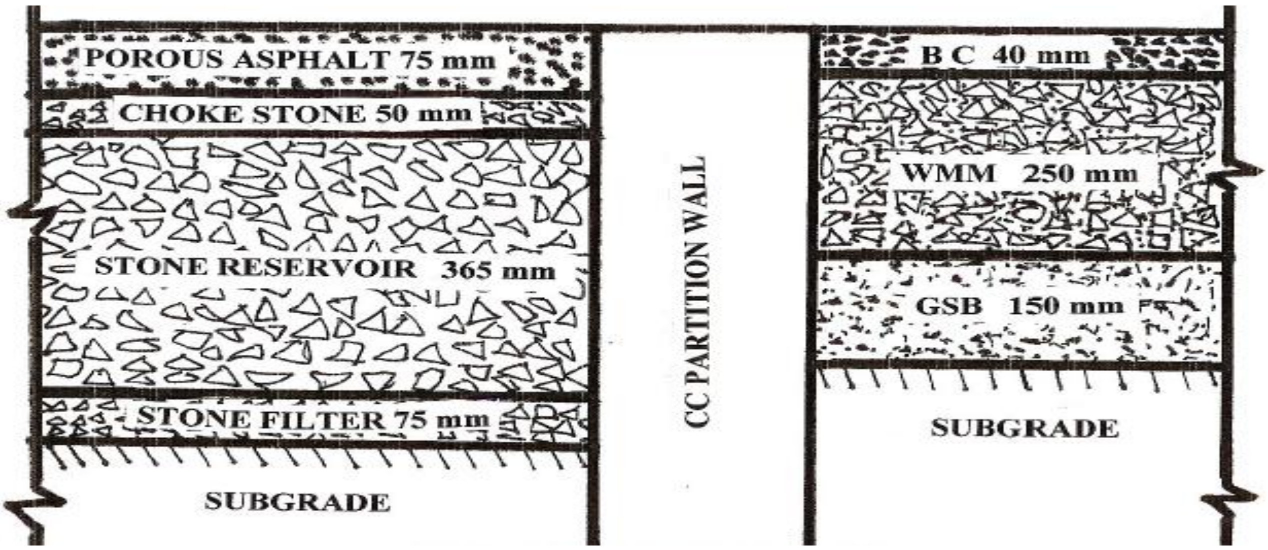



Fig.1.5: - Porous Pavement(Left) & Normal Pavement(Right)

| Normal Pavement | Epoxy 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 |

# CHAPTER 2

## LITERATURE REVIEW

## 2.1. General

| Sr No. | Tittle | Year of Publication | Author |
|---|---|---|---|
| 1 | Modification of local asphalt with epoxy resin to be used in pavement | 2007 | "A.M.M. Abd El Rahman ; M. EL-Shafie ; S.A. El Kholy." |
| 2 | A Rational Mix Design Method for Porous Asphalt Mixtures | 2012 | "Hussain A Khalid ;Christopher M Waish" |
| 3 | Characteristics of two-component epoxy modified Bitumen | 2013 | "Y. Xiao , M. F. C. van de Ven ," "A. A. A. Molenaar , Z. Su , F. Zandvoort" |
| 4 | Design and laboratory evaluation of small particle porous epoxy asphalt surface mixture for roadway pavements | 2014 | "Zhendong Qian , Qing Lu" |
| 5 | Experimental study on filtration effect and mechanism of pavement runoff in permeable asphalt pavement | 2015 | "Wei Jiang , Aimin Sha , Jingjing Xiao , Yuliang Li , Yue Huang " |
| 6 | Comparative Study on Short Term Ageing of Bitumen VG 10 and VG 30 by using Epoxy Resin as a Modifier | 2015 | "Dhara D Kalasariya, Keval Patel, Harpalsinh Raol" |

## 2.2. SUMMARY

**1. Modification of local asphalt with epoxy resin to be used in pavement**

A.M.M. Abd El Rahman ; M. EL-Shafie ; S.A. El Kholy (2007)

In this paper, the preparation of asphalt modified by mixing asphalt 60/70 with Epoxy resin in different percentages (5, 10 and 15%),. Marshall test was used to evaluate the asphalt pavement performance depending on the curing time and hardener concentration. To measure Marshall test, the pervious mixture was stirred with aggregate job formula mix (JMF) and 40% MA at 150–170 °C for 20 h and 1600 rpm. From the obtained data, it was found that asphalt mixed with 15% of ENR + 40% MA achieves a high stability (16,632 Newton). While, the stability of the unmodified asphalt was (11,500 Newton).

**2. A Rational Mix Design Method for Porous Asphalt Mixtures**

Hussain A Khalid; Christopher M Waish (2012)

This paper describes the development and application of a rational design method for porous asphalt mixes that consider the material's overall performance requirements and failure criteria. Compared to other surfacing, porous asphalt has been considered the "Rolls Royce" of noise and spray reduction (Daines, 1996). This paper give the criteria for designing Mix Design for porous mixtures, specification requirement and the laboratory test .

**3. Characteristics of two-component epoxy modified Bitumen**

Y. Xiao ; M. F. C. van de Ven ;A. A. A. Molenaar ; Z. Su ; F. Zandvoort (2013)

In this study two types epoxy modified bitumen have been studied by means of direct tensile tests (DTT), relaxation tests (RT), direct shear rheometer tests (DSR). The effect of curing temperature on strength development of epoxy modified has been reported, DTT and RT tests show that the epoxy modified bitumen has a much higher tensile strength and cures much faster than a bitumen emulsion as a binder. The DSR results show that the complex modulus of this epoxy bitumen is less susceptible to change in temperature, which suggests that the epoxy modified bitumen has much better anti-crack properties at lower temperatures, and less deformation at higher temperatures.

**4. Design and laboratory evaluation of small particle porous epoxy asphalt surface mixture for roadway pavements**

Zhendong Qian ; Qing Lu (2014)

In this paper to increase the durability of pavement surface with porous asphalt mixtures, a small particle porous asphalt mixture modified with epoxy resin is proposed. The paper focuses on designing a small particle porous epoxy asphalt (SPPEA) mixture and evaluates in the laboratory its pavement surface related performance, including high temperature stability, low temperature crack resistance, moisture resistance, friction, and permeability and proves that the porous pavements are sustainable.

**5. Experimental study on filtration effect and mechanism of pavement runoff in permeable asphalt pavement**

Wei Jiang , Aimin Sha ; Jingjing Xiao ;Yuliang Li ; Yue Huang (2015)

In this study a self-developed laboratory apparatus was used to study filtration effects of permeable asphalt pavements (PAP). Results show that the PAP is highly effective in removing copper (Cu), zinc (Zn), lead (Pb), and cadmium (Cd).Influences of sampling time on pollutant concentration have been studied, which indicate that increasing sampling time reduces pollutant concentration to some level. The decrease in pollutant concentration can attributed to the pshyiosorption porous material used in PAP.

**6. Comparative Study on Short Term Ageing of Bitumen VG 10 and VG 30 by using Epoxy Resin as a Modifier**

Dhara D Kalasariya; Keval Patel; Harpalsinh Raol (2015)

The paper shows Epoxy Resin modification of the bitumen can improve the quality of binders and enhance the properties of binders used for the construction of pavements. In this paper the physical properties of Epoxy Resin modified bitumen is discussed, optimum dose is determined and the effect of ageing on the binder prepared using the optimum dose is evaluate by doing a number of different tests such as Penetration test, Elastic recovery test, Softening point etc. on bitumen after adding epoxy resins.

# CHAPTER 3

## OBJECTIVES

## 3.1. OBJECTIVES OF STUDY

The Study focus on following objectives:

1. To investigate various physical, mechanical & durability properties of epoxy plastic modified bitumen.

2. Check the feasibility & reliability of using Epoxy Plastic as a modifier for bitumen.

3. To select and prepare the most appropriate amount of modifier used for bitumen.

4. To determine the optimum bitumen content using Epoxy Plastic for Design of Porous Pavement

5. To investigate the permeability of surface course to test the surface course working as porous one.

6. To Design a pavement Model according to various Standards (American & Indian)

# CHAPTER 4

## METHODOLOGY

## 4.1. Ductility Test

### 4.1.1. Significance of Test

The ductility test of bitumen specimen tells us about tensile strength of bitumen It is used to grade the material in terms of hardness Road expand at day time while they contract at night so if the bitumen is not adequately ductile cracking will occur. As Epoxy resin is an adhesive thus it's important to analyses to what extent it effect the tensile strength of bitumen.

### 4.1.2. Procedure of Test (IS: 1208:1978)

#### 4.1.2.1. Sample Preparation

1. For preparation of Epoxy Resin Blends Epoxy resin and hardener (2:1) was added to the hot bitumen at percentage varying between 0% and 25% and mixed for 1 hour at $80^0$C-$100^0$C

2. This sample was then maintained at $80^0$C-$100^0$C and for 1 hour as shown in Fig. 4.1

3. When the binder appears visually homogeneous, it was passed into the testing mould.


Fig.4.1: - Boiling of Sample

#### 4.1.2.2. Testing Methodology

1. The bitumen sample is maintained to a pouring temperature (80°C to 100°C) and poured into the mould assembly, where a solution of glycerine or soap solution is applied at all surfaces of briquette mould exposed to bitumen as shown in Fig.4.2.

2. After the sample is poured to the mould, thirty to forty minutes the entire assembly is placed in a water bath at 27°C.

3. Then the sample is removed from the water bath maintained at 27°C and excess bitumen material is cut off by levelling the surface using hot knife.

4. After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27°C for 60 to 70 minutes. Then the sides of mould are removed and the clips are carefully booked on the machine without causing any initial strain.

5. The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally. As shown in Fig.4.3, The rate of elongation of bitumen is 5 cm/min.

6. While the test is in operation, the sample is checked that it is immersed in water at depth of at least 10 mm from the bottom or the bitumen break apart from the centre.

7. The above procedure is repeated for bitumen with varying modified content.

Fig.4.2: - Briquette mould (Glycerin Applied)

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Fig.4.3: - Elongated Sample in Ductility Apparatus

## 4.2. Penetration Test

### 4.2.1. Significance of Test

Penetration test is used to measure the consistency of bitumen to classify the bitumen into standard grades. Greater value of penetration indicates the softer consistency. By adding modifier to bitumen the change in the properties(consistency) of bitumen has been investigated and the change in grade is also checked, if any, because generally higher penetration bitumen is preferred for use in cold climate and the smaller penetration Bitumen is used in hot climate.

### 4.2.2. Procedure of Test (IS: 1203:1978)

#### 4.2.2.1. Sample Preparation

1. For preparation of Epoxy Resin Blends Epoxy resin and hardener (2:1) was added to the hot bitumen at varying percentage between 0% and 25% and mixed for 1 h

2. This sample was then maintained at 800C and for 1 h and at room temperature for 1 hour

3. When the binder appears visually homogeneous, it will be ready for pouring into the testing mould.

#### 4.2.2.2. Testing Methodology

1. The melt was transfer into the container to a depth of at least 10mm more than the expected penetration.

2. The sample was cooled in atmosphere at a temperature between $15^0$C to $30^0$C for 1 to 1(1 /2) hours. Then the sample was transfer to water bath at $25^0$C for 1 (1 /2) hour.

3. The Container is kept on the stand of the penetration apparatus. Correct the needle to make contact with the surface of the sample.

4. The dialis adjusted  to zero. With the help of the timer, release the needle for exactly 5 seconds.

5. Record the dial Reading and do the above process for 5 times for single sample.

6. Vary the Modifier Content from 0-25% and repeat the above procedure for different samples.


Fig.4.4: - Penetrometer

## 4.3. Specific Gravity Test

### 4.3.1. Significance of Test

Specific gravity is the ratio of mass of bitumen of particular volume to the mass of water of the exact same volume at the same temperature. Specific gravity is a fundamental property and it can be used to determine the source of the binder. Specific gravity test is also used to find out impurities in the bitumen as higher the impurities higher will be the specific gravity

### 4.3.2. Procedure of Test (IS: 1202:1978)

#### 4.3.2.1. Testing Methodology

1. The specific gravity bottle is cleaned, dried and weighed.
2. Water is filled in it and weight of bottle along with water is taken.
3. Bituminous material is heated to pouring temperature and poured in the bottle to its one-fourth
4. Sample is cooled for 30 minutes in air and then weighed.
5. Then water is filled in it and weight is taken.
6. From the weights taken, the specific gravity of bitumen can be found out by calculations.

Fig.4.5: - Density Bottle (50 ml)

## 4.4. Softening Point Test

### 4.4.1. Significance of Test

The softening point of bitumen is the temperature at which the substance retains particular degree of softening. the determination of softening point helps to know the temperature of 2 which of the Binder should be heated for various road use application material without particularly define melting point. They gradually become softer as the temperature rises for this reason also Softening Point Must be determined by closely defined method. The softening point is useful in classification of bitumen as it indicates the material to flow at elevated temperature occurs at elevated temperature occurs at service.

### 4.4.2. Procedure of Test (IS: 1205:1978)

#### 4.4.2.1. Sample Preparation

1. The Bitumen with epoxy resin and hardener (2:1) is heated between 75$^o$C and 100$^o$C. The air bubbles and water are removed by stirring it, and filter it through IS Sieve 30, if necessary.

2. Heat the rings and apply glycerine. Fill the material in it and cool it for 30 minutes.

3. Remove excess material with the help of a warmed, sharp knife.

Fig.4.6: - Rings Filled with Bitumen

#### 4.4.2.2. Testing Methodology

1. The apparatus is assembled with the rings, thermometer and ball guides in position.

2. Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5$^{o}$C per minute.

3. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0 ± 0.5$^{o}$C per minute.

4. The heat is until the material softens and allow the ball to pass through the ring.

5. The Temperature is recorded at which the ball touches the bottom, which is nothing but the softening point of that material.

6. The temperature is recorded at which the ball touches the bottom.

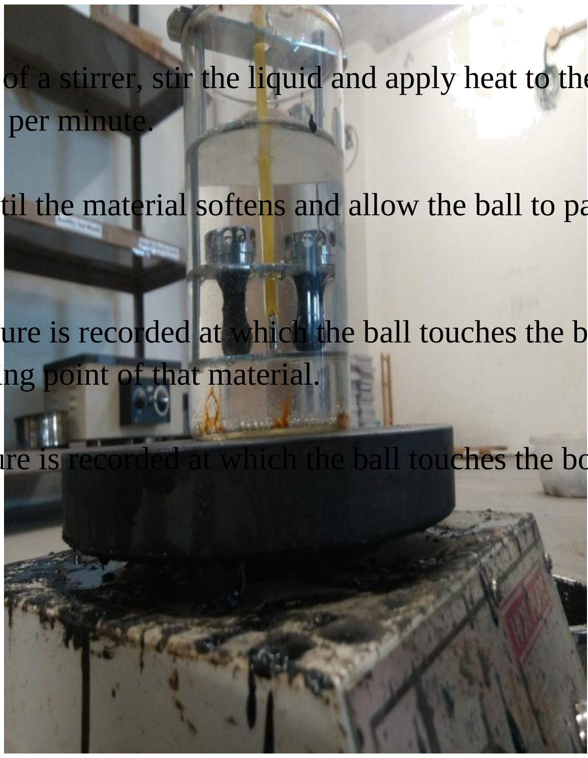


Fig.4.6: -Softening Point Apparatus

## 4.5. MARSHALL STABILITY

### 4.5.1. Significance of Test

Marshall stability and flow test provides the performance prediction measures for Marshall mix design. The stability portion of the test measures maximum load supported by the test specimens at the rate of 50.8 mm. Basically, Marshall stability and flow value test is performed along with determination of bulk density, air voids in in mineral aggregate, void filled with bitumen, for laboratory mix design for evaluation of optimum bitumen content for mix design. There is optimum amount of bitumen which act as sufficient Binder for certain amount of aggregate.

### 4.5.2. Procedure of Test (ASTM-D6927)

#### 4.5.2.1. Preparation of Sample

1. A particular gradation of aggregate to be tested on weighing 1200gm.
2. A range of 4-7% bitumen by mass in increasing order of bitumen concentration.
3. The weighed aggregates and the bitumen are heated separately up to $120^{o}$C and $100^{o}$C respectively as shown in Fig 4.7.

4. Mix them thoroughly, the mixed material is transferred to the compaction mould arranged on the compaction pedestal as shown in Fig 4.8.

5. On the top side of the specimen mix 75 blows are given with a standard hammer (45cm, 4.86kg) as shown in Fig 4.10. Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.

6. Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.

7. A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (5 specimens).
8. Before testing of the mould, keep the mould in the water bath having a temperature of $60^oC$ for half an hour.

9. Weigh the samples in water to calculate other parameters as shown in Fig.4.12.

Fig.4.7: - Boiling of Bitumen

Fig.4.8:- Mixing of Aggregate with Bitumen

Fig.4.9: - Marshall Core

Fig.4.10: - Compacting of Core

Fig.4.11: -Marshall Cores With Varying Modified Bitumen Content(4%-6%)

Fig.4.12: - Curing of Cores and Weight measurement

### 4.5.3. Testing Methodology

1. The samples are placed in Marshall stability apparatus one by one.
2. The readings are noted for different parameters along with Marshall stability and the optimum bitumen content is determined.

Fig.4.13: -Marshall Stability Appratus


Fig.4.14: -Application of Load

Fig.4.15: - Cracked Sample

## 4.6. Cantabro Loss Test (Unaged)

### 4.6.1. Significance of Work

The Cantabro Loss test is conducted to evaluate the resistance to the particle loss of mixture. The Cantabro Loss test is performed to determine the abrasion resistance of Marshall Compacted specimen.

### 4.6.2. Procedure of Test (ASTM-D7064)

#### 4.6.2.1 Testing Methodology

1. The Marshall Stability core is prepared with the modified bitumen and the amount of bitumen taken is optimum one.
2. The core was then placed in water bath at $25^0$C for 24 hour.
3. Weigh the core and then placed it in Los Angeles Abrasion machine without steel balls for 300 revolutions.
4. The core is taken out from the Los Angeles machine and weighted again.

5. The percentage loss in weight is represented as Cantabro loss abrasion.

## 4.7. PERMEABILITY TEST

### 4.7.1. Significance of Work

The Permeability Test of Marshall stability core is done to determine the permeability of surface course, as for design of porous pavement it's important to check the permeability of surface course to determine to what extent the surface course is permeable, we have to check that via modification of aggregate composition how the permeability change.

### 4.7.2. Procedure of Test

#### 4.7.2.1 Testing Methodology

1. The Marshall Stability core is prepared with the modified bitumen and the amount of bitumen taken is optimum one.

2. The core is dried for at least 2-3 days at room temperature @ $27^0$C

3. The core is then sealed from the sides so no water can seep out through the sides

4. The core is placed beneath the permeability apparatus and water is allowed to flow through the core up to certain depth.

5. The time taken by water to travel this depth is noted.

6. The amount of water passed through the core is collected in container and amount of water is noted.

7. the Permeability constant of core is determined using Falling Head Permeability Principle which is used for expressing the permeability

**4.8.3.2. Permeability Apparatus**


Fig.4.16: - Permeability Setup for Surface Course

# CHAPTER 5

## RESULTS & DISCUSSION

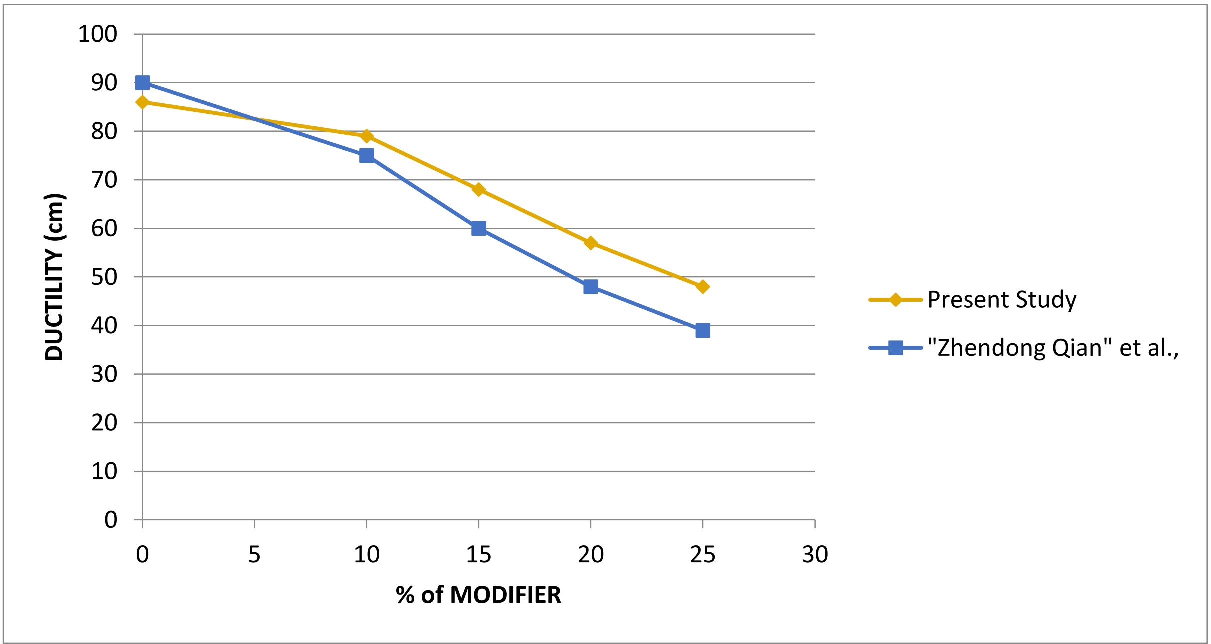
## 5.1. Ductility Test

### 5.1.1. Observations Table

| S.No. | Weight of bitumen | Modifier Added | Ductility Value (cm) |
|---|---|---|---|
| 1 | 250gm | 0% | 86 |
| 2 | 250gm | 10% | 79 |
| 3 | 250gm | 15% | 68 |
| 4 | 250gm | 20% | 57 |
| 5 | 250gm | 25% | 48 |

Table 5.1: - Result of Ductility Test

### 5.1.2. Results



### 5.1.3. Discussion

Ductility test has been performed as per IS 1208:1978 and it can be concluded from the test that the length up to which the sample can be stretched out without being broken has continuously decreased with the addition of modifier. Addition of epoxy resins and hardener decreases the ductility of the sample and there is a proportional decrease in ductility with the increase in concentration of modifier in the bitumen. As shown in the Fig. 5.1. Almost an average decrease of 10cm in ductility value has been noted with every 5% increment in concentration of modifier.

Decrease in Ductility value relates to decrease in bitumen's ability to be transformed into thin wire. This decrease in ductility does not hold much significance in the performance of pavement but it indicates the increase in the hardness of the bitumen after addition of modifier. Hence according to *Zhendong Qian a,* et al., *(2014),* the taken values between 10 to 15% as after 15% modifier content the ductility slope (see Fig 5.1) decrease at a very steeper rate which result in decrease in hardness property which is not required as it will render the pavement inflexibility. Thus, 15% modifier content has been accepted according to ductility test for further test and designing.

## 5.2. Penetration Test

### 5.2.1. Observations Table

| S.No. | Weight of Bitumen | Modifier Added | Penetration Value (mm) |
|---|---|---|---|
| 1 | 250gm | 0% | 79,76,77,76,72 |
| 2 | 250gm | 10% | 64,69,74,68,68 |
| 3 | 250gm | 15% | 58,58,62,60,60 |
| 4 | 250gm | 20% | 49,52,53,48,48 |
| 5 | 250gm | 25% | 38,42,44,42,40 |

Table 5.2: - Results of penetration test

### 5.2.2. Results

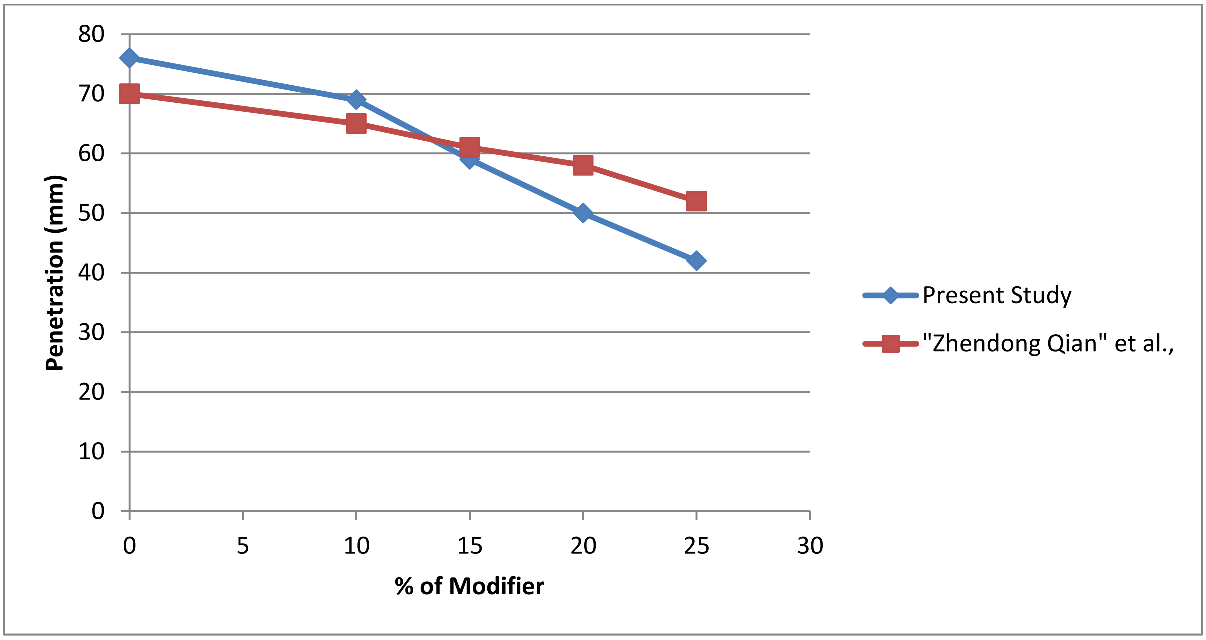



Fig.5.2: - Variation of penetration with %modifier variation

### 5.2.3. Discussion

Penetration test has been performed, as per IS:1203-1978, on the bitumen and the results and From the Fig.5.2 shows that the addition of more percentage of Modifier (Epoxy resins and hardener in ratio of 2:1) lead to decrease in the penetration value. There is almost 0.5mm decrease in penetration with every 5% increment in the concentration of the modifier.

Decrease in the penetration value implies that the hardness of bitumen is increasing and this property of bitumen will lead to better resistance and better holding of aggregate during the impact loading of vehicles on the pavement but as hardness increases the tensile strength of bitumen decreases which is not required. It can be concluded from the results that after 15 % modifier content the slope of graph starts decreasing at more rate than earlier thus sample is becoming hardened at faster rate thus optimum modifier content is taken between 10%-15%

## 5.3. Specific Gravity

### 5.3.1. Observations Table

| S.No. | Weight of bitumen | Modifier Added | Specific Gravity |
|---|---|---|---|
| 1 | 250gm | 0% | 1.0 |
| 2 | 250gm | 10% | 1.01 |
| 3 | 250gm | 15% | 1.016 |
| 4 | 250gm | 20% | 1.024 |
| 5 | 250gm | 25% | 1.03 |

Table 5.3: - Results of specific gravity test

### 5.3.2. Results

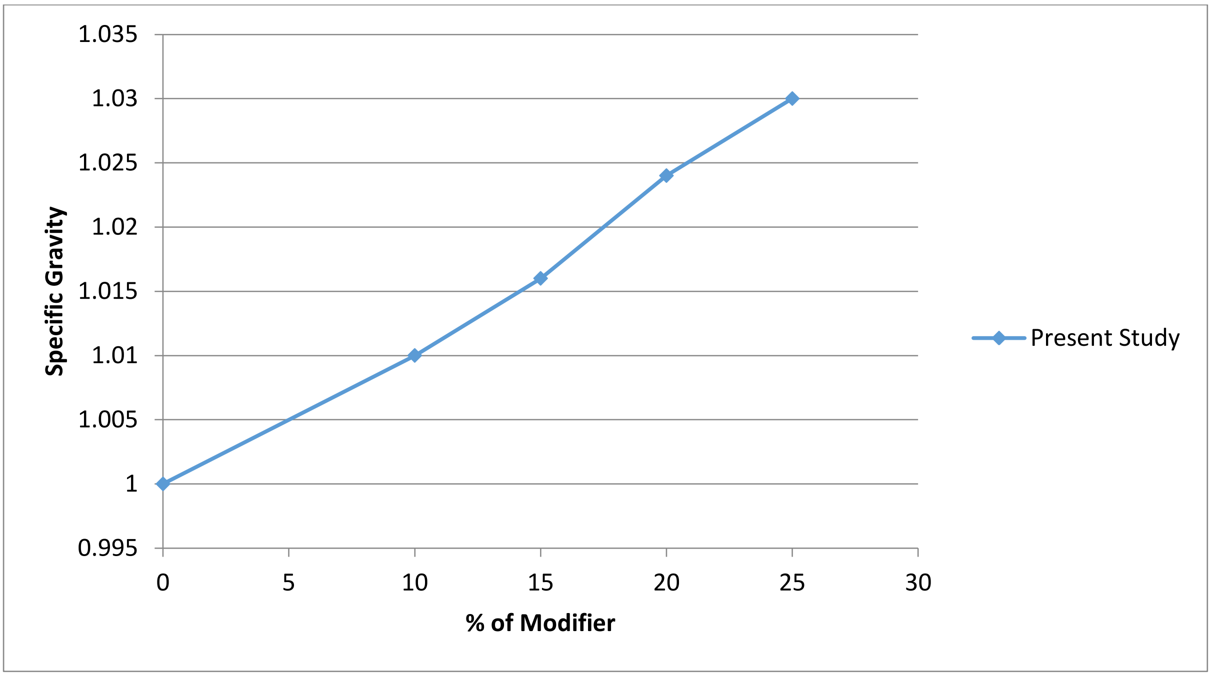



Fig.5.3: - Variation of specific gravity with %modifier variation

### 5.3.3. Specific Gravity Given by:

$$\textbf{Specific Gravity}: \frac{W2 - W1}{(W3 - W1) - (W4 - W2)}$$

W1=Weight of empty specific gravity bottle, (gm)

W2=Weight of bottle +bitumen, (gm)

W4=Weight of bottle + water +bitumen(gm)

W3=Weight of bottle +water, (gm)

### 5.3.4. Discussion

Specific Gravity test has been carried out by using specific gravity bottles and it has been found out that there is not much significant change in the specific gravity of the bitumen with the concentration of modifier. As shown in Fig.5.3 the specific gravity increase but in a very low and insignificant. Specific gravity appears to be risen from 1 to 1.03 but still it is in the range of bitumen's specific gravity.

Specific gravity of the bitumen has increased by small amounts but it doesn't have any effect on the behavior of bitumen under loading whatsoever.

## 5.4. Softening Point Test

### 5.4.1. Observations Table

| S.No. | Weight of bitumen | Modifier Added | Softening Point |
|---|---|---|---|
| 1 | 250gm | 0% | $40^0$C, $41^0$C |
| 2 | 250gm | 10% | $44^0$C,$50^0$C |
| 3 | 250gm | 15% | $53^0$C,$54^0$C |
| 4 | 250gm | 20% | $58^0$C,$60^0$C |
| 5 | 250gm | 25% | $63^0$C,$64^0$C |

Table 5.4: -Result of softening Point

### 5.4.2. Result

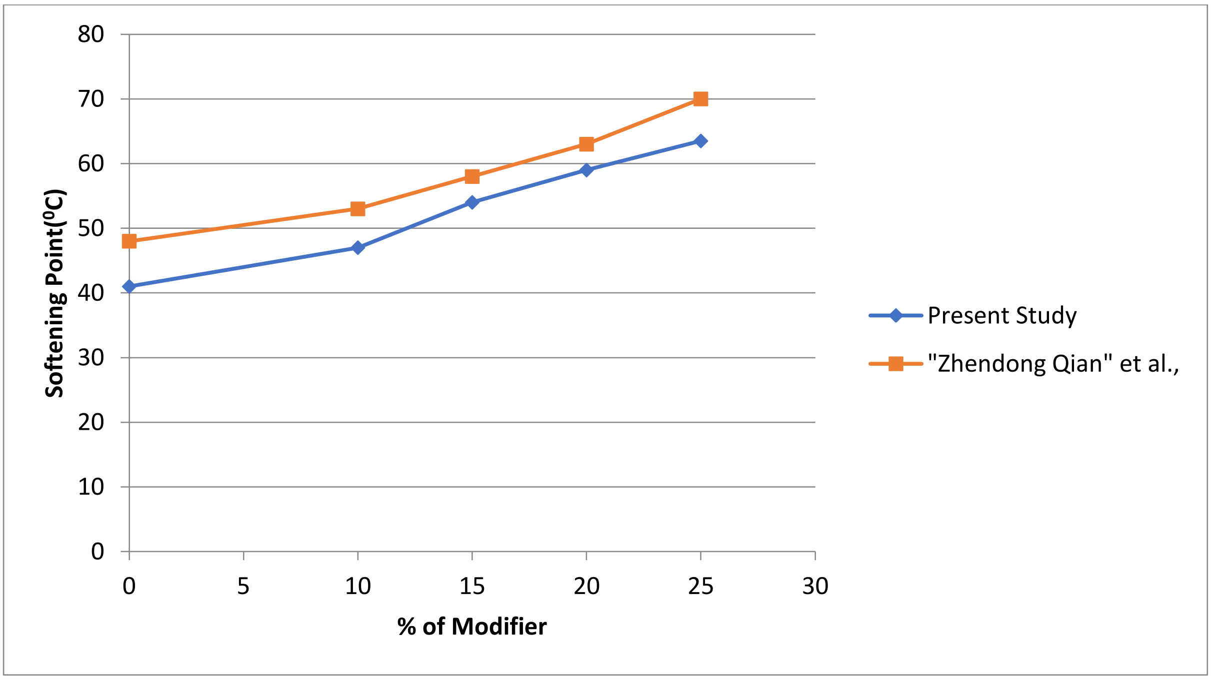



Fig.5.4: - Variation of softening point with %modifier variation

### 5.4.3. Discussion

Softening Point Test has been carried out according to IS: 1205:1978 and it has been found out that the softening point is increasing with respect to increase in the concentration of epoxy resins and hardener in the bitumen sample. From the Fig.5.4, it is analyzed that increase of $5^0$C to $7^0$C has been noted with every incremental increase of 5% modifier concentration.

Softening point of the bitumen has increased. It is due to the strengthening effect of the epoxy resins and hardener present in the bitumen. This will cause modified bitumen to perform well even at higher temperature zones.

## 5.5. Marshall Stability Test

### 5.5.1 Observations Table

| Sr.No | %age Bitumen With 15% Modifier | Marshall Stability (kN) (Min 3.4kN) | Flow Value(mm) (2.5-5.0) |
|---|---|---|---|
| 1 | 4 | 9.4 | 3.36 |
| 2 | 4.5 | 11.9 | 3.80 |
| 3 | 5 | 13.1 | 4.20 |
| 4 | 5.5 | 15.7 | 4.53 |
| 5 | 6 | 2.4 | 4.8 |

#### 5.5.1.1. Gradation of Aggregates

| Sieve Size(mm) | Percentage Passing (Taken Values) | Percentage Passing (NAPA Recommendations) |
|---|---|---|
| 19 | 100 | 100 |
| 12.5 | 85 | 85-100 |
| 9.5 | 50 | 55-75 |
| 4.75 | 10 | 10-25 |
| 2.36 | 5 | 5-10 |

Table 5.5.1: - Gradation of Aggregate for Marshall Stability

### 5.5.2. Results

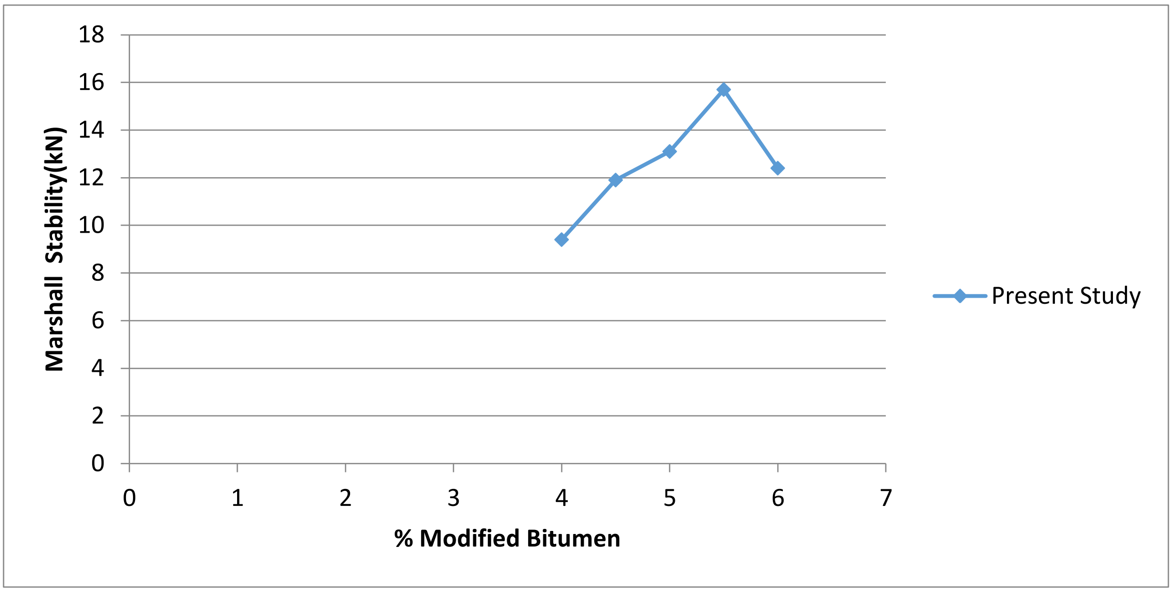



Fig.5.5: - Variation of Marshall stability with % bitumen

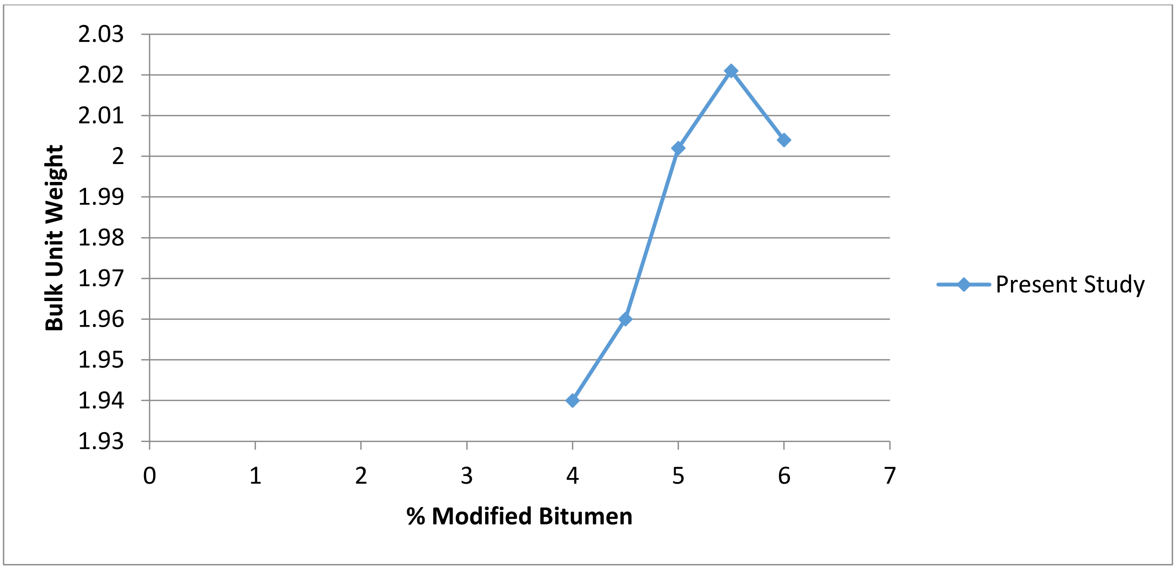



Fig.5.6: - Variation of bulk unit weight with % bitumen

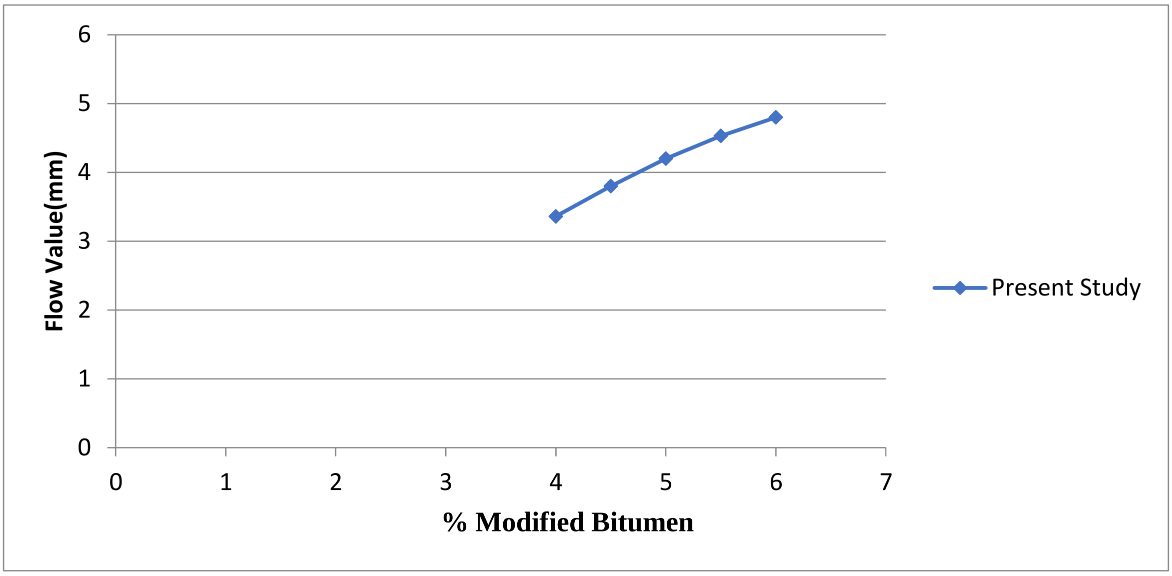



Fig.5.7: - Variation of flow value with % bitumen

According to ASTM-D6927 Optimum Bitumen Content:

:$(OBC_1+OBC_2)$ /2

:(5.5+5.6+5)/3

: 5.4%.

$OBC_1$=Optimum Bitumen Content according to Maximum Stability Values

$OBC_2$= Optimum Bitumen Content according to maximum unit wieght

### 5.2.3. Various mathematical Expression Used

Theoretical specific gravity of the mix $G_t$:

$$Gt = \frac{W1 + W2 + W3 + Wb}{\frac{W1}{G1} + \frac{W2}{G2} + \frac{W3}{G3} + \frac{Wb}{Gb}}$$

Bulk specific gravity of mix $G_m$:

$$Gm = \frac{Wm}{Wm - Ww}$$

Air voids percent $V_v$:

$$\mathrm{Vv} = \frac{(Gt - Gm)100}{Gt}$$

Percent volume of bitumen $V_b$:

$$Vb = \frac{\frac{Wb}{Gb}}{\frac{W1 + W2 + W3 + Wb}{Gm}}$$

Voids in mineral aggregate V M A:

$$V\ M\ A = Vv + Vb$$

Voids filled with bitumen V F B:

$$V\ F\ B = \frac{Vb\ X\ 100}{V\ M\ A}$$

### 5.5.4. Discussion

1. As shown in Fig.5.5**,** 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
2. As shown in Fig 5.6., with increase in bitumen content bulk unit weight increases up to 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.
3. As shown in Fig 5.7., 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

## 5.6 Cantabro Loss Abrasion Test (Unaged)

### 5.6.1. Observation Table

| Sr. No | % Bitumen Content modified with Epoxy Plastic (15%) | Weight of Marshall core before test(gm) | Weight of Marshall core after test(gm) |
|---|---|---|---|
| 1. | 4% | 1050 | 871.5 |
| 2. | 4.5% | 1060 | 906.3 |
| 3. | 5% | 1080 | 931 |
| 4. | 5.5% | 1104 | 984.5 |
| 5. | 5% | 1120 | 1014.72 |

Table 5.6: - Observation of Cantabro Loss Abrasion Test

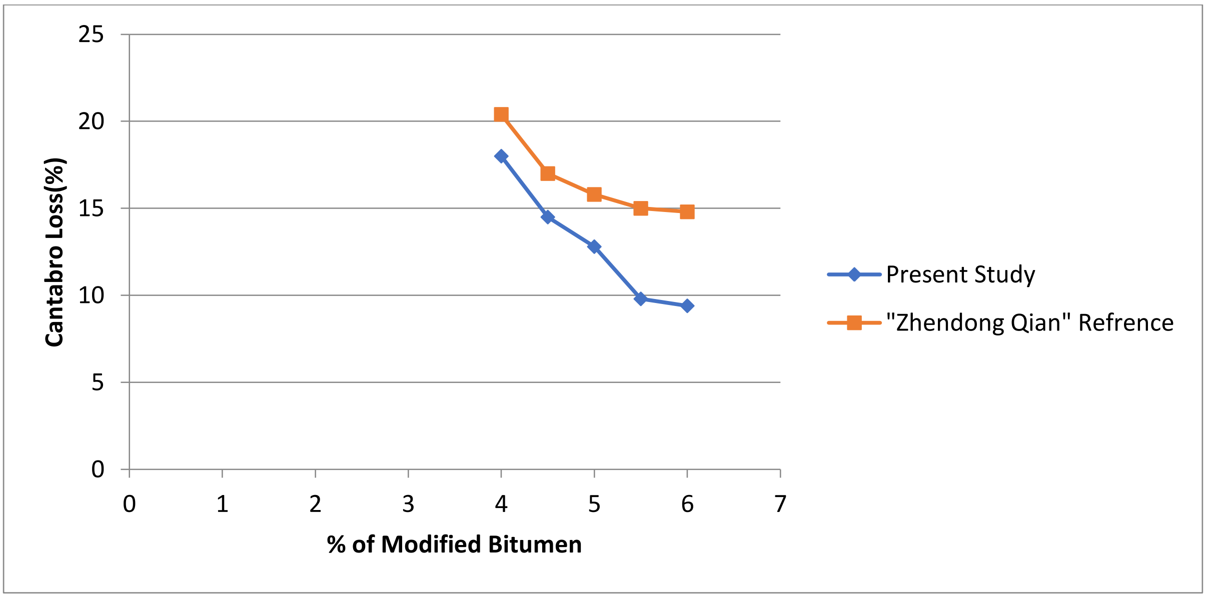
### 5.6.2. The Loss Abrasion Percentage is computed

$$\%\boldsymbol{L.A} = \frac{\boldsymbol{A - B}}{\boldsymbol{B}}$$

Where **A=** Weight of Marshall core before test(gm)

**B=** Weight of Marshall core after test(gm)

### 5.6.3. Results



### 5.6.4. Discussion

The Cantabro Test is performed according to ASTM-D7064 and it has been found that For the Cantabro loss, it increases more quickly when the binder content is less than around 5.5%, Thus we consider it as optimum Bitumen content. According to National Centre of Asphalt Technology the surface course is recommended as open graded porous course for Cantabro Abrasion of unaged specimen less than 20% and from Fig 5.8, all values are less than 20% Thus our Mix Sample is porous one.

## 5.7. Permeability Test

### 5.7.1. Observations

| S.NO. | PARAMETER | VALUES |
|---|---|---|
| 1 | Dimensions of sample | Diameter =10.1cm<br>Height = 8.7cm |
| 2 | Area of Standing tank | 240 $cm^2$ |
| 3 | Initial Level of water | h1=16.3 cm |
| 4. | Final Level of water | h2=3 cm |
| 5. | Time taken | t=25 seconds |

Table 5.7:-Observation of Permeability Test

### 5.7.2. Coefficient of permeability is given by:

$$k = 2.303 \frac{aL}{At} \log \frac{h1}{h2}$$

Where **k=** Permeability coefficient (cm/sec) **h1=** Initial Level (cm)

**A=**Area of specimen ($cm^2$) **h2=**Final Level (cm)

**a=** Area of standing tank ($cm^2$)

**L=**Length of sample (cm)

### 5.7.3. Results

Permeability of surface coarse comes out to be =1.57 cm/sec

### 5.7.4. Discussion

Our permeability comes out to be 1.57 cm/sec. The permeability standards for pavements is not specified particularly in Indian standards but it is vaguely defined that for porous course it should be more than 1cm/sec as per the paper by Wei Jiang et al., (2015) (Reference no.3). Our value comes out to be 1.57 cm/sec which means that our pavement is sufficiently permeable.

# CHAPTER 6

## DESIGN OF POROUS PAVEMENT

## 6.1. Concept of Porous Pavement

The concept of porous pavement is developed by Franklin Institute in Philadelphia and published a design guide for porous pavements. Pervious concrete can be used for several applications, but its primary use is in road pavement such as in rural areas. Pervious pavement is a unique and effective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff. In fact, the use of pervious concrete is among the Best Management Practices (BMPs) recommended by the EPA—and by other agencies and geotechnical engineers across the country—for the management of storm water runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices.

Porous pavements allow for land development plans that are more thoughtful, harmonious with natural processes, and sustainable. They conserve water, reduce runoff, promote infiltration which cleanses storm water, replenish aquifers, and protect streams

A typical porous pavement has an open-graded surface over an underlying stone recharge bed. The water drains through the porous asphalt and into the stone bed, then, slowly, infiltrates into the soil. Many contaminants are removed as the storm water passes through the porous asphalt, stone recharge bed, and soils through filtration and microbial action

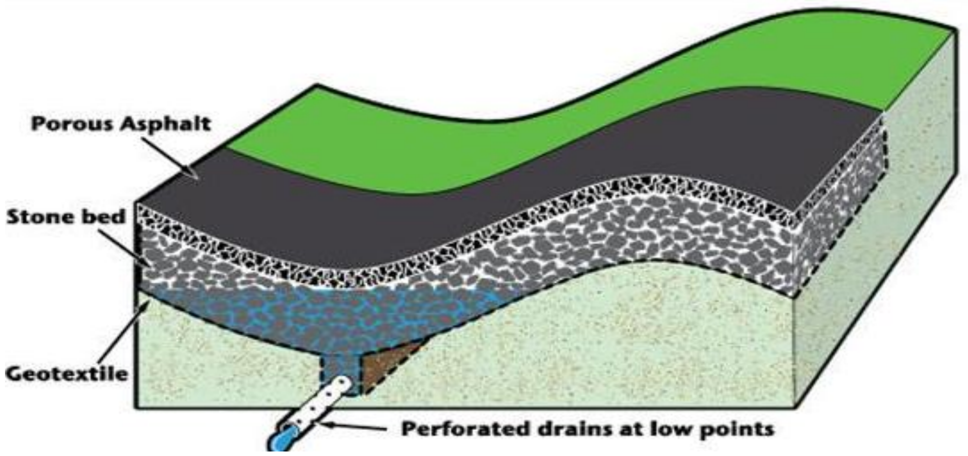



Fig.6.1: -Typical Porous Pavement

## 6.2. Design Guidelines for Porous Pavement

These guidelines deal with the basic outline for the design, construction and controls needed for constructing porous asphalt pavement for parking lots and low-trafficked roads the porous asphalt pavement consists of the following starting from the bottom upwards: subgrade; stone filter course; stone reservoir course; stone choking layer; and porous asphalt course. Guidelines for constructing these different courses or layers are given below in that order.

### 6.2.1. Subgrade

Subgrade should be allowed to remain natural and uncompacted to maintain its permeability. No excessive construction traffic should be permitted on the subgrade. It is advised to excavate for the desired subgrade level (at least the last 150 mm or 6 inches) when all preparations have been made for laying the stone filter course and the stone reservoir course. If there are any depressions in the subgrade which need to be filled and levelled, use permeable sand and compact it lightly. The slope of the finished subgrade should not exceed 5 percent.

### 6.2.2. Stone Filter Course / Nonwoven Geotextile Fabric

The stone filter course is provided between the subgrade and the stone reservoir course so that fines from the subgrade do not migrate upwards into the stone reservoir thereby reducing its storage capacity. It also provides some platform for laying the stone reservoir course. Although nonwoven geotextile fabric has been used between the subgrade and the stone reservoir for this purpose, some clogging of the geotextile material has been reported from the fines washed down on its surface.

### 6.2.3. Stone Reservoir Course

The function of the stone reservoir course is to temporarily store rainwater which percolates slowly from the drainage pipes to the outlet. Its AASHTO Gradation 2 consists of large uniformly graded aggregate particles 40 mm to 65 mm (1.5 to 2.5 inches) in size with about 40% voids to accommodate rainwater. The stone should be clean. thickness of this course is designed to hold rainwater during a 25-year, 24-hour rain storm. Its minimum thickness is 230 mm (9 inches). It should empty within 72 hours. Its thickness is designed based on expected rainfall and desired structural strength.

| Sieve Size(mm) | Percentage Passing (AASHTO No. 2) | Sieve Size(mm) | Percentage Passing (Used in study) |
|---|---|---|---|
| 75 | 100 | 70 | 100 |
| 63.5 | 90-100 | 60 | 90 |
| 50 | 35-70 | 31.5 | 50 |
| 38.5 | 0-15 | 19 | 15 |
| 19 | 0-5 | 12.5 | 5 |

Table 6.1: - Design Gradation of reservoir course

### 6.2.4. Stone Choking Layer

The stone choking layer is placed on the stone reservoir course to fill and level its open large surface voids and makes it stable and smooth for Bitumen Paver. Normally, it is placed in 50 mm (2 inches) thick layer and compacted well with a light roller in static mode only until a smooth surface is obtained for paving above it.

The stone choking layer consists of either a clean, single size aggregate (12.5 mm) .

### 6.2.5. Porous Asphalt Course

The porous asphalt course is usually placed in 75 mm (3inches) thickness. After compaction in the field it must have at least 16% air voids to provide the desired porosity and permeability. Specifications for Dense Graded Bituminous Mixes IRC: 111-2009 shall generally be followed to produce and lay porous asphalt with the additional/special requirements noted here.It is important that the gradation given is adhered to obtain the desired porosity and permeability.

| Sieve Size(mm) | Percentage Passing (Taken Values) | Percentage Passing (National Asphalt Pavement Association (2003) Reference) |
|---|---|---|
| 19 | 100 | 100 |
| 12.5 | 85 | 85-100 |
| 9.5 | 50 | 55-75 |
| 4.75 | 10 | 10-25 |
| 2.36 | 5 | 5-10 |

## 6.3. MAINTAINENCE OF POROUS PAVEMENT

Factors to Keep in Mind

- Runoff Volumes: A pervious pavement project should be properly designed to accommodate the amount of storm water runoff that is expected in the area. If not adequately designed, the water table below the pavement can rise, preventing storm water from being absorbed into the ground.
- Because pervious concrete has such a high void content and its overall strength is generally lower than that of regular concrete, it is not recommended for highways, high-volume streets, potential spill sites (in case of clogging), and heavy loading areas.
- While it is estimated that this modified Bitumen can be more expensive than regular Bitumen or concrete, cost savings are simultaneously achieved as storm water installations are not necessary.
- Certain types of pervious pavements require frequent maintenance due to the possibility that solids and particles may get trapped and clog pavement pores. If the proper "vacuuming" or flushing is not carried out, pervious concrete will assume the traits of impervious concrete.

Maintenance of permeable pavement is driven by annual inspections that evaluate the condition and performance of the practice. The following are suggested annual maintenance inspection points for permeable pavements:

- The drawdown rate should be measured at the observation well for three (3) days following a storm event more than 1/2 inch in depth. If standing water is still observed in the well after three days, this is a clear sign that clogging is a problem.
- Inspect the surface of the permeable pavement for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging. If any signs of clogging are noted, schedule a vacuum sweeper (no brooms or water spray) to remove deposited material. Then, test sections by pouring water from a bucket to ensure they work.

- Inspect the structural integrity of the pavement surface, looking for signs of surface deterioration, such as slumping, cracking, spalling or broken pavers. Replace or repair affected areas, as necessary.
- Check inlets, pretreatment cells and any flow diversion structures for sediment buildup and structural damage. Note if any sediment needs to be removed.
- Inspect the condition of the observation well and make sure it is still capped.
- Generally, inspect any contributing drainage area for any controllable sources of sediment or erosion.

## 6.4 Pavement Model


Fig. 6.2.: - Pavement Model

Fig.6.3.: -Provision of pipes for water outlet

Fig. 6.4.: - Top Porous Surface Course

# CHAPTER 7

## CONCLUSION

## 7.1. Summary

- Epoxy Resin modifications of bitumen have been proven to improve characteristics of bituminous binder such as the viscosity, softening point, Ductility, and storage modulus. This subsequently improves the rutting resistance, resilience, and improving fatigue cracking resistance of asphaltic mixes.
- To achieve a superior and balanced Epoxy resin modified bitumen in term of high and low temperature properties, factors such as the mixing time, temperature, characteristics, and bitumen type must be considered since these are the factors that govern the resulting performance of Bitumen mixes.
- The chemical modification of bitumen with Epoxy Resin is a new area that has promising possibilities in the future to further enhance the properties of Bitumen that a small particle. If the porous pavements become strong enough to withstand moving loads and still prove durable then it would be very successful in replacing the conventional pavements and will be very good for the environment.
- Porous bitumen pavements are generally used in parking lots and other places where the loading is not impact but in case of Porous bitumen mixture modified with epoxy resin can be designed to possess excellent performance desired for pavement surface functions, including permeability, friction, and moisture resistance and also as it allows water to pass through it helps in restoring the underground water resources and reduces the load on waste treatment plants.

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

- The aggregate gradation consists of 100 percent of 19mm down sized aggregates but requires less than 20 % of the aggregate fraction passing 4.75 mm, so that the compacted mix becomes permeable and provide adequate permeability. The increase in the binding strength of bitumen by the addition of epoxy resins and hardener it should be able to counteract the increased size of aggregate and still provide adequate strength to the pavement.

- Mixing of Epoxy Resin with plain Bitumen shows significant changes in the properties of bitumen such as decrease in ductility, penetration value and increase in softening value. Which means the bitumen would now have higher strength to hold the aggregates and would work better in higher temperature regions as the softening point is increased.

- To improve the strength of Porous Bitumen Pavements, Epoxy Resin Modified Bitumen has been shown to can improve the rutting resistance, ductility and increases the viscosity.

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

- Marshall Mix Design test reveals that strength of porous pavement mix is maximum at Optimum Bitumen Content 5.4 % and the bitumen used in it has a modifier content of 15%.

- Permeability of the pavement gives a good idea that water would be absorbed at high rates by the pavements almost as soon as it falls so it would prevent skidding of vehicles on the road and prevent water splashes. Tyres would have a good grip even in rainy day and it could reduce the occurrence of accidents.

# CHAPTER 8

## SCOPE OF FUTURE STUDY

## 8.1 FUTURE SCOPE

8.1.1. Though epoxy plastic increases the strength of bitumen but still there is significant properties whose results are not according to our expectations which show that epoxy plastic is not the perfect modifier. But it increases many of the significant properties. Hence to improve that properties laboratory test will be performed in the future with different modifier.

8.1.2. From ductility test we leave seen that as we use the modifier content the tensile strength of bitumen decrease which is not expected. Thus, we have to find out whether this loss of tensile strength varies linearly of exponentially with age of bitumen and because constant after a specific age of bitumen. thus, test needs to be performed for longer durations and testing to be done at successive intervals.

8.1.3. We determine the permeability of the base coarse, but we have to determine that to what extent the filtration is done through the porous pavement. IF the water from top coarse reaching ground water then question arises to what extent the water is filtered thus requiring different types of test to be worked.

8.1.4. The main problem with porous pavements is the clogging. As water passes so does the impurities like sand particles with it which fill up the pores and leads to blocking and reduction in permeability of pavement. Studies have to be done to clean out the clogged pores do that pavement remains porous and allows water to go through. One of the methods of cleaning is vacuuming out the impurities. But more efficient and less costly ways are needed to manage the performance of pavement.

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# APPENDICIES

# Annexure I

## Calculation for Marshall Stability and Flow Values Test

1. Calculations for theoretical Specific gravity. ($G_t$)

| S.No. | Bitumen Percentage | Theoretical Specific Gravity | Formula=$(\frac{\sum Wn}{\sum \frac{Wn}{Gn}})$ |
|---|---|---|---|
| 1. | 4 | 2.50 | $\frac{500+700+48}{500/2.7+700/2.61+48/1.01}$ |
| 2. | 4.5 | 2.48 | $\frac{500+700+54}{500/2.7+700/2.61+60/1.01}$ |
| 3. | 5 | 2.467 | $\frac{500+700+60}{500/2.7+700/2.61+72/1.01}$ |
| 4. | 5.5 | 2.458 | $\frac{500+700+66}{500/2.7+700/2.61+84/1.01}$ |
| 5. | 6 | 2.44 | $\frac{500+700+72}{500/2.7+700/2.61+96/1.01}$ |

Table A1: - Calculation of Theoretical Specific Gravity

2. Calculations for Bulk Specific Gravity ($G_m$)

| S.No. | Bitumen Percentage | Bulk Specific Gravity | Formula=$(\frac{Wa}{Wa-Ww})$ |
|---|---|---|---|
| 1. | 4 | 1.91 | $\frac{1050}{1050-510}$ |
| 2. | 4.5 | 1.96 | $\frac{1060}{1060-520}$ |
| 3. | 5 | 2.00 | $\frac{1080}{1080-540}$ |
| 4. | 5.5 | 2.021 | $\frac{1104}{1104-558}$ |
| 5. | 6 | 1.98 | $\frac{1120}{1120-555}$ |

3. Air Void Analysis (Vv)

| S.No. | Bitumen Percentage | %age voids | Formula=$\frac{(Gt-Gm)*100}{Gt}$ |
|---|---|---|---|
| 1. | 4 | 22.4 | $\frac{(2.50-1.91)*100}{2.50}$ |
| 2. | 4.5 | 20.8 | $\frac{(2.48-1.96)*100}{2.48}$ |
| 3. | 5 | 19 | $\frac{(2.467-2.00)*100}{2.467}$ |
| 4. | 5.5 | 17.7 | $\frac{(2.458-2.021)*100}{2.458}$ |
| 5. | 6 | 18.27 | $\frac{(2.44-1.98)*100}{2.44}$ |

4. Calculations for %age volume of bitumen ($V_b$)

| S.No | Bitumen %age | %age volume of bitumen | $Formula(\frac{Wb/Gb}{\sum W/Gm})$ |
|---|---|---|---|
| 1. | 4 | 9.5 | $\frac{48/1.01}{500+700+48/2.5}$ |
| 2. | 4.5 | 10.5 | $\frac{54/1.01}{500+700+54/2.48}$ |
| 3. | 5 | 11.6 | $\frac{60/1.01}{500+700+60/2.46}$ |
| 4. | 5.5 | 12.6 | $\frac{66/1.01}{500+700+60/2.458}$ |
| 5 | 6 | 13.67 | $\frac{72/1.01}{500+700+60/2.44}$ |

5. Calculations for voids in mineral aggregate (VMA)

| S.no | Bitumen %age | VMA | $V_v+V_b$ |
|---|---|---|---|
| 1. | 4 | 22.495 | 0.095+22.4 |
| 2. | 4.5 | 20.905 | 0.105+20.8 |
| 3. | 5 | 19.116 | 0.116+19 |
| 4. | 5.5 | 17.826 | 0.126+17.7 |
| 5. | 6 | 16.406 | 0.1367+16.27 |

6. Calculations for voids filled with bitumen (VFB)

| S.No. | Bitumen %age | VFB | $Formula = \frac{Vb * 100}{VMA}$ |
|---|---|---|---|
| 1. | 4 | 42.2 | $\frac{0.095 * 100}{22.495}$ |
| 2. | 4.5 | 0.50 | $\frac{0.105 * 100}{20.905}$ |
| 3. | 5 | 0.60 | $\frac{0.116 * 100}{19.116}$ |
| 4. | 5.5 | 0.70 | $\frac{0.126 * 100}{17.826}$ |
| 5. | 6 | 0.83 | $\frac{0.1367 * 100}{16.406}$ |

## Annexure II

### Calculations of % Cantabro Loss Values

| Sr. No. | % Bitumen Content modified with Epoxy Plastic (15%) | % L.A(Loss Abrasion) | Formula $\frac{A-B}{A} * 100$ | Weight of Marshall core before test(gm) (A) | Weight of Marshall core after test(gm) (B) |
|---|---|---|---|---|---|
| **1.** | 4% | 18 | $\frac{1050-871.5}{1050}$ | 1050 | 871.5 |
| **2.** | 4.5% | 14.5 | $\frac{1060-906.3}{1060}$ | 1060 | 906.3 |
| **3.** | 5% | 12.8 | $\frac{1080-931}{1080}$ | 1080 | 931 |
| **4.** | 5.5% | 9.8 | $\frac{1104-984.5}{1104}$ | 1104 | 984.5 |
| **5.** | 5% | 9.4 | $\frac{1120-1014.72}{1120}$ | 1120 | 1014.72 |

# Annexure III

## Test on Aggregates

| Sr. No. | Test | Results | Recommended Values |
|---|---|---|---|
| 1 | Crushing Value | 28.66% | Should be less than 30 % |
| 2. | Specific Gravity | 2.72 | 2.6-2.9 |
| 3. | Water Absorption | 0.845 | Should be greater than 0.6 % |
| 4. | Impact Value | 6.14 % | Should be less than 30 % |

The Results of Aggregates Test lie in Recommended values according to standards thus these aggregates are best suited for Study

## Submission Info

| | |
|---|---|
| SUBMISSION ID | 806343051 |
| SUBMISSION DATE | 28-Apr-2017 12:26 |
| SUBMISSION COUNT | 1 |
| FILE NAME | Project_Report_Abhishe... |
| FILE SIZE | 3.55M |
| CHARACTER COUNT | 50451 |
| WORD COUNT | 8850 |
| PAGE COUNT | 69 |
| **ORIGINALITY** | |
| OVERALL | 18% |
| INTERNET | 16% |
| PUBLICATIONS | 3% |
| STUDENT PAPERS | 11% |
| **GRADEMARK** | |
| LAST GRADED | N/A |
| COMMENTS | 0 |
| QUICKMARKS | |