Influence of Nanomaterials on Properties of Bituminous Concrete Mixes

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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To

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HIMACHAL PRADESH, INDIA

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Influence of Nanomaterials on Properties of Bituminous Concrete Mixes"** in partial fulfilment 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 Atul Pal (141622), Pranav Sharma (141681) and Piyush Rathore (141683) during a period from July 2017 to June 2018 under the supervision of **Mr.Aakash Gupta** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: - May 10, 2018

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We also thank **Dr. Ashok Kumar Gupta, Professor and Head of Department**, Department of Civil Engineering, Jaypee University of Information Technology, for consent to include copyrighted pictures as a part of our report. We also thank **Mr. Jaswinder Deswal,** Technical and laboratory, Department of Civil Engineering, Jaypee University of Information Technology, for providing us with all the necessary equipment and also being present in the laboratory whenever tests were conducted to ensure our safety.

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ABSTRACT

Being a developing country India has to be frugal in its spending on various sectors and cost cutting is necessary and should be given due consideration wherever possible. In the wake of the above theme, the best solution for any problem is preventing it from happening. Road construction inherently require large amounts of money and time. Cost cutting in construction is not advisable as that can lead to lower quality constructions. Money can be saved however if the roads so constructed require lower maintenance and have a longer service life. This can be achieved in the with the help of modifying admixtures which improve the properties of the construction materials. The use of nanotechnology in these admixtures is however fairly modern and not much researched. The lower dosage requirement along with improvement in various properties are the fundamental benefits of using nanomaterials. Therefore, being "Penny wise-Pound Foolish" should be avoided and good quality materials and admixtures should be used.

In this project, nanomaterials have been used in various proportions in bituminous concrete mixes and tests have been carried out to observe the effects of those on the mix. Optimum dosage of the nanomaterial is also important and has been given due consideration in this project.

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Chapter 1

Introduction

1.1 General Introduction

- Bituminous surfaced flexible pavements are in use in various parts of the world.
- The early distress symptoms are a cause of the heavy traffic in terms of commercial vehicles and hauling vehicles carrying more than their specified limits and due to the change in the temperature of the pavement.
- Research has led us to believe that properties of bitumen and bituminous mixes can be improved considerably with incorporation of certain additives. These admixtures helps to prevent development of distress symptoms.
- For our project, we are using **Nanomaterials** as these additives.

Fig. 1-Pavement Deterioration (Pot Hole)

Factors affecting Pavement Strength:

It has been with the help of previous researches already established that moisture is one of the greatest factors, which adversely affects the performance of bituminous concrete, Decrease in total strength, increased rutting ,decrease enervation life and increased stripping of the bituminous blend are caused by moisture penetration .Engineers and road administrators were not satisfied at macro and micro level so **Nano levels became necessary**.

In addition, these admixtures provide better durability and cost effectiveness to the entire bituminous mix and therefore further researches are being carried out in this field.

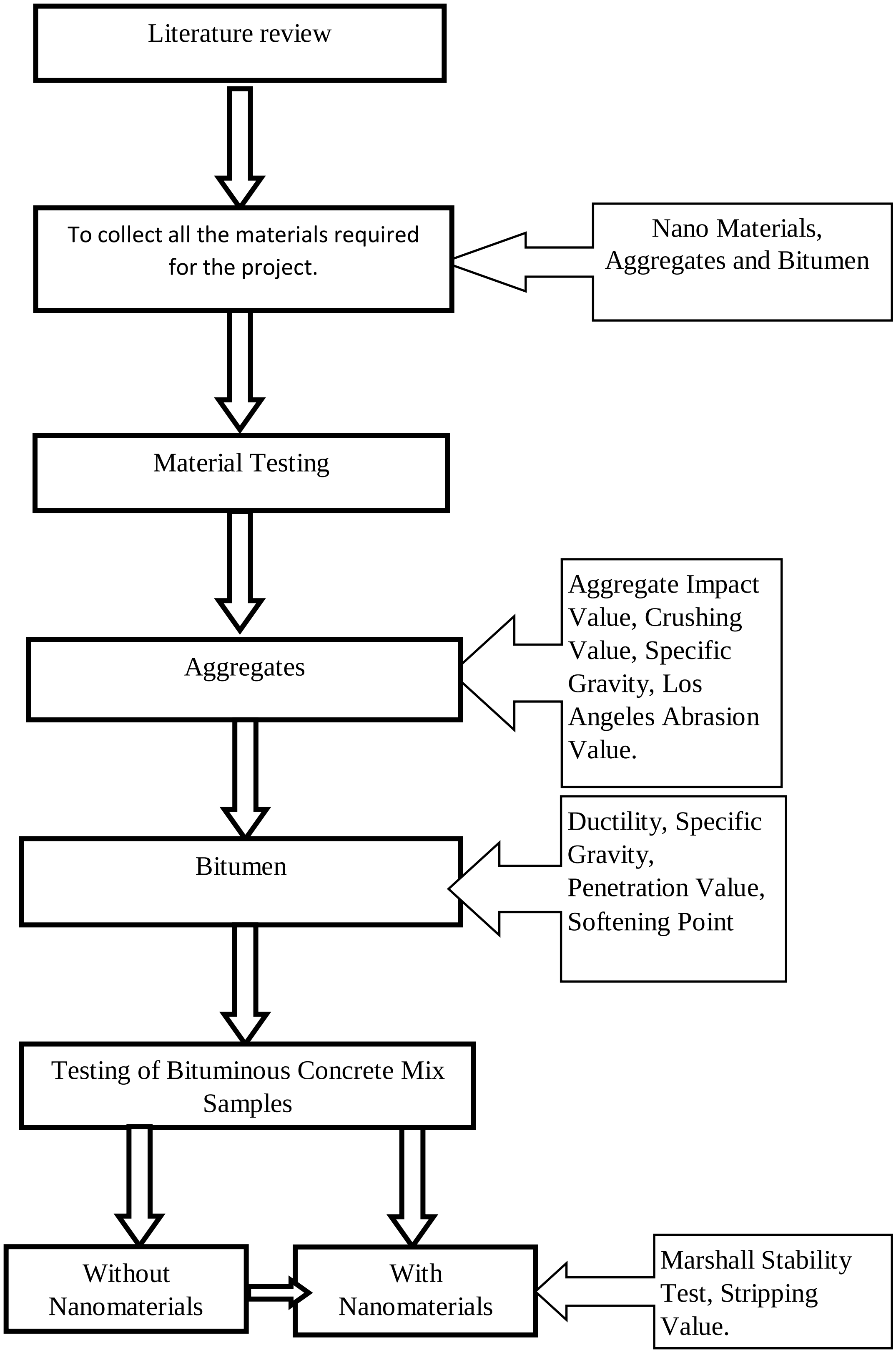
Fig. 2-Pavement Deterioration (Rutting)

1.2 Objectives

- To study the impact of using Nano chemical additive on the properties of bituminous mix.
- To study the impact of the same on economy of the pavement.
- In addition, show variations in these values in comparison to the specimen without the addition of Nano chemical.

In order for the completion of the above objectives various tests have been carried out like Marshall Stability Test, Stripping Value Test; first for the bituminous mix without admixtures and then with admixture in the proportion of 0.1%, 0.2% and 0.3% of the weight of bitumen in case of Zycotherm and 5%, 10% and 15% by weight of bitumen for Nano Clay.

1.3 Methodology



Chapter 2

Literature Review

2.1 Literature review conclusions:

2.1.1 "Marshall Test Properties of Bituminous Concrete Mixes Using Fly Ash Modified Bitumen"

Poorna Prajna, Dr. Mohamed Ilyas Anjum, International Journal of Scientific & Engineering Research (July 2014)

Key Points:

- The Marshall Stability value = 31.38Kn for 8% fly ash at 5.5% bitumen content, more than plain bitumen.
- Decreased air voids, provide better strength and increase service life of the pavement.
- The modification has led to achievement of stability of the bituminous mix at a lower bitumen content leading to overall economy of the mix.

2.1.2 "Experimental Study of Bituminous Concrete Containing Plastic Waste Material"

"Pankaj P.Shedame, Nikhil H.Pitale", IOSR Journal of Mechanical and Civil Engineering (May 2014)

Key Points:

- Coating of plastic waste on aggregates in bituminous concrete mixture for road construction.
- The volumetric properties of bituminous mixes can be improved by using waste plastic 0.76% by weight of aggregate and 3% filler.
- Plastic will increase the melting point of the bitumen.

2.1.3 “Modifiers for Asphalt Concrete”

R. Jones, Air Force Engineering and Services Centre Engineering and Services Laboratory (November 1990)

Key Points:

- All of the modifiers increased the viscosity of the binder at 140°F, and all but Sulphur increased the viscosity at 275°F.
- All of the modifiers increased the Marshall stability of the mixture.
- All of the modifiers were found to be cost-effective in terms of rut prevention.
- All of the modifiers, except Sulphur, demonstrated the ability to improve the temperature susceptibility of the binder.

2.1.4 “Effect of Waste Polymer Modifier on Properties of Bituminous Concrete Mixes”

Sangita, Tabrez Alam Khan, Sabina, DK Sharma, Technical Paper (October 2011)

Key Points:

- Marshall Stability can be improved by adding 8% waste polymer modifier with Bituminous mix .
- Modified bituminous mix shows better performance than traditional mix.
- It also shows higher resistance to stripping than traditional mix.

2.1.5 “Suitability of Sulphur as Modifier in Bitumen for Road Construction”

“Poorna Prajna, Mohamed Ilyas Anjum”, International Journal of Research in Engineering and Technology (May 2015)

Key Points:

- The Marshall Stability value = 30.22 KN (max.) for 9% sulphur at 5% bitumen content, which is more than normal bitumen mix .
- Decreased air void results in improved strength and long life of pavement.

2.1.6 “Emission Reduction Performance of Modified Hot Mix Asphalt Mixtures”

Chaohui_Wang, Qiang Li, Kevin Wang, Xiaolong Sun, Xuancang Wang, Advances in Materials Science and Engineering Volume 2017

Key Points:

- The emission-reduction performance of Hot Mix Asphalt is affected to some extent by the asphalt binder type and mixture grade. For several particular types of binder, in general modified asphalt mixtures achieve the best emission reduction performance.

- When the dosage increases from 20% to 25% relative to the initial asphalt weight, both emission reductions of NOx and COx tend to stabilize as the softening point reduction leads to required properties at a lower temperature.

2.1.7 “Water Effect on Deteriorations of Asphalt Pavements”

Altan Yilmaz, Online Journal of Science and Technology- January 2012, Volume 2

Key Points:

- Effect of water on pavement weakening is a complicated process involving thermodynamic, chemical, physical, and mechanical processes .
- With the use of modifiers, the water damage resistance of pavements can be increased significantly.
- To understand the water effect on pavement weakening, we need to understand the failure mechanism and site-specific treatments applicable to the problem.

2.1.8 “Using Asphalt Modifiers and Additives”

Steven Munchy, Technical Paper (January 2001)

Key Points

- Not all current asphalts can be used for all applications. When needed. Asphalts may be modified to upgraded specifications. There are many modifiers on the market today. They are reported to provide many benefits- reduced rutting, reduced stripping, resistance to cracking, increased longevity and cost efficiency.
- Each agency will have to evaluate the performance of present materials and research the appropriate modifier for their situations.

2.1.9 "A Study on Marshall Stability Properties of Warm Mix Asphalt Using Chemical Additives"

J. Ranjitha, N Rohith, International Journal of Engineering Research & Technology (July 2013)

Key Points:

- For the HMA mix ,OBC(optimum binder content) at 155°C = 5.4%
- WMA mix at 130°C + 0.1% of ZycoTherm =5.37%
- The resulting mixture is shown to have better resistance to damaging factors.

2.2 Summary of Literature Review

- Research has been done on additives in bituminous mix but minimal research has been done in the field of Nano chemicals as additives in bituminous mix.

- Improvements have been shown by the use of additives both economically and environmentally (in terms of lesser emissions); however, such benefits from Nano chemicals have not been studied in detail.

- Cost benefits of these additives have not been studied thoroughly and I general with the amount of bituminous mix that is being produced can have a great impact on economy of the project at hand.

- Benefits of Nano chemicals in preventing water damage have not been given adequate thought or research.

- Research on Nano chemicals in India is still not progressing at a rate to match the world standards.

Chapter 3

Materials

3.1. Aggregate:

“Construction aggregate”, or simply "aggregate", is a wide classification of coarse to medium grained particles which is used in construction comprising sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Concrete and asphalt concrete majorly consists aggregate. The aggregates increases the strength of the overall composite material by serving as reinforcement.

Aggregates having high hydraulic conductivity value then moist soil are broadly used in drainage applications like in foundation and French drains, septic drain fields, retaining wall drains, and roadside edge drains and as base materials in roads, and railway tracks. They have uniform properties which to help prevent differential settling .

Fig. 3-Aggregates

The main characteristics of aggregates are:

1. They are hard, durable, and irregular in shape.
2. In order to be used the aggregates have to be graded accurately and then used according to the grade requirement.
3. Aggregates though different from each other in various aspects, they can be similar based on various parameters like:
    - Impact Value
    - Water Absorption
    - Elongation and Flakiness Index
    - Abrasion Value
    - Specific Gravity

Aggregates are common throughout the country but for our current study aggregates were acquired from a quarry in Solan district in Himachal Pradesh.

3.2 Bitumen

“Asphalt or simply “bitumen”, is a sticky, black, and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product.”It was known by name asphaltum before 20th century.

Asphalt is used as the glue or binder mixed with aggregate particles to create asphalt concrete in road construction. It is also used for manufacturing bituminous waterproofing products.

Fig. 4-Bitumen

Since Bitumen is a by-product of petroleum refining it is available at almost all of the refineries in India as shown in the following map.

However there are some companies that specifically refine crude bitumen like

- Shell India
- Roadstar
- Hincol

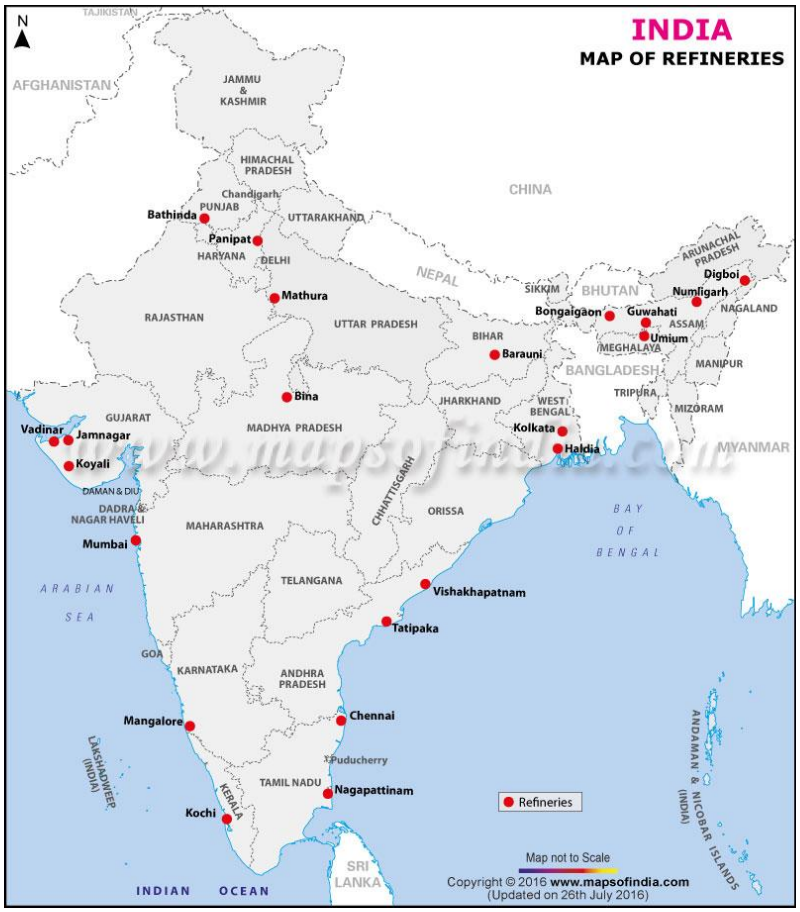


Fig. 5-A map of India showing the major refineries

For our current study, bitumen was procured from the Highway Laboratory of Jaypee University of Information Technology.

3.3 Additives

Additives are added to materials to enhance their properties. They are mostly added to improve either workability or durability. However, there are also certain targeted additives that work on improving a particular aspect of a material, like lowering softening point of bitumen.

In our current study, the nanochemicals used will be **Zycotherm** and **Nano Clay**.

Fig. 6-The Company Logo

Fig. 7- Nano Clay

In India Zydex Industries is a chemical company that produces Zycotherm and for our current study, it was procured by directly contacting their sales headquarters in Vadodara (Gujrat) and the Nano Clay was purchased from a Nano Chemical supplier in Dera Bassi (Punjab).

Chapter 4

Testing Methodology and Results

4.1 List of Experiments

4.1.1. Tests on aggregates

- Aggregate Impact Value Test
- Aggregate Crushing Test
- Los Angeles Abrasion Test
- Specific Gravity of Aggregates Test
- Grading of Aggregates(Sieving) for the Marshall Mix

4.1.2. Tests on Bitumen

- Ductility Test of Bitumen
- Specific Gravity Test of Bitumen
- Penetration Test of Bitumen
- Softening Point of Bitumen

4.1.3. Tests on Bituminous mix (With and Without Modifiers)

- Marshall Stability Test
- Stripping Test

4.2 Testing of Aggregates

4.2.1 Aggregate Impact Value Test

Theory:

Toughness is the property of a material to resist impact. Movement of vehicles on roads causes this impact, which leads to breaking down of aggregates. Therefore, the aggregates used in road construction should be tough enough to resist breaking due to sudden impact. Aggregate Impact Value is a measure of this property.

Equipment and Apparatus:

The apparatus as per **IS 2386 (Part IV) – 1963** consists of:

- A testing machine (**45 to 60 kg)** with a metal base.
- A cylindrical steel cup of internal diameter 102 mm, 6.3 mm thick (minimum) and depth 50mm.
- A metal hammer =**13.5** to **14.0 kg** and the lower end being cylindrical 100 mm in diameter and 50mm in length. The hammer should fall freely through a distance between 380±5 mm.
- A cylindrical metal measure 75 mm diameter (internal) and depth 50 mm for measuring aggregates.
- Tamping rod 10 mm diameter and 230 mm long, rounded at one end.

Procedure:

The aggregates passing 12.5 mm sieve and retained on 10 mm sieve are weighed(W1) and put in the mould of 10.2 mm diameter and 5 mm depth in three layers tamped 25 times each. The hammer is made to free fall onto the aggregates 15 times. The aggregates after the test are allowed to pass through 2.36 mm sieve and the fraction passing(W2) is noted.

$$Aggregate\ Impact\ Value = \frac{W2}{W1} * 100$$

Fig. 8-Impact Value Test Apparatus

Result:

- Aggregate Impact Value(Previous Value)-20.25%
- Aggregate Impact Value(New Value)-22.25%

4.2.2 Aggregate Crushing Test

Theory:

“The aggregate crushing value gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load.”

Fig. 9-Crushing Value Test Apparatus

Procedure:

- Cylinder in the place has been positioned and is weighed.
- Sample has been prepared in 3 layers ,and each layer has been provided with 25 blows using the tamping rod , and has been weighed (W1).
- Surface of aggregate has been leveled and the plunger has been insert so that it rests horizontally on the surface,
- The cylinder with plunger on the loading platform of the compression testing machine has been placed.
- load has been applied at a uniform rate so that a total load of 40T is applied in 10 minutes.
- The load has been released and material has been removed from the cylinder.

- The material has been sieved with 2.36mm IS sieve.
- The fraction that has been passed through the IS sieve is noted(W2).
- $Aggregate\ Crushing\ Value = \frac{W2}{W1} * 100$

Result:

- Aggregate Crushing Value(Previous Value)-28.8%
- Aggregate Crushing Value(New Value)-24.8%

4.2.3 Los Angeles Abrasion Test

Theory:

Due to continuous movement of traffic the wearing of aggregates occur present on surface course. Abrasion of road aggregates is caused by the soil particles present between the pneumatic tires and road surface and also by steel reamed wheels of animal driven vehicles. Therefore, to prevent abrasion road aggregates should be hard enough. Los Angeles test machine is used to measure the resistance to abrasion of aggregates. Los Angeles abrasion testis based on a principle which says that “action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates”.

Los Angeles Abrasion Value = Percentage wear of the aggregates due to rubbing with steel balls.

Fig. 10-Los Angeles Abrasion Value Test Apparatus

Procedure:

Table 1: Grading of Test Samples

Sieve size (square hole)	Weight of test sample in gm							
Passing (mm)	Retained on (mm)	A	B	C	D	E	F	G
80	63					2500*		
63	50					2500*		
50	40					5000*	5000*	
40	25	1250					5000*	5000*
25	20	1250						5000*
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

Table 1-Table for Grading of Test Sample

Our test aggregate corresponds to the **Grade C**.

Table 2: Selection of Abrasive Charge

Grading	No of Steel balls	Weight of charge in gm
A	12	5000 ± 25
B	11	4584 ±25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

Table 2-Table for Selection of Abrasive Charge

Corresponding to the Grade the abrasive charge used is as follows:

Aggregates use for test sample are oven dried at 105° – 110°C. The sample should be according to any of the grading shown in table 1.

- The grading to be used in the test is selected according to grading that has to be used in construction, to the maximum extent possible.
- For grading A, B, C & D take 5 kg sample and E, F & G take 10 kg. (W1)
- The selection of abrasive charge depends on grading of aggregates and is taken from table 2.
- The above selected sample and abrasive charge are placed in the cylinder.

- 30 – 33 revolutions per minute are provided.(For grading A, B, C & D number of revolution =500 and 1000 for grading E, F & G).
- After completing of required revolutions the machine is stopped and material is dispensed into the tray.
- 1.70 mm IS sieve is used to sieve the entire stone dust.
- The material retained on 1.7mm size is weighed (W2).
- $Los\ Angeles\ Abrasion\ Value = \frac{W2}{W1} * 100$

Result:

The experiment has been performed twice since the aggregates in the lab had been replaced.

- Los Angeles Abrasion Value(Previous Value)-35.2%
- Los Angeles Abrasion Value(New Value)-33.8%

4.2.4 Specific Gravity Value of Aggregates

Theory:

The specific gravity of an aggregate is a parameter to define the strength or quality of the material. Low specific gravity represents weaker aggregates than those with higher specific gravity values.

Fig. 11-Specific Gravity Frame and Basket

Procedure:

- Wash, drain and place about 2 kg of aggregate sample in wire basket .and immersed in water such that the top of basket should be at least 5cm below the water level.
- The entrapped air is removed immediately after immersing the sample and lifting the basket 25 mm above the base of the tank and dropping at the rate of about one drop per second.
- For about 24 hour basket with aggregates are completely immersed in water.
- The buoyant weight of sample with basket is taken while suspended in water (temperature 22° – 32°C.) = W1g
- After the removal of aggregates from water and allowed to drain for a few minutes, after which they are towel dried. Weight of empty basket is taken in water after jolting it 25 times (W2g).

- The aggregates are surface dried by transferring them to the second dry cloth spread in single layer and is dried for at least 10 minutes. Weight of surface dried aggregates is taken (W3g).
- Firstly the aggregate are oven dried at temperature 110° C for 24 hrs after removing from oven they are placed in an airtight container and weighted=W4 g.

Specific gravity= (Dry weight of the aggregate /Weight of equal volume of water)

Apparent specific gravity = (Dry weight of the aggregate/Weight of equal volume of water excluding air voids in aggregate)

Result:

Old Results

- Specific gravity =2.66
- Apparent specific gravity = 2.80

New Results

- Specific gravity = 2.76
- Apparent specific gravity = 2.88

4.3 Bitumen

4.3.1 Ductility Test of Bitumen

Theory:

The ability of a material to elongate (undergo significant plastic deformation) without cracking is defined as ductility. It is a very important property as far as bitumen is concerned because it is the main binding material in bituminous concrete mixes. In the construction of flexible pavements, bitumen has to form a ductile film around the aggregates to improve physical interlocking of the aggregates. If bitumen has insufficient ductility, it will crack due to traffic load and lead to formation of pervious pavement surface.

Ductility of bitumen is measured by placing it in a standard briquette and pulling it at a specific speed and at specific temperature and noting the distance in centimetres up to which the bitumen elongates before breaking.

Fig. 12 -Ductility Value Test Apparatus

Fig. 13-Bitumen Sample (After the Test)

Procedure:

- Bitumen is heated to a temperature of 100°C. At this temperature, bitumen attains a certain fluidity needed to put it in the standard briquette.
- Bitumen is then poured into the standard briquette. To prevent bitumen from sticking the surface of the mould plate and interior of the briquette mould are coated with equal parts of glycerin and dextrin.
- This mould with the sample is kept aside for 30-40 minutes and then put into the water bath at a temperature of 27°C for 30 minutes.
- The sample along with the mould is then removed from the water bath and placed onto the ductility value test apparatus.
- Make sure the pointer on the machine is set to zero.
- The machine is then switched on and the clips are pulled apart at 50mm/minute.
- The distance at which the specimen breaks is noted down and is the ductility value.

Result:

Ductility Value of the Bitumen= 85cm.

4.3.2 Specific Gravity Test for Bitumen

Theory:

$$SG = \rho / \rho H_2O$$

SG = specific gravity
ρ = density of fluid or substance (kg/m^3)
ρH_2O = density of water (kg/m^3)

Fig. 14- Specific Gravity Relation

The above image shows the relation for specific gravity. All the values are at a standard temperature of 27°C and it is calculated with the help of a density bottle shown below.

Fig. 15-Density Bottle

Procedure:

- A clean and dry specific gravity bottle is procured and weighed. (A)
- The density bottle is then filled with water and weight of the bottle is taken. (B)
- Bitumen is then heated to attain a certain degree of fluidity and then poured into the bottle to its half. (C)
- The density bottle is then allowed to cool for half an hour and then weight is taken again.
- Then again water is added into the density bottle already containing bitumen and weight is taken. (D)
- From the calculated weights, the specific gravity can be computed with the following formula.

  Specific Gravity= C-A/[(B-A)-(D-C)]

Result:

The Specific Gravity of the Bitumen is = 1

4.3.3 Penetration Test of Bitumen

Theory:

Penetration value is calculated to give an idea about the hardness or the consistency of the bitumen. It is calculated using a penetration value testing machine and is the vertical distance penetrated by a standard needle into the bitumen. The final value is however calculated in one tenths of a millimetre.

A higher penetration value of bitumen corresponds to a bitumen that during its service life is more prone to bleeding and a lower value corresponds to harder bitumen with is less ductile and cracks leading to pervious pavement surface.

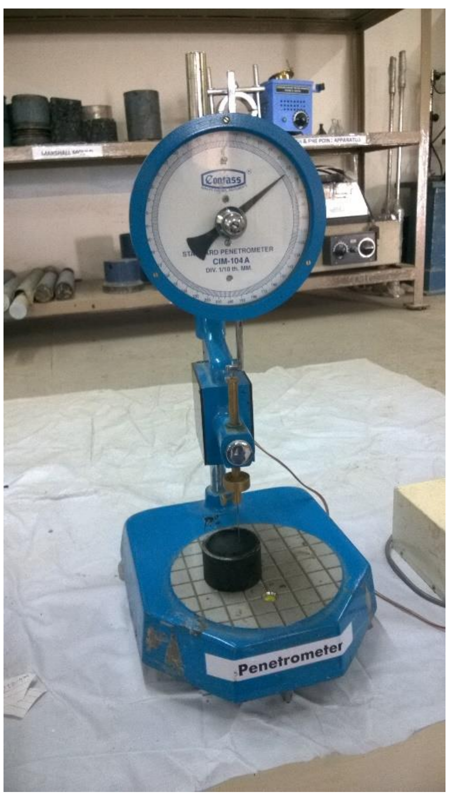


Fig. 16

Penetration Test Apparatus

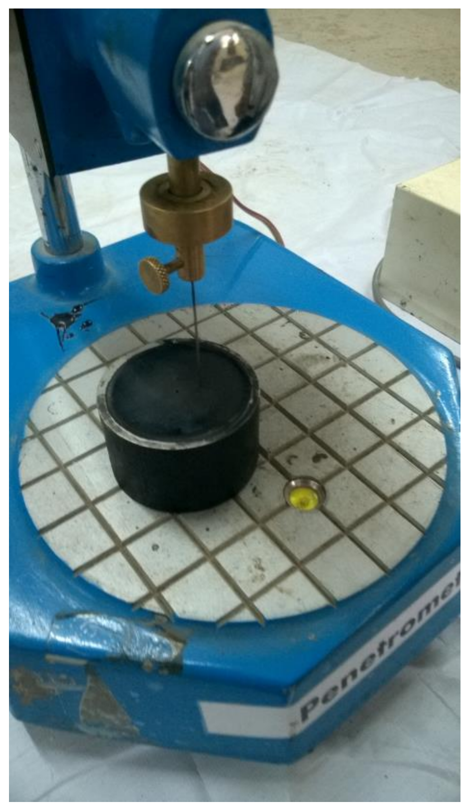


Fig. 17

Needle Penetrating the Sample

Procedure:

- Bitumen is heated to a temperature above its softening point and made to achieve pouring consistency. While being heated the bitumen is also stirred continuously to avoid the formation of any air bubbles.
- The bitumen is then poured into the standard penetration testing mould at least 10mm more than what the expected penetration is.
- The mould is then allowed to cool at room temperature for about 60 minutes.
- The mould is then placed in the water bath at a temperature of 27°C and make sure that water is above the level of the mould so as to completely cover it.
- The sample is then placed on the stand of the penetration testing apparatus.
- The needle of the machine is cleaned with benzene. The load applied is 100 grams, which includes the weight of the needle as well as the super imposed weight.
- The needle is adjusted so as to just touch the surface of the sample.
- The pointer of the apparatus is adjusted to read zero.
- The needle is then released for 5 seconds and the penetration value is noted.
- Three readings are taken at three locations not more than 10mm apart on the surface and the needle is cleaned both before and after each test is conducted.

Result:

The penetration value of the bitumen is 66mm ($1/10^{th}$ mm).

4.3.4 Softening Point of Bitumen

Theory:

The temperature at which bitumen attains a specific degree of softening is termed as the softening point of bitumen. It is defined in **IS: 334-1982** as the temperature at which a standard ball passes through the bitumen and falls through a height of 25mm, when heated under water at standard conditions. This test is done to ensure that the binder has a certain degree of fluidity to be used in flexible pavement construction. Also it is important to know to temperature to which the bitumen has to be heated on site to attain that fluidity.

In laboratory testing the softening point is determined by ring and ball apparatus shown below.

Fig. 18-Ring and Ball Apparatus

Procedure:

- Bitumen is heated to a temperature of 100°C and stirred continuously to avoid formation of air bubbles.
- The rings from the assembly are pre heated to 100°C and placed on a plate coated with equal parts glycerine and dextrin.
- The apparatus is then setup as is shown in a figure above.
- Water is filled in the beaker up to a height of 50mm above the rings.
- The test begins at a temperature of 5°C and rises uniformly at a rate of 5°C/minute.
- The temperature rises and gradually the steel balls begin sinking through the softening bitumen.
- The temperature at which the steel balls along with the bituminous coating touch the bottom plate is noted.
- If both the balls touch the bottom plate at different temperatures an average value of the two readings is taken.
- The value so calculated is the softening point of the bitumen.

Result:

The Softening Point of the Bitumen is 52ºC.

4.4 Tests without Nano Chemical

4.4.1 Marshall Stability Test

Theory:

Marshall Stability Value is defined as the resistance of a standard cylindrical bituminous concrete mix specimen to plastic deformation. It can also be defined as the load which the mix car carry at a temperature of 60°C and is measured in either kN or kg.

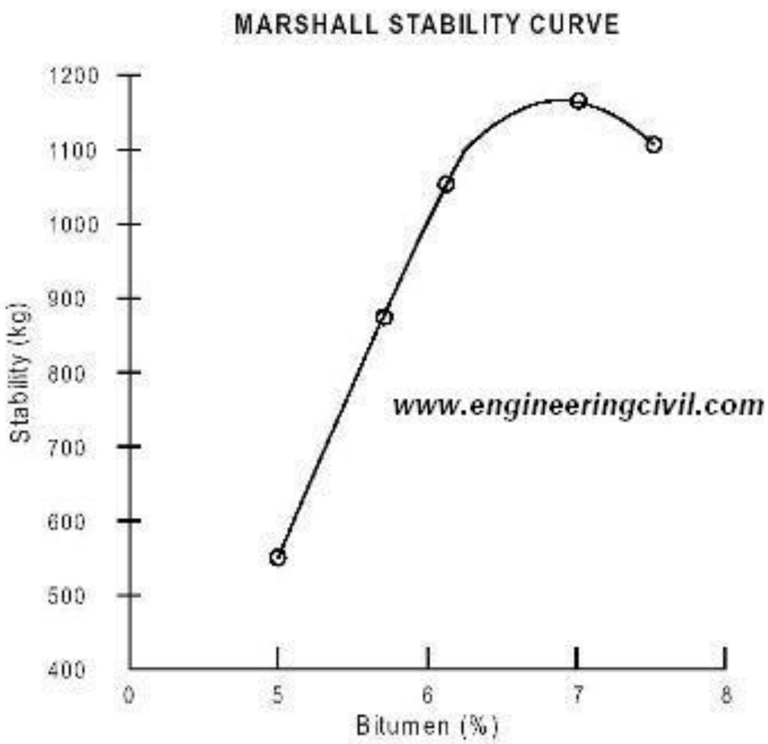


Fig. 19-Marshall Stability Value Graph

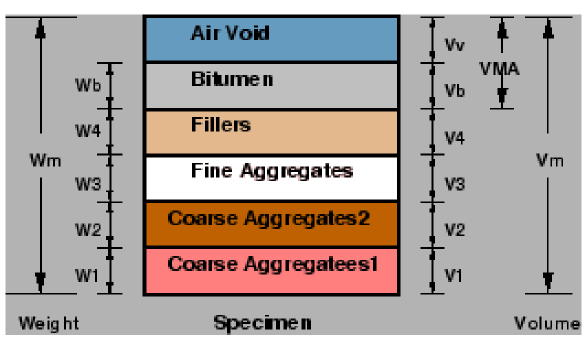


Fig. 20-Visual Representation of Marshall Stability Test Sample

Apparatus:

Fig. 21-Marshall Stability Test Apparatus

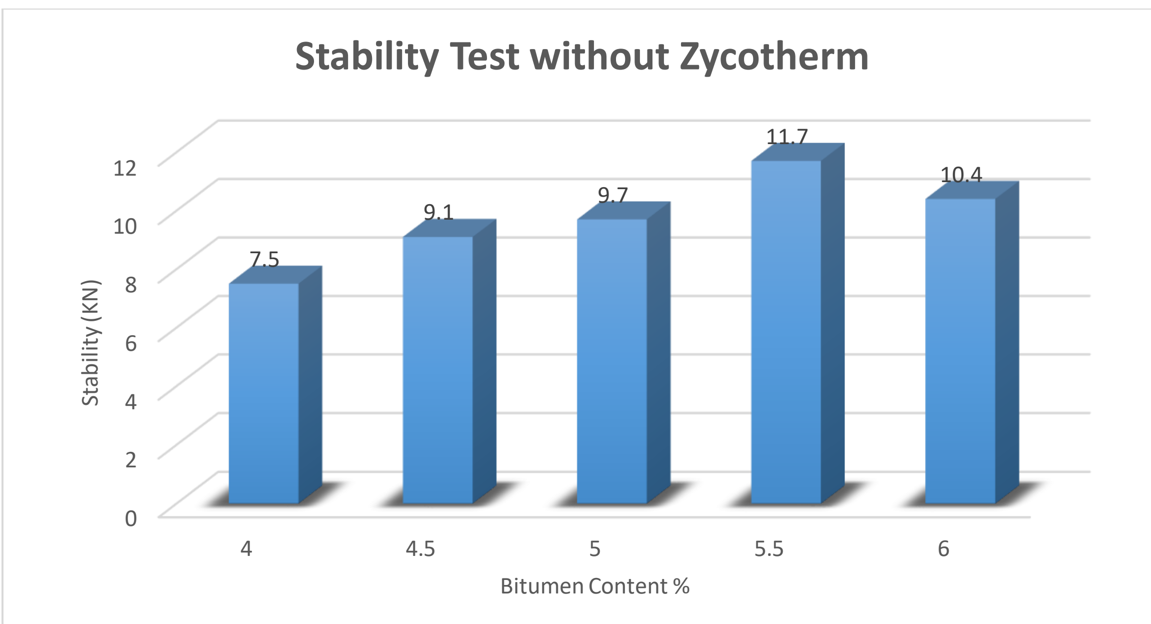
Procedure:

- Aggregates of specific properties are selected based on the selected grading and are weighed to form a mix of about 1200 grams.
- The aggregates are then heated in an oven for 24 hours at 100°C and 150°C for 30 minutes before the test is conducted.
- The bitumen is also heated to a temperature of 140°C.
- The heated aggregates and bitumen are then mixed in a container thoroughly with a trowel so as to ensure complete coating of the bitumen onto the aggregates.
- The mix so formed is then put into the mould and tamped with a standard hammer (4.86 kg) falling from a standard height (45 cm) 65 times on both sides.
- The mould is then allowed to cool at room temperature for 24 hours.
- Similar specimens are made with varying bitumen contents.

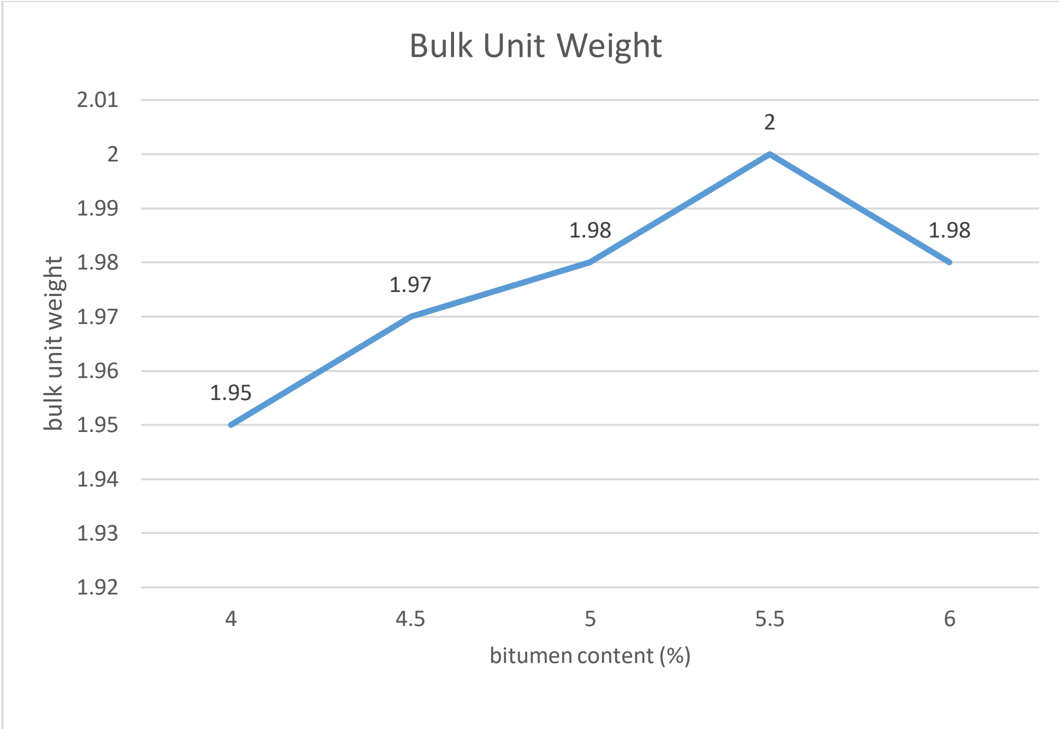
- The specimen is then removed from the mould and put in a water bath maintained at a temperature of 60°C for 30 minutes.
- The stability value of the mix is then calculated with the help of the Marshall Stability Apparatus.

Test Property	Specified Value
Marshall stability, kg	340 (minimum)
Flow value, 0.25 mm units	8 - 17
Percent air voids in the mix V_v%	3 - 5
Voids filled with bitumen VFB%	75 - 85

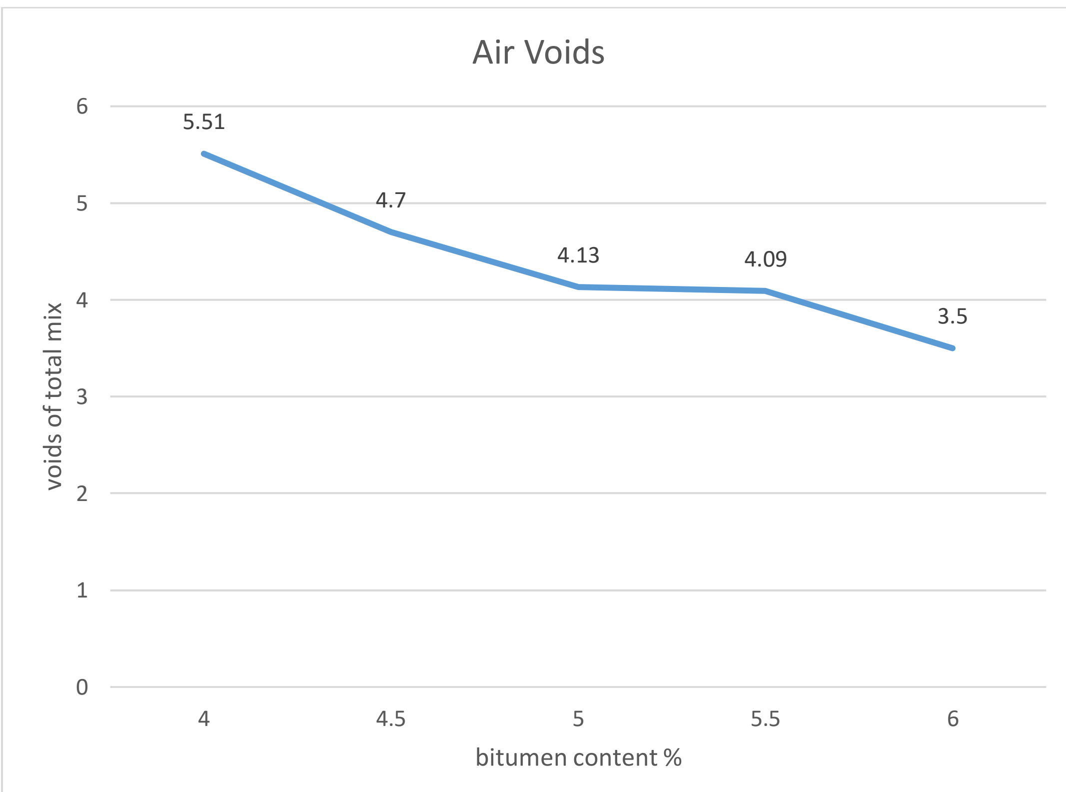
Result:



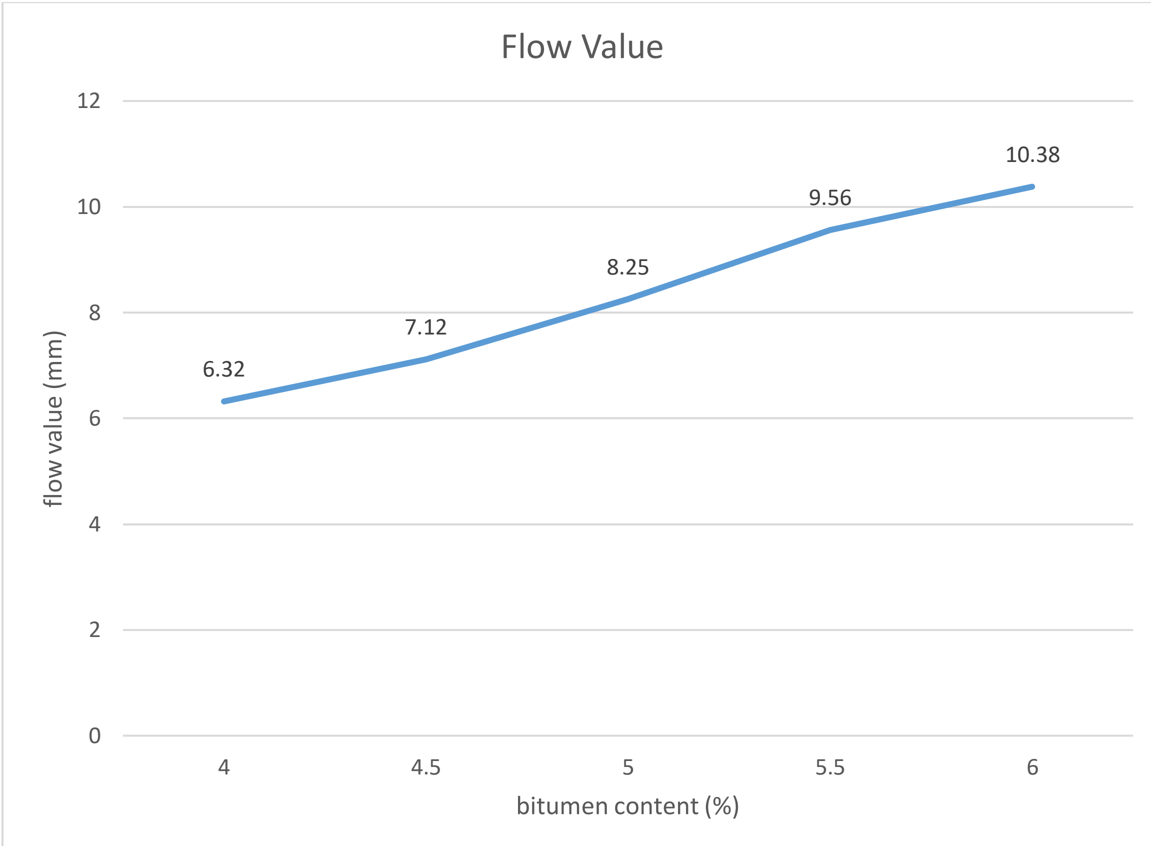
Graph 1-Stability Test without Zycotherm



Graph 2- Bulk Unit Weight



Graph 3- Air Voids



Graph 4- Flow Value

Taking into consideration the result from all of the above graphs the Optimum Bitumen Content was equal to **5.5%**.

4.4.2 Stripping Test of Aggregates

Theory:

The fundamental use of bitumen is as a binding agent and therefore it has to adhere to the surface of the aggregates. Bitumen does adhere to the surface of the aggregates well provided they are not wet and also not very dusty. Stripping of bitumen is a problem in places that are susceptible to damp conditions (high rainfall or coastal areas).

Therefore it becomes important to test the stripping value of the bituminous concrete mix beforehand to avoid premature failure of the pavement.

Fig. 22-Image Showing Stripping of Bitumen from Aggregates

Procedure:

- Aggregates passing 20 mm IS sieve and retained on 12.5 mm IS sieve weighing a total of 200 grams are used.
- These aggregates are heated in the oven to a temperature of 100°C for 24 hours and 150°C for 30 minutes before the test.

- Bitumen which is 5% by weight of aggregates is heated up to 140°C.
- The heated aggregates and bitumen are then mixed and transferred to a beaker and allowed to cool for 2 hours at room temperature.
- This beaker is then filled with distilled water to immerse the coated aggregates.
- This beaker is then covered and is kept in a water bath maintained at a temperature of 40°C for 24 hours.
- The stripping is then estimated visually as a percentage of the original value while the specimen is still under water.

Result:

By visual estimation, stripping value of road aggregates is = 30%.

Fig. 23- Aggregates coated with bitumen after the test

The Indian Road Congress permits a maximum value of 25% for stripping value.

4.5 TESTS WITH ZYCOTHERM

4.5.1 Marshall Stability Test

Sample Preparation:

The sample constituents are the same with the exception of the addition of the Nano chemical (Zycotherm) in the bitumen.

Fig. 24- Zycotherm

Procedure:

1. Since Zycotherm is a hot mix additive, the bitumen is heated before its addition. Therefore, the bitumen is transferred to a heating container and heated to a temperature of about 140°C.

Fig.25-Hot Mixing

2. When the desired fluidity is achieved Zycotherm is added drop wise with the help of a syringe in the desired quantity. In our current experiment three dosages corresponding 0.1%,0.2% and 0.3% by weight of bitumen added which corresponds to 5.5% by the weight of the aggregates used.

Fig. 26- Addition of Zycotherm

3. Next the heated aggregates are transferred into a mixing container. The aggregates are heated at a temperature of 100°C for 24 hours and 150°C for 1 hour before the experiment.

Fig. 27 - Heated Aggregates

4. Then bitumen modified with Zycotherm is added to the heated aggregates. The quantity of bitumen is 5.5% by weight of aggregates, which corresponds to 63 grams in the current study.

Fig. 28- Addition of Modified Bitumen

5. Then the aggregates and the bitumen is mixed thoroughly until all of the aggregates are covered with the bitumen.

Fig.29- Mixing of Modified Bituminous Concrete

*The mixing itself showed increased workability of the mix as compared to the sample without the addition of Zycotherm.

6. The bituminous concrete mix is transferred to the mould and is tamped 65 times on each side with a standard hammer (45cm, 4.86kg). The sample is then allowed to cool.

Fig. 30- Tamping of Sample

7. Similar procedure is followed for casting the remaining samples with varying concentrations of Zycotherm.

Fig. 31- Bituminous concrete mix samples

8. After 24 hours of cooling the samples are put in a water bath maintained at a temperature of about 60°C for about 30 minutes.

Fig. 32- Water Bath

Fig. 33- Samples in a Water Bath

9. The samples are then one by one loaded onto the Marshall Stability Testing machine and the results are obtained.

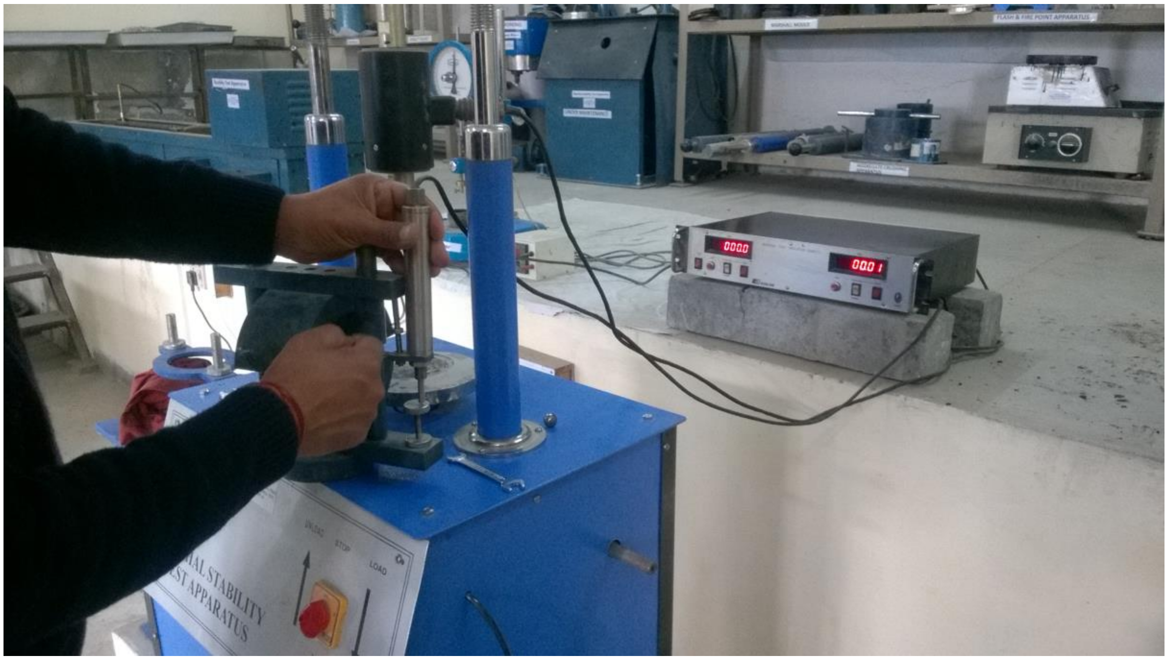
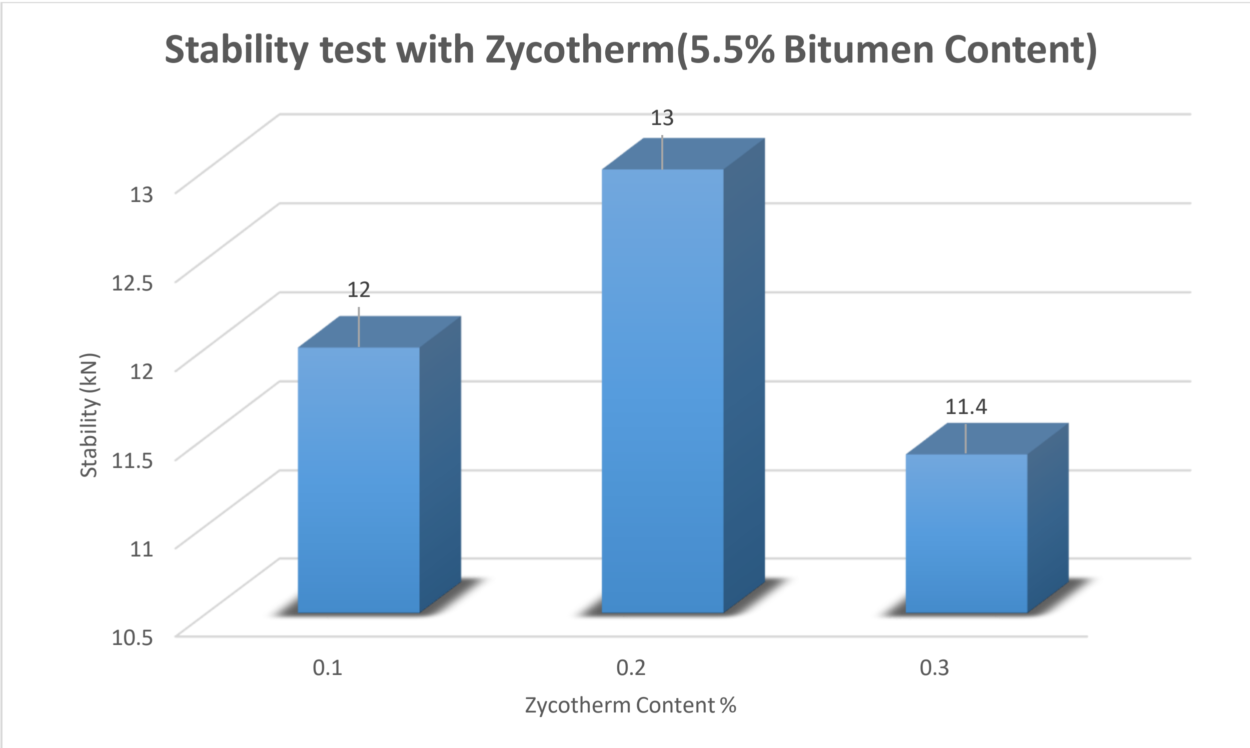


Fig. 34- Marshall Stability Testing

Fig. 35- Sample after Testing (Bulging Failure)

Result of Marshall Stability Test:



Graph 5- Stability Test with Zycotherm

Optimum Zycotherm content= 0.2% by weight of bitumen.

4.5.2 Stripping Test

Procedure:

- Aggregates passing 20 mm IS sieve and retained on 12.5 mm IS sieve weighing a total of 200 grams are used.
- These aggregates are heated in the oven to a temperature of 100°C for 24 hours and 150°C for 30 minutes before the test.
- Bitumen which is 5% by weight of aggregates is heated up to 140°C.
- The heated aggregates and bitumen are then mixed and transferred to a beaker and allowed to cool for 2 hours at room temperature.
- This beaker is then filled with distilled water to immerse the coated aggregates.
- This beaker is then covered and is kept in a water bath maintained at a temperature of 40°C for 24 hours.
- The stripping is then estimated visually as a percentage of the original value while the specimen is still under water.

Result:

The stripping value by visual estimation was= 10%.

Fig. 36- Aggregates coated with bitumen modified with Zycotherm after test

4.6 TESTS WITH NANO CLAY

4.6.1 Marshall Stability Test

The sample constituents are the same with the exception of the addition of the Nano chemical (Nano Clay) in the bitumen.

Fig. 37- Nano Clay

Procedure:

1. Similar to the Zycotherm sample, bitumen is first heated to a temperature of 140°C and stirred regularly.

2. Then the Nano Clay in the required proportion is added to the heated bitumen and stirred continuously.

3. Heated aggregates from the oven are added to a mixing container and the modified bitumen is added to the mix.

4. The aggregates and bitumen are mixed thoroughly with the help of a trowel to ensure complete coating of the aggregates.

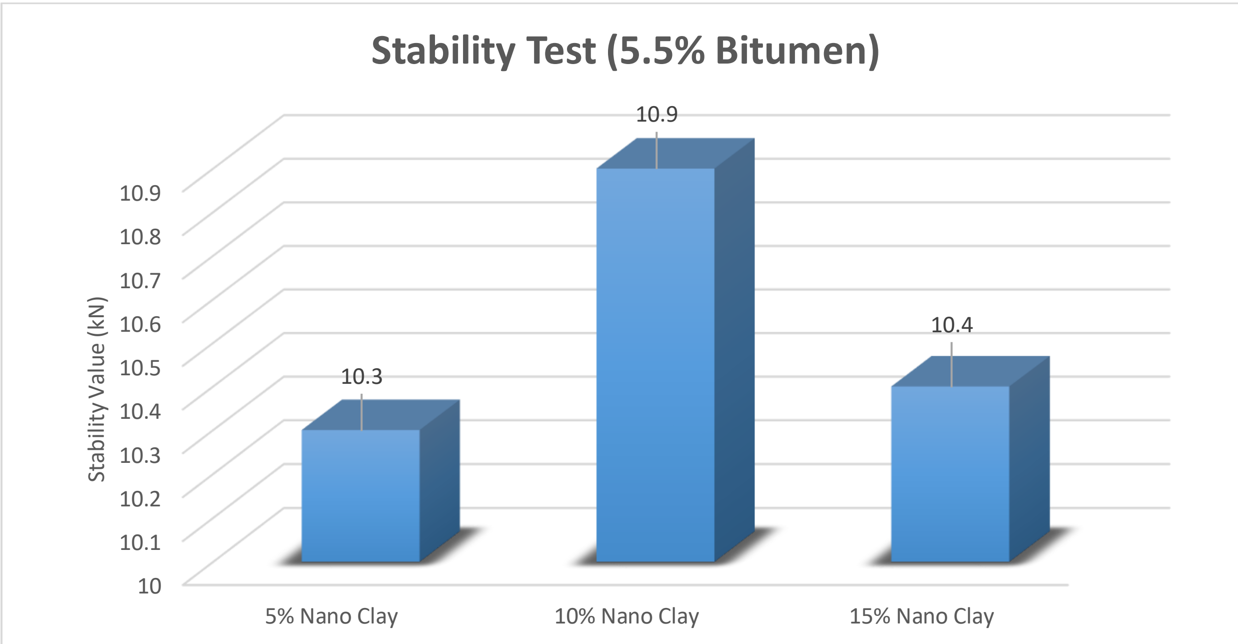
5. The bituminous concrete mix is transferred to the mould and tamped from both sides 65 times with the standard (4.86 Kg) hammer.

6. Similar procedure is followed for other quantities of Nano Clay.

7. After 24 hours of cooling the samples are put in a water bath maintained at a temperature of about 60°C for about 30 minutes.

8. The samples are then one by one loaded onto the Marshall Stability Testing machine and the results are obtained.

Result of Marshall Stability Test:



Graph 6- Stability Test with Nano Clay

Optimum Nano Clay content= 10% by weight of bitumen.

4.6.2 Stripping Test

Procedure:

- Aggregates passing 20 mm IS sieve and retained on 12.5 mm IS sieve weighing a total of 200 grams are used.
- These aggregates are heated in the oven to a temperature of 100°C for 24 hours and 150°C for 30 minutes before the test.
- Bitumen which is 5% by weight of aggregates is heated up to 140°C.
- The heated aggregates and bitumen are then mixed and transferred to a beaker and allowed to cool for 2 hours at room temperature.
- This beaker is then filled with distilled water to immerse the coated aggregates.
- This beaker is then covered and is kept in a water bath maintained at a temperature of 40°C for 24 hours.
- The stripping is then estimated visually as a percentage of the original value while the specimen is still under water.

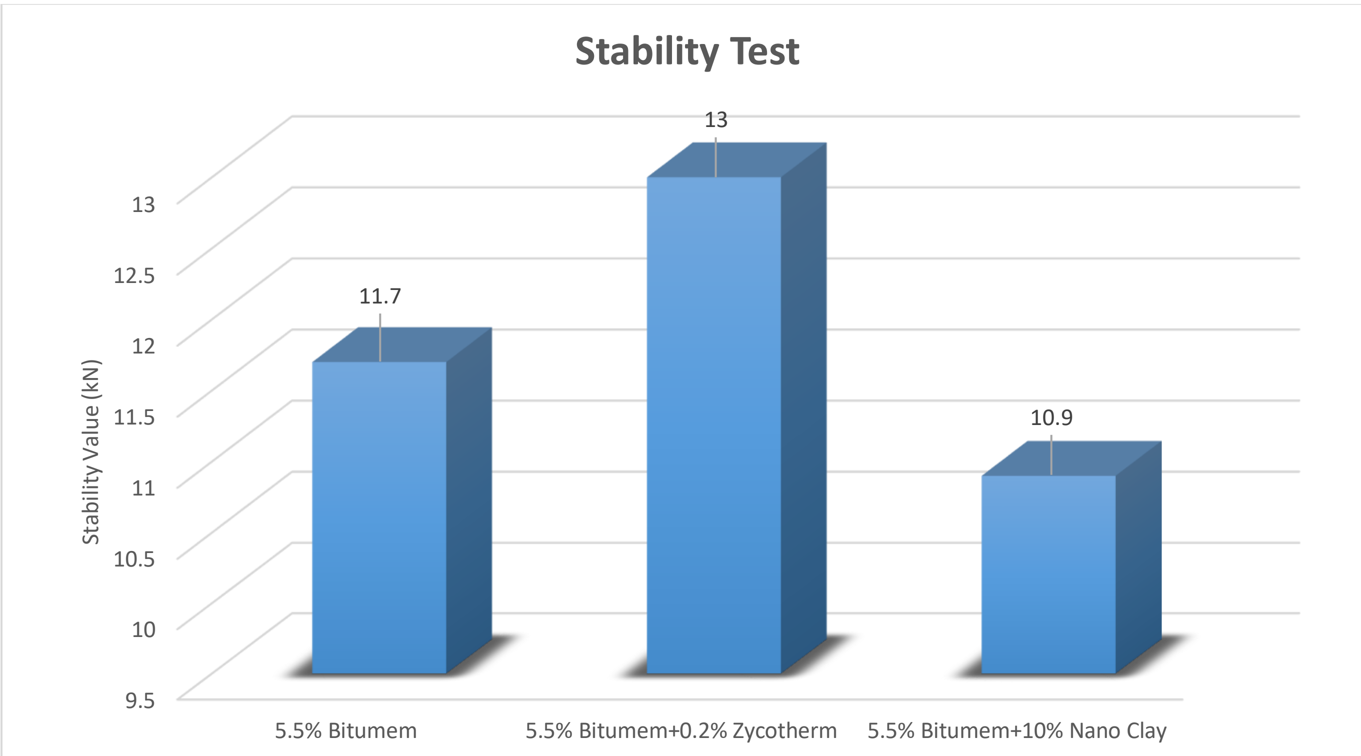
Result:

The stripping value by visual estimation is less than 2%.

Chapter 5

Comparison of Results and Discussion

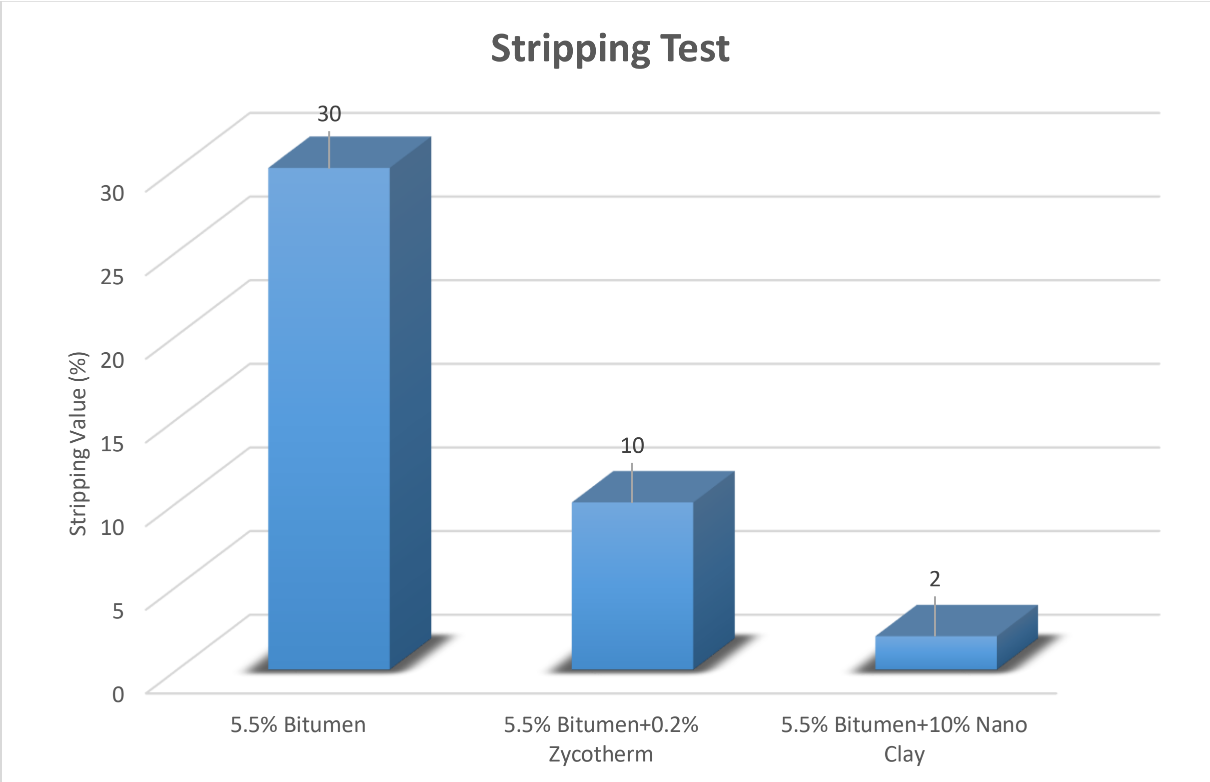
5.1 Marshall Stability Value



Graph 7- Comparison of Marshall Stability Value

The above graph clearly shows increased strength when 0.2% Zycotherm is used with a Bitumen content of 5.5%. The stability value at optimum Nano Clay is lower than when either normal bitumen or Zycotherm is used but it makes up for this loss in strength due to its use as an anti-stripping agent shown in the following graph.

5.2 Stripping Value



Graph 8- Comparison of Stripping Value

The graph clearly shows the immense reduction in stripping value when Nano Clay is used in optimum content along with optimum bitumen content,

Theoretically virtually stripping proof bituminous concrete mix can be produced if optimum content of both the admixtures is used (0.2% Zycotherm+10% Nano Clay).

Chapter 6

Conclusion

The research clearly shows the scope of using Nano Chemicals in the field of pavement construction. The two chemicals that we have used which are Zycotherm and Nano Clay both have their own set of advantages and disadvantages but the advantages in the long term clearly outweigh the disadvantages and cost associated with them.

The benefits of Zycotherm include:

1. Improved Marshall Stability Value:

The Marshall Stability Value at 5.5% bitumen content was **11.7 kN** whereas when Zycotherm at 0.2% (by weight of bitumen) was used which was calculated as the optimum dosage for the nanochemical the Marshall Stability Value was considerably higher at **13 kN**.

2. Improved Workability:

At optimum dosage 0.2%(by weight of bitumen) the workability of the mix was greatly improved. The mixing force required for the manual mixing of the bituminous concrete was enough to support the claim.

3. Improved Compaction:

The height of the two Marshall Stability samples in the two cases with and without Zycotherm were different. The sample with Zycotherm showed improved compaction and therefore was lesser in height when compared to sample without Zycotherm.

Sample Height (Without Zycotherm)= **64 mm**.

Sample Height (With Zycotherm)= **59 mm**.

4. Lesser white fumes while heating bitumen:

When bitumen is heated white fumes are a big problem and the thought put into preventing them is negligible. When Zycotherm was added to the bitumen there was a significant reduction in the white fumes. This leads to improved working conditions on site and also fewer health risks to the workers. This leads to indirect cost savings to the construction contractor.

5. Reduced Stripping Value:

Though Zycotherm is not advertised as an anti-strip its use still improved the stripping resistance of the bituminous concrete mix.

Stripping Value without Zycotherm= **30%**.

Stripping Value with Zycotherm= **10%**.

6. Cost-Benefit Analysis of using Zycotherm:

- The cost of Zycotherm is ₹500/kg.
- The optimum dosage is a meagre 0.2% of the weight of bitumen.
- A ton of bitumen would therefore require just 20 kg of Zycotherm.
- Approximately 250 tons of bitumen is required for the construction of 1 km of one lane flexible pavement (3.75m width).
- Zycotherm Required= 500 kg.
- Average cost of constructing 1 km two lane road in India without land acquisition requirement = 2.5 – 3.0 Crore.
- Cost of Zycotherm= ₹250000 (**0.83%** of total cost/km).

It is therefore evident that not using additives like Zycotherm would be a classic case of "Penny Wise, Pound Foolish" which suggests that money can be saved initially by not using Zycotherm but over time Zycotherm will outweigh the cost and also provide longer service life to the flexible pavement. Such pavements will require lower service and lead to further cost savings both direct and indirect.

Benefits of Using Nano Clay:

In our current study **Montmorillonite Nano Clay** was used. In the current state of affairs Nano Clay is not a cheap and is limited in production in India. Therefore there is heavy cost implication of using it. However it too has benefits especially when considering the stripping resistance of flexible pavement.

1. Highly improved Stripping Resistance:

Stripping Value without Nano Chemicals= **30%**.

Stripping Value with Zycotherm= **10%**.

Stripping Value with Nano Clay= **2%**.

The stripping value when Nano Clay was used was almost negligible.

2. Improved Structure:

Nano Clay within the bitumen leads to improved structure and reduction in air voids. This makes the resulting mix less susceptible to moisture damage. This is also the reason for the improved stripping resistance.

Hence it is evident that Nano Chemicals are a Pandora's Box of pavement technology filled with benefits. Adequate research still needs to be carried out as well as implemented if the sector has to progress. Just like the Nano Chemicals we used there are numerous others available commercially which have not been tested in the flexible pavements and can have other advantages.

The benefits of Zycotherm and Nano Clay mentioned above are a testament to this statement.

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