# Use of Nanotechnology in Bituminous Concrete Pavement

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***Abstract-****A natural earth track under modern traffic load lacks strength and good riding surface. Therefore it is essential to construct a pavement on the top of the natural earth track to provide a support on wheel load safely and good riding surface for extended period. After the road constructed and opened for traffic its pavements are continuously subjected to wear and tear. Due to poor drainage conditions in rainy season, water penetrates into the pavements from sides as well as from top surface in bituminous road. In summer season, the bituminous roads are supposed to get damage due to bleeding at high temperature. To obtain the design strength and durability the bitumen is treated with a zycotherm as an additive. In the present paper, different types of experimental tests are conducted and particular changes in the properties of bitumen are studied by addition of zycotherm in bitumen. Penetration, elastic recovery, softening point, specific gravity and Marshall Mix Design tests were conducted on the bitumen mixed with zycotherm at different percentage such as 0.1, 0.2, 0.3 and 0.4%.*

***Keywords***-Bleeding, Durability, Marshall Mix Design, Strength, Zycotherm

## I. INTRODUCTION

India has 1, 00,087 km (62,191 mi) of national highways (NH) connecting all the major cities and state capitals as of June 2016. National highways comprise 1.7% of India's total road network, but carry about 40% of road traffic.The stability of pavements can only be maintained if their surface and foundation bed remain in dry condition. There are two types of pavements viz. flexible and rigid pavements. Rapid population growth in India has led to the increase in demand of commercial vehicles inducing more stresses on road. Thus it creates a need of innovative material to resist the stresses without any compromise with quality and performance.

Asphalt pavements are mostly damaged due to lack of moisture resistance. Water that infiltrate into pavement can cause damage to the hot mix asphalt layers which ultimately results into loss of adhesion bond between asphalt binder and aggregate or the loss of cohesion in the asphalt binder. The stripping of aggregate from asphalt film results into failure of asphalt pavement.

Recent innovation in science and technology has incorporated the use of nanotechnology to produce ecofriendly organo silicon product at very low cost. This nanotechnology material can provide a better resistance at extreme environmental conditions on a moisture weakened pavement. Zycotherm is a new nanotechnology material to overcome these issues at an economic cost. The effect of zycotherm recognizes the engineering properties of material and study the result of zycotherm on PMB-40 bituminous concrete mixes with and without it as per the standards specified in MoRTH.

## II. LITERATURE

### 2.1 Ilham Ibrahim, Hatice Nur Aras Mehan (2015):

This study was conducted to determine the optimum amount and potential applicability of zycotherm nanomaterial in asphalt and asphalt concrete mixtures with two different systems: directly applying to bitumen and diluting and applying to aggregate in order to address the solution of potential failure problems in flexible pavements. The study is carried out experimentally by conducting tests on bitumen and bituminous mixtures.. Penetration, softening point, RTFOT, PAV, BBR and DSR tests were also performed on bitumen to determine the effect of zycotherm on bitumen's contribution on rutting, fatigue and low temperature cracking of the mixture. It is found that using zycotherm material greatly increases the resistance of asphalt mixture to moisture induced damages and also increases its resistance to rutting, fatigue and low temperature cracking.

### 2.2Tirthankar Dam,Bala Raju Teppala, Prof. C.B. Mishra (2014):

The present paper enlightens the procedure to find out optimum bitumen content by Marshall Mix design method for BC mix which attains maximum stability by using innovative nanotech chemical material. To 5.4 % optimum bitumen content for BC mix obtained in the laboratory investigations, required dosages of Zycosoil chemical in

0.02%, 0.03% and 0.04% is added and changes in properties are recorded showing improved good results for the mix to be suggested for flexible pavement construction.

**2.3Fakhri Mansour, Vanaei Vahid (2014):**

The main objective of this study was to investigate and compare classical and rheological behavior of the base bitumen having penetration grade 85/100 and the same bitumen modified with 0.1, 0.3 and 0.5% of Zycosoil Nano materials by bitumen weight. Another objective was to compare the moisture behavior of asphalt mixtures with and without Zycosoil and mixtures containing hydrated lime. Then rheological properties of bitumen, including viscosity, failure temperature and rutting potential, as well as bitumen classical properties, by rotational viscometer test, Dynamic Shear Rheometer test and multiple stress creep and recovery test were evaluated.

**2.4 A. Khodaii; V. Khalifeh; M. H. Dehnad; and Gh. H. Hamedi (2014):**

In this study, the effects of using Zycosoil as an antistripping additive on moisture susceptibility of asphalt mixtures has been evaluated by determining the mechanism that affects the adhesive bond between the aggregate and asphalt binder using the surface free energy (SFE) method and laboratory dynamic modulus test. The percentage of the aggregate surface exposed to water (P index) has also been calculated by using the measured SFE and dynamic modulus results, and evaluated as an index for the moisture susceptibility of mixtures. The results of the SFE method show that Zycosoil decrease the difference between the free energy of the adhesion of aggregate asphalt binder in dry and wet conditions, and this difference is equal to the amount of energy released when stripping occurs. Coating of the aggregate surface with Zycosoil decreases this difference, and subsequently causes the mixture to be more resistant to moisture damage.

## III. MATERIALS AND METHODS

Crushed stone aggregate plays a major role for constructing a pavement in cement and bituminous concrete pavements. This crushed stone aggregate has to bear the stresses caused by traffic for which the physical properties have to be checked before mix design. The material is obtained from Manchar. The results obtained from laboratory are as follows.

### A. Laboratory Tests:

| Sr. No. | Property | Test | Test Result | MoRTH Specification |
|---|---|---|---|---|
| 1 | Strength | Aggregate Impact Test | 8.53% | 30 |
| 2 | Stripping | Coating and Stripping Bitumen Aggregate Mixture | 97% | Coating should not be less than 95% |
| 3 | Hardness | Los Angeles Abrasion Test | 13.03 % | Max 45% |
| 4 | Water Absorption Value | Water Absorption test | 1.25% | Max 2% |

### B. Properties of Aggregate:

| Sr No | Size of Aggregate | Aggregate Proportion | Bulk Specific Gravity | App. Specific Gravity | Water Absorption |
|---|---|---|---|---|---|
| 1 | 12.5-7mm | 33% | 2.868 | 2.936 | 1.21 |
| 2 | 7-3mm | 10% | 2.849 | 2.927 | 1.25 |
| 3 | 3 mm down | 55% | 2.808 | 2.937 | 1.24 |
| 4 | Filler | 2% | 3.131 | - | - |

The sieve analysis is performed on the aggregate to determine the gradation or distribution of aggregate particles in given sample. The sieve analysis has been done for the aggregate size 19mm, 13.2mm, 9.5mm, 4.75mm and stone dust. A graphical representation of gradation curve showing how evenly the sizes are distributed by MoRTH requirement.

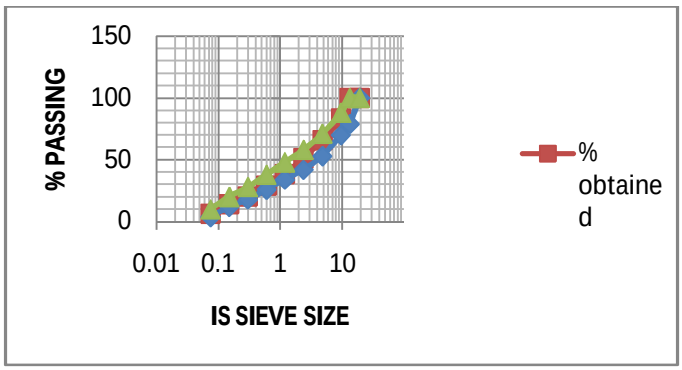


FIG.1. Graph of BC gradation Curve (Grade 2)

## IV. POLYMER MODIFIED BITUMEN (PMB-40)

Polymer Modified Bitumen is a mixture of highly specialized bitumen with optimum quality of polymer (Elastomeric) making the binder homogeneous and storage stable. It enhances the vital properties of asphalt mixes i.e. deformation resistance and fatigue life and provide overall extended life of pavement. This bitumen can further be used in asphalt mix design which provides the good elasticity suitable for all types of traffic.

## V. ZYCOTHERM AS AN ADDITIVE

Zycotherm nanotechnology material enhances coating of asphalt binder on aggregates. Zycotherm reaction causes conversion of water loving silanol groups to water repellent siloxane bond. The Si-O-Si siloxane bond is the strongest bond in the nature. Zycotherm improves coating of asphalt binder and helps to almost eliminate stripping for durable asphalt pavement. Zycotherm is added for modified binders PMB-40 grade mixes at 0.1%, 0.2%, 0.3% and 0.4% by weight of asphalt binder directly and blended to mixing at 1600C.

**Table -1**
**Comparative statement showing PMB-40 grade bitumen with and without Zycotherm**

| Sr. No. | Characteristics of tests | PMB40 (plain) | PMB40+0.1% Zycotherm (Additive) | PMB40+0.2% Zycotherm ( Additive) | PMB40+0.3% Zycotherm (Additive) | PMB40+0.4% Zycotherm (Additive) | Recommendation as per IS 15462- 2004 |
|---|---|---|---|---|---|---|---|
| 1 | Penetration Test at 25$^0$C(1/10mm) | 43.67 | 38.33 | 35.37 | 33.33 | 37 | 30-50 |
| 2 | Softening Point Test by Ring and Ball Apparatus ($^0$C) | 67.2 | 70.1 | 71.8 | 70.6 | 68.5 | 60 |
| 3 | Elastic Recovery Test at 15$^0$C,% | 78.67 | 81.33 | 82.33 | 83 | 79 | 70 |
| 4 | Stripping Test | 97 | 99 | 100 | 100 | 100 | Min 95% |

## VI. MARSHAL STABILITY TEST FOR BC MIX DESIGN GRADE-2

In this test optimum bitumen content for bituminous concrete mixes is to be determined to attain the maximum stability. Initially for BC grade 2 aggregates gradation is performed as per MoRTH specification. This test incorporates with the properties of mix design i.e. stability, flow value, bulk specific gravity, air voids, voids filled with bitumen and voids in mineral aggregate are evaluated. The optimum bitumen content is determined from graph which is average of the entire test. The optimum bitumen content is worked out as 5.65% for BC mix design Grade-2. Table 2 shows Marshall Mix Design for varying bitumen content.

**Table-2**

**Marshall Mix Design for BC Grade- 2**

| Sr. No. | % of Bitumen | Bulk Sp. Gravity | Air Voids in % | VMA in % | VFB in % | Stability (KN ) | Flow in mm |
|---|---|---|---|---|---|---|---|
| 1 | 4.5 | 2.451 | 8.01 | 17.51 | 54.29 | 16.05 | 3.1 |
| 2 | 5.0 | 2.477 | 6.32 | 17.08 | 62.99 | 18.41 | 3.4 |
| 3 | 5.5 | 2.500 | 4.96 | 16.75 | 70.42 | 17.36 | 3.6 |
| 4 | 6.0 | 2.511 | 3.47 | 16.82 | 79.40 | 15.81 | 3.9 |
| 5 | 6.5 | 2.507 | 2.64 | 17.40 | 84.82 | 14.28 | 5.1 |

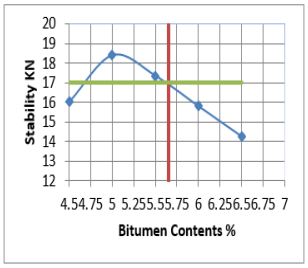


Fig. 2. Bitumen Contents vs Stability

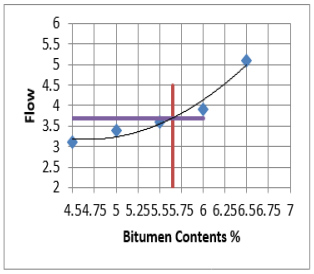


Fig. 3. Bitumen Contents vs Flow

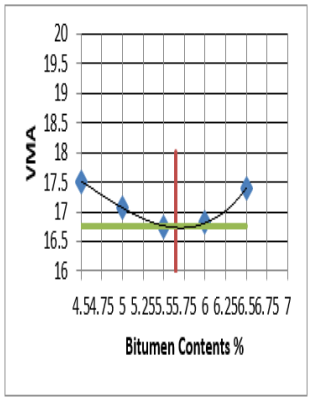


Fig. 4. Bitumen Contents vs Voids in Mineral Aggregate

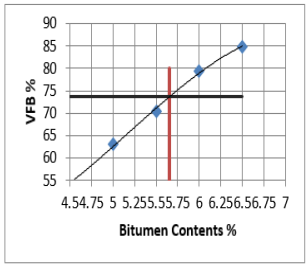


Fig. 5. Bitumen Contents vs Voids filled with Bitumen

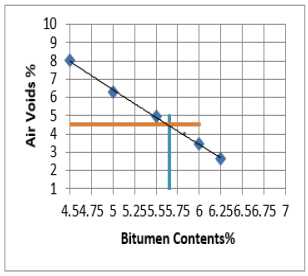


Fig. 6. Bitumen Contents vs Air Voids

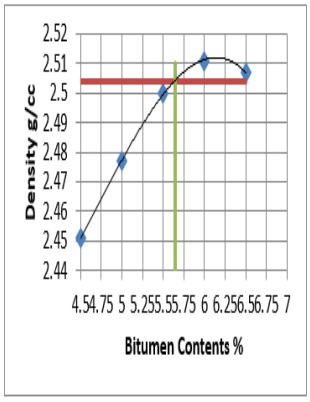


Fig. 7. Bitumen Contents vs Density

For various individual mixes of Marshall Mix Design are tested, the optimum bitumen content is obtained at 5.65% for maximum stability. The confirmatory test is performed for Modified Marshal Mix design, 5.65% of bitumen content with and without addition of 0.1%, 0.2%, 0.3% and 0.4% dosage of Zycotherm as an additive and corresponding test results are compared in table-3.

**Table – 3**

**Comparative Statement for confirmatory test**

| Sr. No | % of Bitumen + Zycotherm | Bulk Sp. Gravity | Air Voids in % | VMA in % | VFB in % | Stability (KN ) | Flow in mm |
|---|---|---|---|---|---|---|---|
| 1 | 5.65% | 2.488 | 4.59 | 16.84 | 72.74 | 16.78 | 3.5 |
| 2 | 5.65 +0.1% | 2.497 | 4.55 | 16.99 | 73.20 | 24.03 | 3.6 |
| 3 | 5.65 +0.2% | 2.498 | 4.49 | 16.94 | 73.46 | 25.10 | 3.8 |
| 4 | 5.65 +0.3% | 2.499 | 4.47 | 17.11 | 73.88 | 25.46 | 4.1 |
| 5 | 5.65 +0.4% | 2.504 | 4.28 | 16.75 | 74.43 | 22.59 | 4.2 |

## VII. CONCLUSION

1. The penetration value of bitumen is decreases by addition of zycotherm, but increases the stiffness property of bitumen.
2. Due to increase in softening point, bitumen gets more stable at higher temperature.
3. The adhesive bond between aggregate and bitumen is enhanced by addition of zycotherm in bitumen due to which moisture resistance increases.
4. In Marshall Mix design the reduction in air voids enhances the chances of shear resistance of mix. Thestability increases up to 0.3% of zycotherm however the flow value increases continuously.

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