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Nanotechnology for Advancement in Transportation Engineering

Road Pavements Improvement by Using Nanotechnology

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Abstract: ***The applications, innovations, developments in the field of nanotechnology in various applied fields is receiving widespread attention. It is essential to note that these applications are improving general well-being of the public. The development of nanotechnology and its significance in civil engineering practice is illustrated in this paper for enhancing the vision of nanotechnology in the field of road pavements. Although good pavements can be constructed using existing techniques and available materials, there are a number of areas where the judicious application of nanotechnology techniques should be able to improve the longevity and performance of the service provided by the pavement facility. These include improved and smart materials and characterization of materials. Nanotechnology is focused on materials in nanoscale while civil engineering infrastructure (especially road pavements) focused on the macro scale(100s of kilometer in length).This paper focuses on the nanomaterial which gives the effective results on the operation and maintenance costs of the road pavements. The Chennai flood in 2015 effects is being focused on for the development of the road pavement infrastructure. To execute these, the gap between the nanotechnology and construction materials research needs to be bridged. Finally the future trend, potential and implications of nanotechnology development in civil engineering towards more economical infrastructure, low cost maintenance with longer durability are deliberated. This paper concentrates on the macro level analysis of the nanomaterials in pavements.***

Keywords: Civil Engineering, Zycosil, Nanomaterials, Pavements, Nanotechnology

1. Introduction

Nano comes from the Greek word for dwarf, indicating a billionth. The size nanometer is 10^-9 meter i.e 1 meter is cut into 1,000,000,000 pieces, each piece is one nanometer which is a billionth of a meter. Any technology based on particles size less than 10 nanometer is considered as Nano Technology. Zycosil molecule when dissolved in solvent has estimated size of 5-6 nanometer. Therefore this Zycosil waterproofing technology is the Nano Technology. This focuses on providing the required background and information on the status of nanotechnology applications in road pavements. It deals with background on pavements and nanotechnology, and then focuses on the materials, characterization and concerns and issues.

2. Pavements

Pavements consists of a combination of layers of engineered materials that generally provide all-weather access to vehicles to travel in a safe economical way. The layers of materials used are selected and engineered to provide a structure which can withstand the applied vehicular loads under a range of varying environmental conditions for a expected period of time. Pavement in construction is an outdoor floor or superficial surface covering. Paving materials include asphalt, concrete, stone such as flagstone, cobblestone, artificial stone, bricks, tiles, and sometimes wood. In landscape architecture pavements are part of the hardscape and are used on sidewalks, road surfaces, patios, courtyards, etc.

2.1. Zycosil Nanomaterial

Zycosil is new generation of nanotechnology, which has been developed for waterproofing and has UV resistance, thermal resistance, and an ability to withstand the wind erosion due to its nano-size and penetrative power. Water intrusion in building materials has been a problem for the last 1000 years. Fortunately, new developments in science and technology have incorporated the use of nanotechnology to produce eco-friendly, organo silicon products that can render most materials hydrophobic for cycles of 20 to 30 years at a very economical cost. It is based on nanotechnology; it provides molecular level hydrophobicity to inorganic substrate. It is ecofriendly, because it is applied in water solution and VOC per applied M2 is less than20%compared to solvent based silanes. The product is based on organo silicon chemistry, hence reacts with the inorganic substrate surface and provides long service life of 20-30years.

Eco-Friendly Water Based Nano Technology Zycosil: It is an organo silicon product, which forms a particle size of 4-6 çm in water and penetrates deep into the building material pores 3-5 mm. The product becomes part of the building material and makes it highly water repellent.

2.2. Water the great destroyer of road pavements

Moisture damage is caused by a loss of adhesion, commonly referred to as “stripping” aggregate surface or a loss of cohesion within the binder itself, resulting in a reduction in stiffness. Heavy traffic on a moisture-weakened pavement can result in premature rutting or fatigue cracking. The presence of moisture can also accelerate the formation of potholes. These adverse effects due to the water is being

neglected by the use of the nanomaterial in the road pavements construction.

2.3. Application of nanotechnology in bitumen

The clay nano-particles are the primary materials applying in asphalt construction. Adding nano-particles like nanoclay, nanosilica, and nanotubes in asphalts normally increase the viscosity of asphalt binders and improves the rutting and fatigue resistance of asphalt mixtures. Using nanoclay as the second modifier in polymer modified asphalts can improve the storage stability and the aging resistance of polymer modified asphalts. Various Atomic Force Microscopy (AFM) techniques (e.g. tapping mode imaging, force spectroscopy, and nano-indentation) as well as X-ray diffraction (XRD) experiments can be conducted on modified asphalt binders to characterize the micro or nano-scale structures of nano-asphalts. Through the reasonable selection of nano-materials used in asphalt, nano-modified asphalt can offer many benefits in cold regions.

The bentonite (BT) and organically modified bentonite (OBT) were used to reinforce and modify asphalt binder by melt processing under sonication and shearing stresses. The BT modified asphalt possess intercalated structure while OBT modified asphalt possessed exfoliated structure. The BT and OBT modified asphalts have shown greater softening point, viscosity, higher complex modulus, lower phase angle and higher rutting parameter and better rheological properties than the base asphalt. But the ductility of the modified asphalts decreased with the addition of BT and OBT. They have significantly lower creep stiffness. Therefore the lower temperature cracking resistance was improved by the addition of BT and OBT. The OBT modified asphalts has better properties than the BT modified asphalts.

2.4. Gas Liquid Permeability

Effects were studied of zycosil nanoparticles, with size range from 20 to 80 nm, on liquid and gas permeability of medium density fiberboard. Nanozycosil was used at four consumption levels of 0, 50, 100, and 150 g/kg dry wood fibers. Density of all treatments was kept constant at 0.67 g/cm3. The obtained results indicated that the addition of zycosil to the mat resulted in a significant increase in gas permeability due to the lower fiber-content in the nanozycosil-treated specimens and the consequent micro-cavities that were formed in the boards. However, the water-repellant property of zycosil nanoparticles compensated for the micro-cavities to some extent. High correlation was observed between gas and liquid permeability. The consumption level of 50 g of nanozycosil/kg can be recommended to improve the impermeability property of medium density fiberboard to water.

3. Revolutionary Nanotechnology

Revolutionary nanotechnology for building moisture resistant, long lasting & maintenance free roads through innovative adaptation of Organosilane chemistry.

Zydex Nanotechnology: A Game Changer- Zycosil, Zycofil, Zycoprime.

Zydex Nanotechnology has a value propositions for all layers of the road.

3.1 Soil Layers

Zydex Nanotechnology makes the soil moisture resistant, reduces expansiveness and stabilizes the soil to improve its bearing strength manifold. If used with 1% cement, it can stabilize almost any type of soil, by improving the California Bearing Ratio (CBR) to even 100 or above.

Here is the real change in game, as stronger soil bases would now allow optimization of road section thicknesses, potentially saving 10-15% road construction cost.

3.2 Bond Coats

Prime & Tack coats become 100 % waterproofed, due to penetration and chemical bonding. This also ensures uniform load transfer. And all this at lower residual bitumen.

3.3 Asphaltic Layers

Chemical bonding between aggregates and asphalt eliminates moisture induced damage of asphaltic layers.

4. Water Repellents

- Resistance to water intrusion
- Prevention of water-soluble salts, particularly chloride salts
- Penetration of repellent treatment to a measurable depth
- Long-term stability in an alkaline environment
- Low environmental and health risk
- UV stability (20+ years)

4.1 Types of Water Repellent

Film formers: These film formers have a particle size greater than 100 nm, which will not allow them to penetrate inside the pores of the building materials but instead form a film covering and protecting the surface from water absorption. Failure of film formers: –

- Blocks breathability
- Life of only 2 – 5 years

Penetrants: They are solvent based, soluble monomeric materials less than 6 ηm in size which can easily penetrate inside the pores and sub-branches of the pores. Failure of penetrants: –

- Flammability
- High cost
- Toxic VOC solvents

5. Zycosil on Soil Pavements

Zycosil is new generation of nanotechnology, which has been developed for waterproofing and has UV resistance, thermal resistance, and an ability to withstand the wind erosion due to its nano-size and penetrative power. Water intrusion in building materials has been a problem for the last 1000 years. Fortunately, new developments in science

and technology have incorporated the use of nanotechnology to produce eco-friendly, organo silicon products that can render most materials hydrophobic for cycles of 20 to 30 years at a very economical cost.

5.1 Moisture Damage

Moisture damage is caused by a loss of adhesion, commonly referred to as "stripping" aggregate surface or a loss of cohesion within the binder itself, resulting in a reduction in stiffness. Heavy traffic on a moisture-weakened pavement can result in premature rutting or fatigue cracking. The presence of moisture can also accelerate the formation of potholes.

5.2 Zycosil Nanotechnology

Any technology based on particles size less than 10 ηm is considered Nano Technology. Zycosil molecule when dissolved in solvent has estimated size of 3-6 ηm. Most pavement materials contain hydroxyl (OH) groups. These OH groups can chemically react with alkoxy groups of Silane to form permanent, Mother Nature's strongest siloxane bonds. These types of products impart water repellency by modifying surface characteristics from hydrophilic to hydrophobic.

5.3 Features of Zycosil

1) Permanent water repellent layer on all types of soils, aggregates and other inorganic road construction materials.
2) The technology addresses the critical subsurface drainage problems in road making and repairs.
3) Zycosil's reactive bonding ability with the aggregates and asphalt helps to eliminate stripping of aggregates t a great extent.

5.4 Advantages of Using Zycosil

In subgrade & GSB
- Maintaining CBR value
- Reduction of Soil Plasticity
- Maintaining Breathability

Used in stone base course,In surface layers.

5.5 Limitations of Zycosil

1) Adverse effects of the solvent used- ethylene glycol.
2) A lot of precautions to be taken.
3) More effective on pre-existing cracks than cracks which occur after the application.
4) It cannot be applied if:

- Ambient temperature is below 10º C or above 50ºC
- Rain is expected within 2 hours following the application.
- Precipitation has occurred within 24 hours prior to application.
- High winds or other conditions prevent proper application and overspray that may have an adverse effect on surrounding materials.

5.6 Maintenance

- Unpaved aggregate roads: – Saturate the aggregate-soil surface including 2 meters each on both sides of the road with diluted Zycosoil solution @ 3-L/M2.
- Black topped roads: – Spray diluted Zycosoil solution @ 1.5- L/M2 on black top, shoulder and slope. Sun dry for 2-3 hours and check for water repellency by drilling a hole in the soil area.

6. Water Damage

If the pavement is not protected from water damage, all of the above is blowing in the wind. There are data that suggest that even pavement protected by amine or lime antistrips will lose much of its strength thus cannot complete its design life. Many aggregates are wetted by water better than asphalt so that if the surface cannot be permanently altered to prefer wetting by asphalt, eventually water will replace the asphalt.

6.1 Chip Seals

The application of a seal coat has a number of functions however one of the most important is to waterproof the pavements, protecting them from water damage and oxidation. If pavements were sealed early in their life, e.g. within a year, the pavements would last a lot longer. Chips seals are used especial on highways.

6.2 Chip Seal Emulsion

The emulsified asphalt used for chip seals are specially designed to break very fast on contact with aggregate. Emulsions can be either anionic (basic) or cationic (acidic) although the cationic are very popular. With asphalts from some crude oils the amount of emulsifier required for anionic chip seal emulsions is very small, approaching zero as a result naphthenic acids in the asphalt which serve as emulsifiers when neutralized with caustic soda.

6.3 Special Seal Emulsion

There is a product called PASS that has the ability to re-seal cracks and regenerate pavements.

6.4. Where to Use

A chip seal does an excellent job as a seal. While it can be used in cities, in my opinion a slurry seal would be better, unless it is a Capeseal in which a slurry is placed over the chip. The disadvantage of use in cities is that the chips can spread over lawns, in driveways, etc.

7. Causes of Pavement Failures

- Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic is a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road. This accelerates the fatigue failure (Alligator Cracking).

- Temperature variation ranging from 50º C to below zero conditions in the plain areas of North and Central India leads to bleeding and cracking. Provision of poor shoulders leads to edge failures.
- Provision of poor clayey subgrade results in corrugation at the surface and increase in unevenness.
- Poor drainage conditions especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface. In case of open graded bituminous layer, this phenomenon becomes more dangerous and the top layer gets detached from the lower layers.
- If the temperature of bitumen/bituminous mixes is not maintained properly, then it also leads to pavement failure. Over heating of bitumen reduces the binding property of bitumen. If the temperature of bituminous mix has been lowered down then the compaction will not be proper leading to longitudinal corrugations.

8. Solution for the Road Pavements Damage Due to Flood Using Nanotechnology Materials

When considering the Chennai flood in 2015 the damage to the road pavements was very high due to the water that stagnated for a long time and due to the penetration of water into the pavement layers which worn out the surface materials from the pavements. The damage due to the pavement failures during this flood is estimated as around 50000 crores since several kilometers of roads were damaged. Hence the surface area of the pavements can be prevented from this type of damage by using the nanotechnology materials which were introduced on the road pavement layers. Zycosil like materials prevents the intrusion of water into the pavement layers thus protecting the pavement layers from failures.

9. Conclusion

Research in nanotechnology that is related to construction is still in its infancy; however, this paper has demonstrated the main benefits and barriers that allow the effect of nanotechnology on construction of road pavements. Recent years of R&D have shown massive investments in Nano-construction. Nanotechnology offers the possibility of great advances whereas conventional approaches, at best, offer only incremental improvements in the field of construction engineering. Nanotechnology is not exactly a new technology, rather it is an extrapolation of current ones to a new scale and at that scale the conventional tools and rules no longer apply. Nanotechnology is therefore the opposite of the traditional top-down process of construction, or indeed any production technique, and it offers the ability to work from the "bottom" of materials and design to the "top" in the built environment. Thus the application of nanotechnology in transportation field can save crores of amount which is being spent up for the maintenance and the repair works.

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