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Comparative Study on Asphalt Mixture with Nano Materials and Nano Particles

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ABSTRACT

Pavement materials are crucial factors affecting pavement durability. Now-adays, there is dire necessity for roads which are more stable and stronger. Due to weathering conditions and heavy traffic, the pavement surfaces are getting deteriorated by rutting, pot holes etc. Among them asphalt is the most sustainable pavement material for construction pavements and can be used for many applications including highways, airport runways, parking lots and drive ways. In order to provide effective durability than that of asphalt, in its original form it has been modified using Nano-materials known as modified asphalt.

This research will deal with the advances in Nano-materials in hot mix asphalt and also addition of recronfibre and the comparison was made. With the addition of this Recronfibre, there is an improvement in the properties of bitumen like increase in stability value and decrease in the flow value, % of air voids etc. Recronfibre is an artificial material obtained from the polyester and which is also used as a secondary reinforcement for attaining tensile strength. It helps to resist the cracks obtained by the improper laying of pavement surface and heavy loaded vehicles. But whereas, the clay Nano-particles are the primary materials applying in asphalt construction adding Nano- particles like Nano clay, Nano silica and nanotubes in asphalts normally increase the viscosity of asphalt binders and improves the rutting and fatigue resistance of asphalt mixtures. From this the performance of asphalt when treated with Nano-particles and its sustainability compared to that of other pavement materials is examined and studied.

Keywords : Modified Bitumen, Flexible Pavement, Polyester [Recron 3s] Fibber, Nano-materials, Rutting, and fatigue resistance.

I. INTRODUCTION

Generally, roads are basic requirement for transportation facilities. The pavement should be stronger and more stable. But flexible pavements are generally affected to heavy traffic, weathering and geological conditions of the pavement which causes a reduction of quality and performance. In order to overcome from the effects like rutting, pot holes, shrinkage cracks etc., properties of bitumen are improved with addition of fiber and Nano silica.

The fibers used is Polyester (Recron-3S) Fibber. This is an artificial material obtained from polyester. This Fibre helps to resist the cracks obtained by heavy loaded vehicles and any changes occurred due to varying temperatures. This also helps to increase in flexural strength and tensile strength to the pavement. Bitumen is viscous fluid material which consists of binding and adhesive property (which binds all the components in it without any changes in their properties and it is insoluble and acts as a sealant). During the construction of flexible pavements, the bitumen binder is added to increase the life span of the pavement surface. While layingof road, the bitumen and coarse aggregate are mixed together providing good bonding and frictionbetween vehicle wheels and road surface. But the major problem in the bitumen pavements is due to rising high temperatures, the volatile compounds present in the bitumen are evaporated and the bitumen will become hard.

Silicon dioxide (SiO2) is a compound of Silicon and Oxygen, commonly called silica and the elements are linked by the covalent bond. It is one of the components of the sand and can be found naturally in Quartz. It is usually white or colorless and is not soluble in water or ethanol. By associating with minerals, it forms the silicate family. Silicon dioxide (SiO2) has several industrial applications such as an additive in the food industry. Its function is to act as an anti-binder, anti-foaming agent, viscosity controller, desiccant, beverage clarifier and as an excipient of medications and vitamins. Due to its insolubility in water, silica has little biological availability and is not considered a source of silicon. Silicon found in other more soluble forms contributes to the formation and maintenance of bones and cartilage.

Application of Silicon Dioxide (SiO2) Nano Powder

Silica (SiO2) nano powder is used to make flat glass, glass products, molten sand, cement, fiberglass, ceramic enamel, sandblasting for antioxidants, filter sand, flux, refractory and light concrete. Silicon dioxide (SiO2) Nanoparticles is widely used in many industrial products. Rare crystals in nature can be used to create important parts of the electronics, optical instruments and crafts industry. Silicon dioxide (SiO2) nano powder is an important raw material for the manufacture of optical fibers. Generally, pure quartz can be used to make quartz glass. The coefficient of expansion of quartz glass is very small. It is equivalent to 1/18 of ordinary glass. It can withstand temperature change and acid resistance is good. Therefore, quartz glass is often used to make chemical instruments resistant to high temperatures. Quartz sand is often used as a glass material and as a building material.

The main applications and uses of Silicon dioxide (SiO2)Nanoparticles are stated below

- **SiO2 Nanoparticles as Adhesive and Sealer**

Silica (SiO2)nano powder is the preferred material in the adhesive and sealant field. Adding it to the sealant can quickly form a net structure, inhibit colloidal liquid, increases speed, improves the effect of bonding, and because the particles are small, the sealing of the adhesive increases. Moreover, due to the special development of hydrophobic silicon dioxide,

structural adhesives belonging to advanced technologies have been produced. These structural adhesives allow the joining of different materials such as steel, aluminum, magnesium, and plastic.

- **SiO2 Nanoparticles in Material Packing**

Silicon dioxide (SiO2) Nanoparticles has a three-dimensional network structure and a large specific surface area. They show great activity and can form a mesh structure when the paint dries, it increases the strength and finish of the coating and improves the suspended pigment of the paint which do not fade for a long time.

- **SiO2 Nanoparticles in Textile Industry**

Silica (SiO2)nano powder has played an important role in functional textiles, at present, it has been used to prevent ultraviolet and works as an anti-aging and anti-bacterial deodorant. For example, the appropriate proportion of Silicon dioxide (SiO2)Nanoparticles is an important additive in resistance to ultraviolet radiation fiber.

- **SiO2 Nanoparticles in Catalysis**

Due to its large specific surface area, high porosity and good surface activity, Silicon dioxide (SiO2)nano powder has potential applications in the catalysis. Silicon dioxide (SiO2)nano powder works as a catalyst carrier. It shows the unique response performance for many sensitive reactions.

- **SiO2 Nanoparticles in Bactericide field**

Silica (SiO2)nano powder is used as a carrier in the preparation of fungicides, in which the antibacterial ion can be adsorbed and achieve the objective of sterilization. The application is used for the manufacture of items such as the refrigerator case, the computer keyboard. Etc.

- **SiO2 Nanoparticles' Ceramic use**

It is a glass former. It is incorporated into the glaze as ground quartz. It is part of feldspars, clays, as a soluble source in the form of sodium silicate, it is found in all frits as well as in ashes especially rice or reeds. It has little influence on colors, except chrome and nickel reds. Increases opacity in glazes is rich in zinc and borax.

Polyester (Recron-3S) Fibre

Polyester (Recron-3S) Fibre is an artificial Fibre. Polyester (Recron-3S) polymers have discovered noteworthy business applications in Fibres. Polyester (Recron-3S) Fibre helps to prevent the micro shrinkage cracks caused due to hydration in the bitumen pavement. It also helps to increase flexural strength of the pavement.

Fig Polyester (Recron-3S) Fibre

Advantages of Polyester (Recron-3S) Fibre

- Improves homogeneity of the concrete by reducing segregation of aggregates.
- Reduces shrinkage cracks/microcracks
- Abrasion resistance increases by more than25%.
- Impact and shatter resistance increase by100%.
- Increases ductility, compressive, flexural and tensile strength.
- Reduces water permeability which helps to prevent correction of primary steel.
- Increases energy absorption capability of concrete.

Replaces or reduces non-structural steel in floors, roads and pavement.

II. LITERATURE REVIEW

Falak Naza et.al (2021) in the research paper, five kinds of carbons were prepared under high speed shearing method: 0.1 Wt.%, 0.3 Wt.%, 0.6 Wt.%, 1 Wt.%, 2 Wt.%. The traditional carbon nanomaterials and optimized carbon nanomaterials were analyzed by macroscopic mechanics, microstructure and chemical composition. Based on the basic technical indicators and the macroscopic properties of the mixture, the formation mechanism of the microstructure and macroscopic properties of the carbon nanomaterial/SBS modified asphalt was explained by Scanning Electron Microscopy (SEM), fluorescence microscopy and infrared spectroscopy (FTIR).

The results showed that the optimum content of carbon nanomaterials is 1%, and the high and low temperature properties and storage stability of the modified asphalt are improved under the optimal dosage. The optimized carbon nanomaterials have become a bridge between SBS and asphalt due to their microscopic cyclic structure and conjugated bonds. The good microscopic compatibility with asphalt was the key to improving the modification performance.

Shahab Hasaninasab (2021) research paper investigated the effect of Nano-clay, Nano-Lime, and Nano-Alumina on the mechanical properties of cold recycled asphalt using bitumen emulsions. The experiments carried out resilient modulus and fatigue properties with four point bending tests. Three different percent of Nano- particles used in this research were 1%, 2.5% and 3%.

Adding Nano-particles increases the resilient modulus. The specimen resilience modulus with 2.5 percent of Nano-alumina increases more than 110 percent, and with Nano-clay and Nano-lime this value is 98 and 85 percent. 2 percent addition of Nano-clay improves the asphalt fatigue performance of 0.2 stress by 4 percent, 0.3 stress by 14 percent, and 0.5 stress by 64 percent. Fatigue strength for modified asphalt is more than non additive asphalt. Number of loads increased 22 percent with Nano-clay, 53 percent with Nano-lime, and 31 percent with Nano-alumina in 0.2 stress ratio. For 0.3 stress ratio, the number of loads increases 57 percent with Nano-clay, 82 percent with Nano-lime, and 57 percent with Nano-alumina. Nano- particles have more than 100 percent loading in 0.5 stress ratio.

Aakash Gupta et.al (2019) research paper compared 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.

Kedar Ashish. R et.al (2019) in the research paper, different contents of Nano silica,1.5wt %,3wt.%, have been added to bitumen to modify the physical, mechanical and rheological properties of asphalt. Various quality control tests have been carried out to characterize the modified bitumen and bitumen. The modified bitumen tested on ductility, penetration, Specific Gravity, Softening Point. The engineering property such as Marshall Stability, Bitumen

Extractor, and Stripping Value of the bituminous mix are evaluated. This paper focus on the advancement of important Nano technology and its effects on roadway design practice for widening vision and inspiring the creativity of highway engineering.

Results stated that additives of Nano silica increase the penetration at 1.5wt%, 3wt.%, increasing the softening point at 1.5wt%,3wt.%, increasing the specific gravity at 1.5wt%,3wt.%. And decreasing ductility at 1.5wt%, 3wt%. It was found that presence of Nano silica significantly improve Anti-aging property rutting performance and rheological property of bitumen asphalt binder. It was observed that addition of Nano silica in bitumen (1.5wt%, 3wt %) is more effective than the normal bitumen.

Objectives behind the research

a) To study the properties of bitumen by adding different proportions of Polyester(Recorn-3S).
b) To modify the strength of the bitumen and the sample by using Polyester(Recorn-3S) Fiber.
c) To obtain the optimum value of Recron fiber to be mixed with the nominalbitumen.

To study the properties of bitumen by adding different proportions of Polyester(Recorn-3S).

III. MATERIAL AND THEIR PROPERTIES

Polyester (Recron-3S)fibre

Recron fiber is a modified polyester fiber and helps to resist the micro shrinkage cracks caused due to hydration in the bitumen pavement. It also helps to increase flexural strength of the pavement.

Addition of Nano Silica

a) For 1% Nano-Silica content

Required Nano-silica content = 0.66 g and then bitumen content =65.94 g

Table Sample Testing with 1% Nano-silica content

Requirements	SAM 1	SAM 2	SAM 3	AVG
Height (cm)	6	6.1	6	6
Diameter (cm)	10	10.2	10.1	10.1
Volume	471 cc	498.19 cc	480.46 cc	483.21
Air Weight (gm)	1246	1258	1252	1252
Weight in water (gm)	702	698	710	703
Ut. Weight (g/cc)	2.645	2.525	2.605	2.59
Gt	2.39	2.39	2.39	2.39
GM	2.29	2.24	2.3	2.27
Vv (%)	4.18	6.27	3.76	4.73
Vb (%)	12.1	11.84	12.15	12.03
VMW	16.28	18.11	15.91	16.76
VFB	74.32	65.38	76.36	72.02
Marshall Value	350 div	365 div	370 div	361.6 div
Flow Value	370 div	390 div	380 div	380 div

For Marshall Value 116 div = 5 KN
for 361.6 div = 1588.58 kg
Flow value for 380 div = 3.8 mm

b) For 3% Nano-silica content:

Required Nano-silica content = 1.95g and then bitumen content =65.27 g

Table **Sample Testing with 3% Nano-silica content**

Requirements	SAM 1	SAM 2	SAM 3	AVG
Height (cm)	5.9	6.1	6	6
Diameter (cm)	10.1	10.1	10	10.05
Volume	472.45 cc	488.47 cc	471 cc	477.3
Air Weight (gm)	1240 gm	1253 gm	1249 gm	1247
Weight in water (gm)	725gm	705gm	712gm	714
Ut. Weight (g/cc)	2.62	2.56	2.65	2.61
Gt	2.4	2.4	2.4	2.4
GM	2.35	2.29	2.32	2.33
Vv (%)	2.08	4.58	3.33	3.33
Vb (%)	12.17	11.86	12	12.01
VMW (%)	14.25	16.44	15.33	15.34
VFB %	85.4	72.14	78.28	78.6
Marshall Value	395 div	360 div	390 div	381.66 div
Flow Value	460 div	390 div	430 div	426.67 div

For Marshall Value 381.66 div =1676.84 kg

Flow value for 426.67 div =4.26 mm

c) For 5% Nano-silica content:

Required Nano-silica content = 3.23g and bitumen content = 64.6g

Table 1 Sample Testing with 5% Nano-silica content

Requirements	SAM 1	SAM 2	SAM 3	AVG
Height (cm)	5.9	6.2	6.1	6.1
Diameter (cm)	10.2	10	10	10.06
Volume	481.86 cc	486.7 cc	478.85 cc	482.47 cc
Air Weight (gm)	1256	1240	1250	1248.66
Weight in water (gm)	725	730	709	721.33
Ut. Weight (g/cc)	2.6	2.54	2.61	2.58

Gt	2.39	2.39	2.39	2.39
GM	2.36	2.38	2.31	2.353
Vv (%)	1.25	0.418	3.34	1.67
Vb (%)	12.09	12.19	11.83	12.03
VMW (%)	13.34	12.6	15.17	13.7
VFB %	90.62	96.74	78	88.45
Marshall Value	505 div	445 div	520 div	490 div
Flow Value	250 div	340 div	242 div	278 div

For Marshall Value 490 div = 2152.80 kg

Flow value for 278 div = 2.78 mm

d) For 7% Nano-Silica Content

Required Nano-silica content = 4.47g and bitumen content = 63.93g

Table Sample Testing with 7% Nano-silica content

Requirements	SAM 1	SAM 2	SAM 3	AVG
Height (cm)	6.1	6.1	6	6.05
Diameter (cm)	10.1	10	10.1	10.05
Volume	488.47 cc	478.85 cc	480.46 cc	482.5 cc
Air Weight (gm)	1242	1256	1240	1246
Weight in water (gm)	698	715	705	706
Ut. Weight (g/cc)	2.54	2.62	2.58	2.58
Gt	2.35	2.35	2.35	2.35
GM	2.28	2.32	2.31	2.3
Vv (%)	2.98	1.3	1.82	2.03
Vb (%)	11.55	11.75	11.07	11.67
VMW (%)	14.53	13.05	13.52	13.7
VFB %	79.49	90.03	86.53	85.35
Marshall Value	590 div	680 div	630 div	633.33 div
Flow Value	250 div	260 div	270 div	245 div

For Marshall Value 633.33 div = 2782.52 kg

Flow value for 255 div = 2.55 mm

Marshall Stability test

The average values that are obtained are

Table Average Value considering different percentage of Nano SIlica

Nano Silica (%)	1	3	5	7	9
Marshall stability (kg)	1588.58	1676.84	2152.8	2782.52	2116.16
Flow value (mm)	3.8	4.26	2.77	2.55	3.68
Air voids (%)	4.73	3.33	1.67	2.03	4.3
Unit weight (g/cc)	2.59	2.61	2.58	2.62	2.57
VFB (%)	72.02	78.6	88.45	85.35	72.64
VMA (%)	16.76	15.34	13.7	13.7	15.17

IV. CONCLUSION

a) The stability value is higher for the Mix-3 proportion than others. The maximum stability value for modified Bitumen is 16.79 KN, whereas for nominal mix the maximum value is 12.07kN.

b) The optimal percentages for Nano-silica is7%. 7) A 7% Nano-silica content decreases the penetration degree by 7.13% in case of mechanical mixing and by 8.1% in case of high shearmixing.

c) A 7% Nano-silica increases softening by 9.52% in case of mechanical mixing and by 11.9% in case of high shearmixing. A 7% Nano-silica increases ductility by 8.33% in case of mechanical mixing and by 10% in case of high shear mixing.Mechanical mixing is better for Nanosilica.

Mixing Nano-silica using a hand mixer yields a heterogeneous mixture; Nano-silica agglomerates on mixing through mechanical means giving a homogenous mixture with agglomerationNano-silica.

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