Influence Of Nanomaterials On Properties Of Bituminous Concrete Mixes

Aakash Gupta, Aditya Kalra, Atul pal, Pranav Sharma

Abstract: ***Bituminous concrete mix is commonly used as a surface course in India. Use of chemical additives in the conventional mix helps to improve the pavement performance. This research paper attempts to compare the use of Nanomaterials in form of Zycotherm and Nano clay as an admixture in bituminous concrete mix against the orthodox design mix. Initially optimum bitumen content was determined by plotting graphs for stability value, flow value, air voids and bulk unit weight with respect to bitumen content percentage by weight. Different samples with quantity of Zycotherm corresponding to 0.1 % 0.2% and 0.3% by the weight of bitumen (Optimum Bitumen Content 5.5%) were made. The laboratory study concludes that the stability value was improved upon the addition of the additive and optimum Zycotherm content was also determined. Nano clay was also added similarly to the conventional mix and was tested for Marshall Stability and Stripping test. The addition of only Nano clay to the bitumen mix indicates a reduced Marshall Stability value while the Stripping resistance was increased considerably.***

Index Terms: Marshall Stability Test, Nano clay, Nanomaterials, Zycotherm

I. INTRODUCTION

Bituminous surfacing or simply flexible pavements find their use mostly in the developing parts of the world. These bituminous surfaces do not generally have great lifespan and maintenance is needed after duration of time. Distress in the pavement is caused due to damage by heavy vehicles and seasonal temperature changes in the pavement[1].Water also has many adverse effects on pavement performance and leads to loss of strength and durability in the bituminous mix[2].This parameter thus leads to increase in cost for maintenance. However consequent researches have proved that incorporating some additives in these bituminous mixes can lead to improvement in pavement properties and help in preventing distress symptoms. Adding these admixtures also helps in providing increased durability and cost effectiveness to the entire bituminous mix.

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The additive used in the current study is Zycotherm an organosilane additive. Zycotherm comes in form of pale yellow liquid which is miscible with water. The chemical is stable under normal temperature and pressure conditions. It works as a bitumen binder and is added to bitumen before it is mixed with aggregates. It helps in resisting moisture by promoting chemical bonding at aggregate interface. The Nano clay exists as minute particles of layered mineral silicates. Clays occur in different forms such as bentonite, kaolinite, montmorillonite etc. However not all clays are Nano-sized and not every clay finds its application as a modifier in asphalt mixtures. Some may have only one dimension that is Nano-sized such as the thickness of bentonite and montmorillonite platelets. The Nano clay utilized in this study is Montmorillonite Bentonite Clay of 99.9 % purity. Montmorillonite is the most common type of Nano clay used as a modifier because of its easy modification through use of nanotechnology. Previously done researches are evident that the additions of Nanomaterials to bituminous mixes considerably enhance the properties of the mixes.

A. Literature review

According to Manjunath S Sharanappanavar the optimum binder content for Fresh mix and Warm Mix Asphalt are different with varying additive dosage rate, so the Optimum Binder Content should be found out individually for both Fresh mix and Warm Mix Asphalt for varying temperatures and additive dosage rate[3]. Rohith N., J.Ranjitha concluded from their study WMA mix produced using Zycotherm at 130°C with additive dosage rate of 0.1% showed good results when compared with the HMA mix produced at 130°C.The stability and Marshall Properties of WMA specimens prepared at 130°C and 115°C were improved by the addition of Zycotherm at an additive dosage rate of 0.1% by weight of the binder[4].R Jones found out that the modifiers i.e. carbon black, sulphur, styrene-butadiene & ethyl-vinyl-acetate increased the viscosity of the binder at 1400F, and all but sulphur increased the viscosity at 2750F[5].Research indicates that modifiers can be used to successfully reduce rutting by improving the high-temperature properties of a mixture[6]. The modifiers can result in increased resistance to stripping and reduce the effect of bleeding of binder during peak summer[7].

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The modifiers help to increase the tenacity as well as the fatigue resistance of the bitumen pavement[8][9][10][11].The magnitude of Marshall stability indicates the properties of a flexible pavement to resist shoving and rutting due to heavy taffic[12].

Nano clays are one of the newest additives being used in paving grade bitumen to increase their in-service performance[13]. A study in advancement of Nanotechnology by Jun yang and Susan tighe states that the addition of Nano clay increases the viscosity of bitumen binders and improves the rutting and fatigue resistance of asphalt mixtures[14].

A research conducted also shows the modified binders modified with nanomaterials are more stable under fatigue loads, braking and accelerating forces and thus show increased resistance to permanent deformation even in hot weather[15].

Nano clay influences both the physical and rheological properties of the modified bituminous mix[16]. Nano clay changes rheological properties of bitumen and increases stiffness, it also decreases angle phase and improves ageing resistances[17].

Different proportions of Nano clay (2% 3.5% & 5%) have resulted in increased tensile strength and increase in Stripping resistance as the concentration of Nano Clay was increased[18].

Water infiltration into asphalt mixtures is one of the serious distresses which lower the pavement performance. Addition of Nano clay enhances the bitumen's resistance to water damage[19].

A laboratory study on effects of Nano clay on asphalt pavement indicates that a mixture modified by 5.5 % SBS (Styrene-Butadiene-Styrene) and 0.5 % of Nano clay powder increases the mechanical properties of the asphalt binders and mixtures[20].

B. Objectives of current study

The objective of the current study is to study the impact of Nanoparticle additives on the properties of bituminous mixtures.

In addition show variation in the values in comparison to the specimen without the addition of Nano chemicals.

II. MATERIALS

A. Aggregates

The aggregate utilized for this study are acquired from a quarry situated in Solan (Himachal Pradesh).The aggregates chosen for this study have sufficient strength, toughness and hardness. The tests conducted on the aggregates with their following results are given in table 2.1.

Table I: Physical Properties Of Aggregates

S No.	Tests	Results
1	Aggregate impact value	22.25%
2	Aggregate crushing value	24.8%
3	Los Angeles abrasion value	33.8%
4	Specific gravity	2.76
5	Apparent specific gravity	2.88

B. Bitumen

The bitumen used for the preparation of the specimen is Plain bitumen of Viscosity grade (V30).The tests done to check for the physical
properties of bitumen are given in table 2.2.

Table Ii: Physical Properties Of Bitumen

S No.	Tests	Results
1	Ductility test of bitumen	85 cm
2	Specific gravity of bitumen	1
3	Penetration value of bitumen	66mm ($1/10^{th}$ mm).
4	Softening point of bitumen	52^{o}C

C. Zycotherm (Additive)

ZycoTherm is an organo silane odour free, chemical warm-mix additive(WMA) .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 this study the Nanomaterial used is Zycotherm. Zycotherm is an organo silane odour free, chemical warm-mix additive (WMA).

In India Zydex Industries is a chemical company that produces Zycotherm and for the current study, it was procured by directly contacting their sales headquarters in Vadodara (Gujrat).

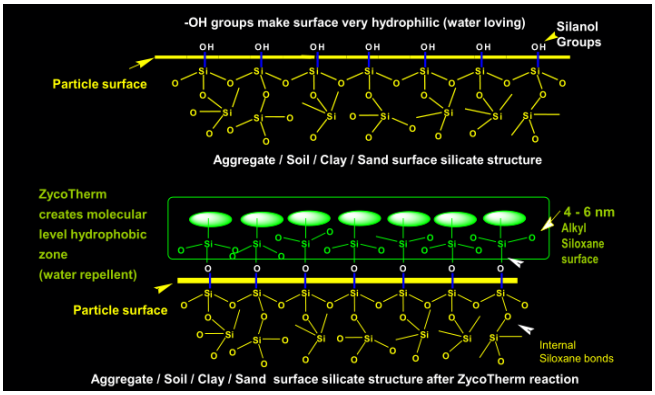

Fig 1: Chemical action of Zycotherm

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D. Nano clay (Additive)

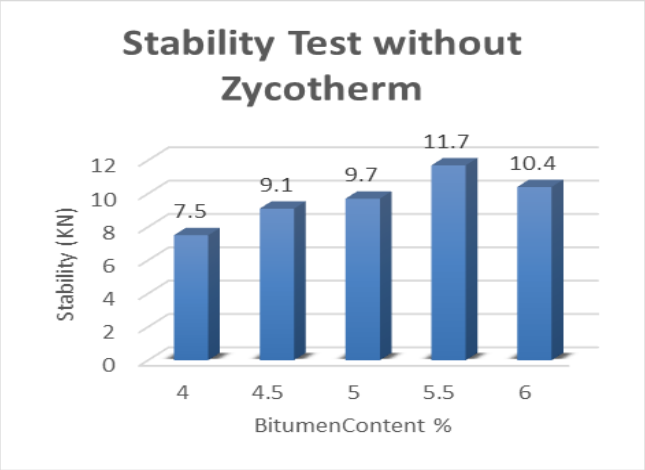
The Nanomaterial additive is added to the mixture to enhance the properties of the bituminous mixture. The nanomaterial used for this study is the Nano clay. The Nano clay used is Montmorillonite Bentonite Clay ($Al_2O_{34}SiO_2H_2O$) with purity of 99.9%.The clay comes in form of powder and the colour of the clay is light cream.
For the following study the Nano clay was procured by order from Intelligent Materials Pvt limited (www.nanoshel.com).

III. EXPERIMENTAL

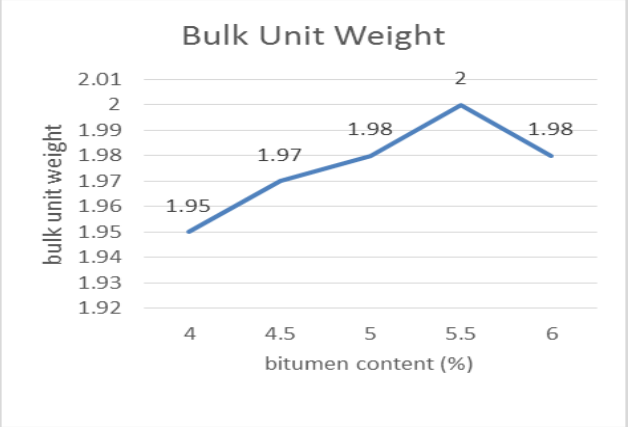
A. Test without adding Nano chemical Additives

A.1. Marshall Stability Test

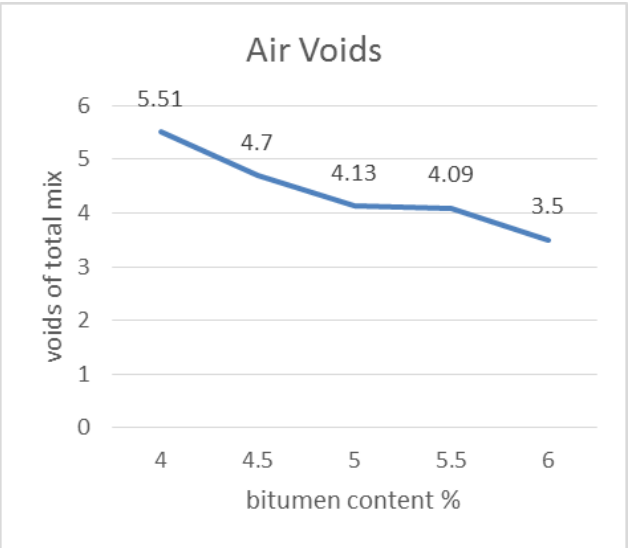
For the preparation of the sample the aggregates of specific grading and properties are chosen and a mix of 1200g is taken. The aggregates are heated in the oven at 100°C for 24 hours and 150°C for 30 min before the test is to be conducted. The bitumen is also heated at around 140°C.The bitumen is then mixed with the aggregates in a container with the help of a trowel. The mix is then poured into a mould which is tampered with a hammer weighing (4.86 kg) with 65 blows on both of its sides. This mould is then cooled for 24 hours at room temperature. Similar specimens are then created with different bitumen content. After the moulds are removed the moulds are placed in a water bath for 30 min at a maintained temperature of 60°C.The stability value is then calculated by the Marshall Stability Apparatus[21].



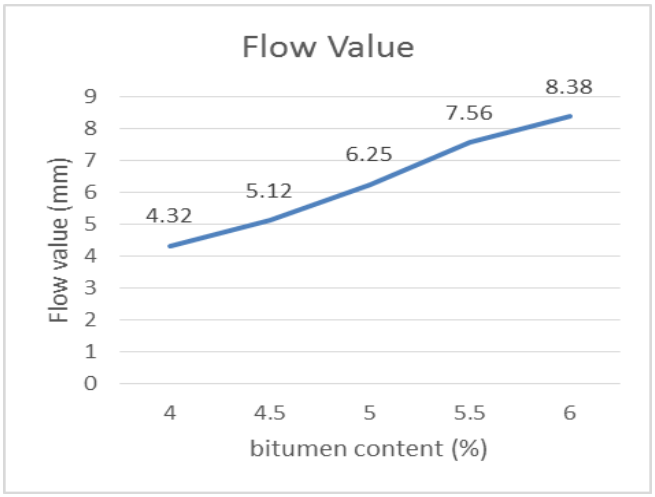
Graph 1: Stability value without Zycotherm at differnt bitumious content



Graph 2: Bulk unit weight at different bituminous content



Graph 3: Air voids at different bituminous content



Graph 4: Flow value at different bituminous content

Taking in consideration all the graphs and the results the Optimum Bitumen Content was found to be 5.5 %.

A.2. Stripping Test

For this particular test aggregates passing 20 mm IS sieve and retained on 12.5 mm IS sieve are used. The sample obtained is taken in 200 g portion. 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. The bitumen is taken 5% by weight of aggregates and is heated up to 140°C.The aggregates and the bitumen is then thoroughly mixed in a container. This container is then filled with distilled water to immerse the coated aggregates. The container 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.

The stripping value of the road aggregate by visual estimation was about =20%

The permissible stripping value by Indian Road Congress = 25%

Fig 2: Aggregates coated with bitumen after the test

B. Tests with addition of additive Zycotherm

B.1. Marshall Stability Test

The sample constituents are the same with the exception of the addition of the Nano chemical (Zycotherm) in the bitumen. Since Zycotherm is a hot mix additive, the bitumen is heated to a temperature of about 140°C before the chemicals addition. When the desired fluidity is achieved Zycotherm is added drop wise with the help of a syringe in the desired quantity. In 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. The aggregates are heated at a temperature of 100°C for 24 hours and 150°C for 1 hour before the experiment. 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. The bitumen and the aggregates are then mixed thoroughly. The bituminous concrete mix is transferred to the mold and is tamped 65 times on each side with a standard hammer (4.86kg). The sample is then allowed to cool. Similar procedure is followed for casting the remaining samples with varying concentrations of Zycotherm. 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. The samples are loaded onto the Marshall Stability Testing machine and the results obtained are represented in Graph 4.

Fig 3: Addition of Zycotherm

Fig 4: Mixing of bituminous concrete

Fig 5: Bituminous samples with different Zycotherm concentration

B.2. Stripping Test

The sample constituents for the test are same as taken before except the addition of the additive Zycotherm. The chemical is added with the help of a syringe in desired concentration in bitumen after it is heated to temperature of 140^{o}C.

The stripping value after the addition of the Zycotherm chemical =5 %

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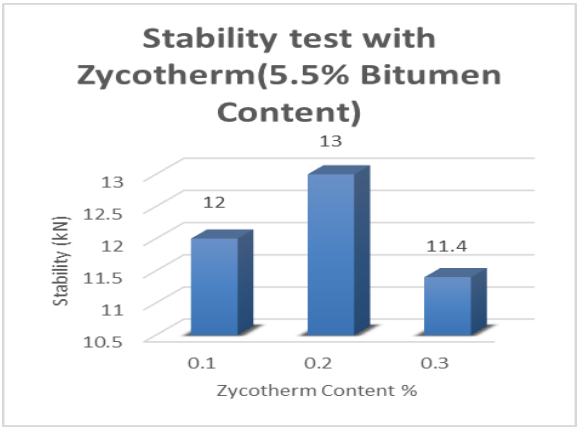
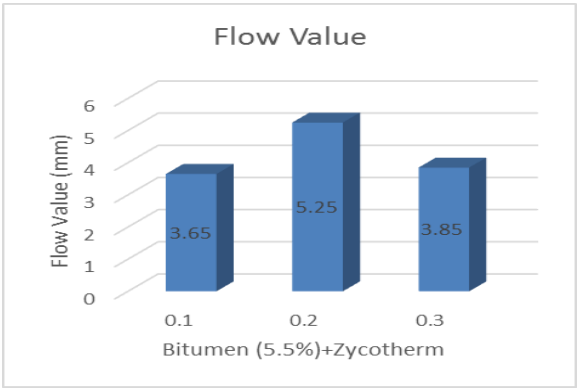
Fig 6: Aggregates after stripping test



Graph 5:Values of Marshall Stability test with different Zycotherm concentration



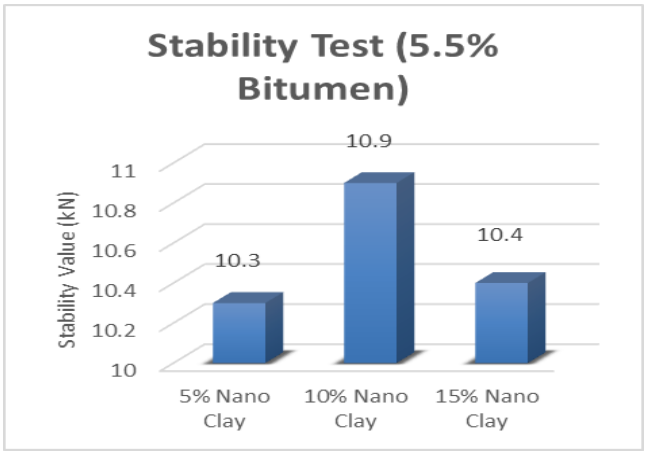
Graph 6: Comparison of Flow Value with different Zycotherm concentration

C. Tests with addition of additive Nano clay

C.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.

- Aggregates of specific grading and properties are taken (1200g).
- Sample heated at 100°C for 24 hours & 150°C for 30 min at the start of the test.
- The bitumen is heated at 140°C.
- Then the Nano Clay in the required proportion (Optimum Nano Clay content= 10% by weight of bitumen) is added to the heated bitumen and stirred continuously.
- The bitumen is then mixed with the aggregates and then poured into a mould.
- 75 blows are delivered on both the sides.
- The mould is cooled for 24 hours at room temperature.
- Similar specimens are then created with different bitumen content.
- Moulds are placed in a water bath for 30 min at a maintained temperature of 60°C.
- The stability value is then calculated by the Marshall Stability Apparatus.



Graph 7: Marshall stability value of bitumen (5.5%)+ Nano clay

C.2. Stripping Test

The sample constituents for the test are same as taken before except the addition of the additive Nano clay. The chemical is added with the help of a syringe in desired concentration in bitumen after it is heated to temperature of 140°C.

The stripping value after the addition of the Nano clay chemical < **2%**

IV. RESULT AND DISCUSSION

A. Zycotherm

The research clearly shows the scope of using Nano Chemicals in the field of pavement construction. Addition of Zycotherm has the following advantages:

- **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 Nano chemical the Marshall Stability Value was considerably higher at **13 kN**.

- **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.

- **Improved Compaction**

The heights 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**.

- **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= **20%**.

Stripping Value with Zycotherm= **5%**.

B. Nano Clay

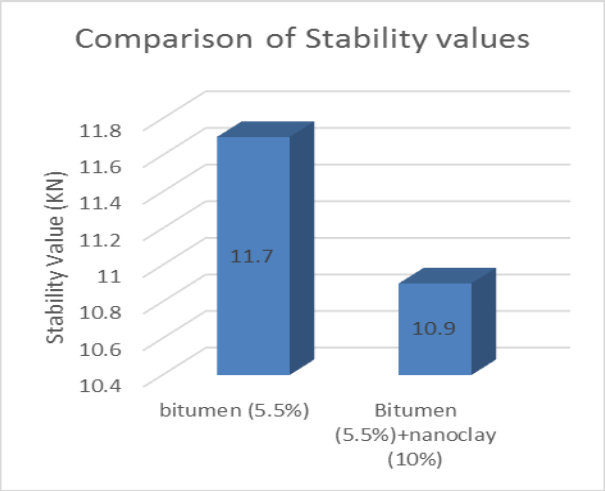
In the current study **Montmorillonite Nano Clay** was used. In the current state of affairs Nano Clay is not a cheap and is limited in production in India. Therefore there is heavy cost implication of using it. However it too has benefits especially when considering the stripping resistance of flexible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

- **Insignificant change in stability value**

Marshall stability value without Nano clay =**11.7 KN**

Marshall stability value with Nano clay (10%) =**10.9 KN**

The Marshall stability value got slightly reduced.



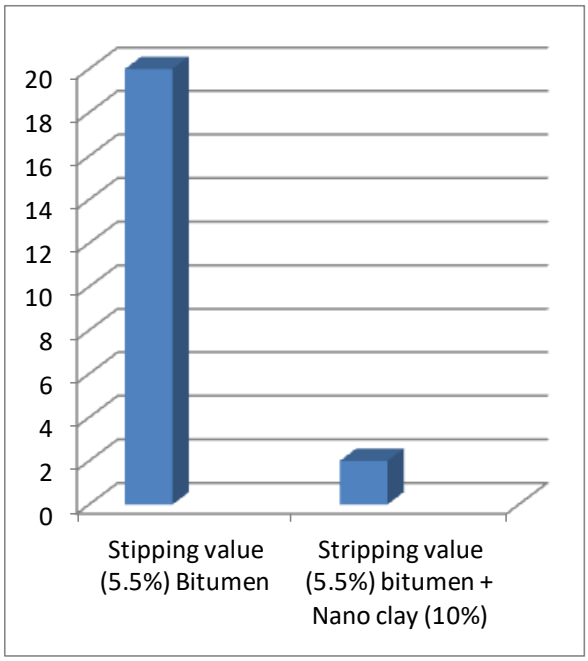
Graph 8: Comparison of Marshall Stability value

- **Highly improved Stripping Resistance:**

Stripping Value without Nano Chemicals= **20%**.

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

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



Graph 9: Comparison of Stripping value

- **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.

V. CONCLUSION

Nanotechnology offers the possibility of great advances and incremental improvements in construction materials. Nano particle additives have high potential for application in bituminous concrete mixes. Addition of Zycotherm as an additive improves the durability of the pavement and hence helps in decreasing the maintenance cost. Hence it is evident that Nano Chemicals such as Zycotherm have many benefits and have favorable results for flexible pavements. It helps in stiffening of the binder material and also increases its stripping resistance. The only problem with utilization of Nano materials is its cost effectiveness. As the cost of these Nano materials are very high the application of these materials is therefore limited. Adequate research still needs to be carried out as well as implemented if the sector has to progress. Just like the Nano Chemicals used in this study there are numerous others available commercially manufactured chemicals which have not been tested for the flexible pavements and can have other advantages.

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

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