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INFLUENCE OF SILICA IN PERFORMANCE CHARACTERISTICS OF ASPHALTMIXES

P. Sai Shravani[*1], Dr. A. Ramesh[2] & Dr. T. Rajani[3]
[*1]PG Student, [2]Assosiate Professor, Department of Civil Engineering
[3] Assistant Professor, Department of Humanities and Sciences,
VNR Vignan Jyothi Institute of Engineering and Technology, Hyderabad, India

ABSTRACT

Asphalt layers subjected to distress due to weather and excessive application of repetitive loads which results in failure causes the fatigue and rutting. Hot mix asphalt (HMA) layer should be prepared with new materials such that durability of pavement increases and shall withstand the excessive application of repetitive load. The use of nanomaterials shall provide solution in an effective process for improving performance characteristics. In the present study nanosilica was prepared and modified with bitumen binder to understand the performance characteristics. The nano structure was synthesized with microscopic observation. Rheological properties of modified binder when investigated and observed that inclusion of silica has increased the visco-elastic properties of the binder which provides better fatigue and rutting properties. The mixes prepared with modified bitumen exhibited better resistant for rutting and moisture sustainability.

Keywords: *Rice husk ash, Dynamic Shear rheometer, Marshall Stability, Tensile ratio and X-ray diffraction.*

I. INTRODUCTION

HMA preparation requires asphalt and aggregates and is provided at different bond layers of flexible pavements. This layer in pavement structure shall distribute the stress caused by wheel load to the bottom layers and protect them against failures. Asphalt material when exposed to atmosphere causes aging due to oxidation. Many researchers have been done on asphalt mixes were some are written herewith emergence of nanotechnology, researchers have made use of nanomaterials to modify the characteristics of binder and asphalt mixture. Distresses associated with asphalt mixtures, such as fatigue, rutting, and thermal cracking reduces the strength of pavement so in order to improve performance and behavior at different environments additives are being used. Silica is of two forms where it is present naturally and can also be made. Naturally available silica is non-reinforcing and is used as additive to reduce the cost. Silica is available in different forms some natural varieties are silica amorphous, silica crystalline, silica diatomaceous (fossil origin) and silica microcrystalline. Rice husks an agricultural waste where it is used to make bricks, due to the amount of silica present in rice husk now it is used for production of silica from ash and is economically effective. Having a high surface area

and creating powerful networks in asphalt binder, nanomaterials increase stiffness of asphalt binder, which can lead to an increase in the mixture's resistance to permanent deformation [1]. Due to the large specific surface area and the high surface energy, Nano materials have a great inclination to agglomerate to form secondary particles. When Nano-materials are poorly dispersed in base asphalt binder, the modified effect of the Nano composites will be similar to that of the micrometer-sized composites [2]. Nano silica increased the stability of modified samples so that the mixtures containing 8% of nanosilica improved the stability of mixture by 31% and by increasing the amount of nanosilica MR values have increased as well [3]. Silica content in RHA is about 60% and is economically raw material for production silica gels and powders. The obtained silica at the temperature of 700ºC for 6h is 98.14% [4]. Different techniques were obtained to understand the efficiency of silica when prepared with the RHA, results showed that using simple methods the purity of silica is about 98% in RHA than acid leaching and thermal treatment [5]. The advances in using different nano materials in HMA are examined were the low-temperature grade of nanosilica into the control asphalt improved the recovery ability of asphalt binders. The properties and stress relaxation capacity of nanosilica modified asphalt binder was the same as the control asphalt. The anti-aging performance and fatigue cracking performance of nanosilica modified asphalt binder and mixture were enhanced and the rutting resistance and anti-stripping property of nanosilica modified asphalt mixture were also enhanced significantly [6].

a) Critical Appraisal

When a pavement is constructed the performance of bituminous mixtures are decreasing day by day before the life time through cracks, stripping and pot holes. Researchers are introducing the new additives and admixtures to overcome from such problems and to increase the duration of pavement. In this study silica prepared from RHA was used at 2, 4, 6, and 8 % to the weight of bitumen to the conventional mix.

b) Objectives

The current study will explain the influence of nanosilica prepared with (RHA) on performance characteristics of asphalt concrete mixture.

II. METHODOLOGY

Following stages were obtained to achieve the objectives of the current study

Stage 1: Literature Study

Stage 2: Aggregate gradation for conventional mix.

Stage 3: Preparation of Silica using rice husk ash.

Stage 4: X-Ray diffraction is used to identify the Silica particles.

Stage5: Dynamic shear rheometer test was performed on binder content mixed with silica.

Stage 6: Marshall Mix design for silica mixes.

Stage7: Tensile strength ratio and rutting test were performed to the above mix combinations.

Stage 8: Explanation of test results.

III. EXPERIMENTAL PROGRAM

In current research, the silica was added to the binder with an increment of 2% to the optimum binder content. Laboratory tests are performed to evaluate the performance characteristics.

a) Materials

Aggregates and stone dust are gathered from quarry. VG 30 grade bitumen was collected from the provider by (IOCL). To confirm the grades of bitumen research facility tests were directed and Silica has been utilized for this present study.

b) Gradation of mix

By using (MORTH specifications) Bitumen Concrete Grade I have been used in the present study. Gradation is important in HMA were the aggregates are sieved from highest to lowest grade. Proper gradation should be done to the sample of aggregates were the mix should contain all sizes of aggregate so that it reduces voids. Strength is gained only when grading is done for maximum density. As per MORTH for BC-I the combined gradation for different size of aggregates is depicted in fig1:

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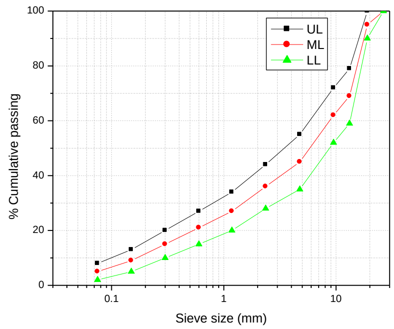

Figure 1: Gradation of mix

c) Binder characteristics

To determine the binder properties of modified bitumen DSR test has been conducted. Silica was added at 2% increment to the binder.

d) Preparation of Silica from rice husk

High purity Nano silica powder from rice husk using a simple chemical method:

- Raw rice husk wash with distilled water
- Washed rice husk was air dried at room temperature for 24hrs
- Samples were heated in a muffle Furnace in air at 700ºC-800ºC for 5hours
- The obtained Rice Husk Ash (RHA) was washed with distilled water
- Then add 6NHCL (Hydrochloric acid) stir it for 2-3 hours and then filtered in order to remove metallic impurities.
- The obtained one was thoroughly rinsed with distilled water repeatedly and then boiled with different concentrations of NaOH for 3hrs on magnetic stirrer.
- The obtained residue was washed with distilled water for complete extraction of sodium silicate. The obtained PH was modified by adding concentrated $H2SO_4$ (sulphuric acid) while being stirred magnetically, to extract the Nano silica precipitates.
- Then it is washed thrice with distilled water and then filtered
- Then obtained powder sintered in Muffle Furnace for 4hrs at 800ºC

The process of silica preparation is shown in depicted fig2:

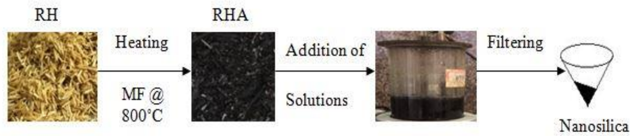

Figure 2: Preparation of nanosilica in laboratory

e) Binder characteristics

Binder modification with inclusion of silica with increment of 2% is added to know the rheological properties of the binder as per ASTM D 7175 (ASTM 2015a). Tests have been conducted with parallel plate that had a gap of 1.0mm and diameter of 25mm. The asphalt specimen was placed between parallel plates; the lowest plate changed into constant. The higher plate changed into oscillated at a loading frequency of 10rad/an s (1.59Hz) .the rheological property of the binder is known by dynamic shear rheometer depicted in fig 3:

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Figure 3: Dynamic Shear rheometer

f) Sample preparation (Marshall Samples)

Marshall Method of mix design is used to arrive OBC. Specimens were prepared as per (ASTM D 6926-04) with 1200 grams of aggregates including filler. Aggregates are preheated at a temperature of 130ºC and bitumen is also heated accordingly. These are added in a bowl and mixed thoroughly at135ºC temperature. Prepared mix is placed in the mould of 100mm diameter and compacted by a 4.54 kg rammer, with a falling height of 45.7 cm and 75 blows on both sides of the specimen. The specimen is kept aside and after some hours when extracted using sample extractor the thickness of specimen is 63.5mm. Three samples are made for each percentage.

Before conducting the test, specimens are kept in water bath at 60ºC and then specimen is placed for test. Maximum load is applied at the rate of 50.8mm/minute. Load is applied until the failure or crack appears and by load cell the load on the specimen will fall. Flow values are recorded through LVDT (Linear Variable Displacement Transducer) and are recorded in mm (1 unit = 0.25mm) MORTH. Along with flow values peak load will also record by DAS (Data Acquisition System). As per (ASTM D 5581-07) Marshall Stability value is taken from peak load resisted by specimen.

Figure 4: Marshall Stability

g) Specimen for Rutting Characteristics

Rutting is a permanent deformation along the wheel path. A rectangular mould which has dimensions of size 400mmX300mmX50mm is taken for casting the rutting specimen. By finding out the OBC from Marshall Stability percentage of mix to be compacted for sample is known. The sample is divided into 3parts and mixed with bitumen, each part of the mix is poured and compacted in oscillatory motion as per (BS EN 12697 33). The volume of mix is around 6000cc.

Immersion type of wheel tracking device

After 24hours the compacted specimen is taken and placed in wheel tracking device. 47mmwide steel wheel and 710N of surcharge including wheel is used in the study. To measure rut depth LVDT is used. Sample was fully immersed in water and temperature of water should be maintained around 50ºC. Approximately 1.46kmph (72-wheel passes per min) is the speed of wheel for one pass and the travel path is 230mm.

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Figure 5: Rutting Machine

h) Tensile Strength Ratio

Moisture damage in bituminous mixes refers to the loss of serviceability due to the presence of moisture which leads to failure of pavement.

$TSR = S_1/S_2$ ————— (1)

j) Silica Characteristics (X-ray diffraction)

To determine the atomic and molecular structure of a crystal X-ray diffraction is used. Crystals and X-rays are considered to be array of atoms and waves of electron magnetic radiation. X-ray striking an electron produces secondary spherical waves emanating from the electron, the electron is known as scattering. Through destructive interference the waves cancel one another in most directions and they add constructively in a few specific directions, determined by Bragg's law:

$2d \sin\theta = n\lambda$ ————— (2)

Where,
d = spacing between diffracting planes,
θ = incident angle,
n = any integer
λ = wavelength of the beam

IV. RESULTS AND DISCUSSIONS

a) Physical Properties of Aggregates

For preparation of mixes tests was carried out for BC Grade – I mix from MORTH specifications. Results are shown in the below table:

Table 1.Physical Properties of Aggregates

TEST CONDUCTED	LABORATORY RESULTS (%)	MORTH SPECIFICATION	TEST STANDARDS
Aggregate crushing value	23	Max 30	IS:2386(IV)
Aggregate Impact Value	20	Max 30	IS:2386(IV)
Elongation index	12.45	<15	IS:2386(I)
Flakiness index	12.32	<15	IS:2386(I)
Water absorption	0.4	0.1-2	IS:2386(III)

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Specific Gravity	2.6	2-3	IS:2386(III)
Los Angeles abrasion value	23	Max 30	IS:2386(IV)

b) Physical Properties of Bitumen
Tests conducted on bitumen were shown below:

Table2.Physical Properties of Bitumen

CONSISTENCY CHARACTERISTICS	VG-30	SPECIFICATIONS OF VG-30	TEST STANDARDS
Penetration at 25^{0}C	55	50-70	IS:1203
Softening point(^{0}C)	47.5	Min 47	IS:1205
Ductility(cm)	50.33	Min 50	IS:1208
Absolute Viscosity (Poise)	2567	Min 2400	IS:1206(II)
Kinematic Viscosity	358.67	Min 350	IS:1206(II)

c) Binder Characteristics
Modified binder is tested in dynamic shear rheometer under 135°C temperature to obtain the rutting characteristics

Table3.DSR Results

MEAN INTERVALS	PHASE ANGLE Δ	COMPLEX MODULUS G* (PA)	STRAIN (%)	G*/SIN Δ(RUTTING PARAMETER) KPA	G* SIN Δ(FATIGUE PARAMETER) KPA
S2	85.5	9.47E+03	11.1	9.510	9.440
S4	85.7	9.60E+03	12.3	8.950	8.900
S6	85.3	1.09E+04	14.1	10.800	10.700
S8	85.1	9.13E+03	15.1	10.68	10.585

From the test results is observed that 4% of silica has improved G*sinδ and G*/sinδ value.

d) Marshall Stability
Based on minimum voids contain performed on Marshall Mix design the optimum binder content for BC Grade –I mix is determined which is obtained at 5%. Following are the result of Marshall Mix:

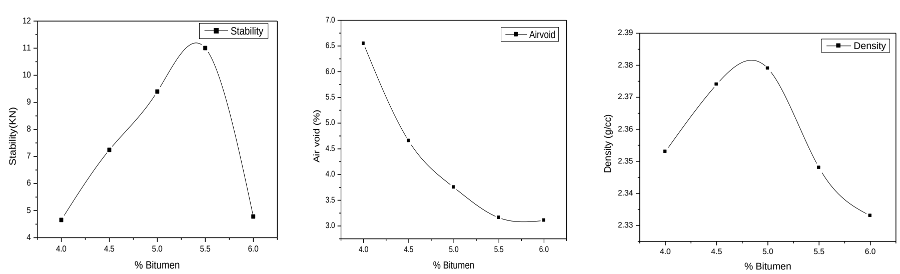

Fig 6: Stability, air voids and density graphs of conventional mixes

After achieving the optimum binder content further steps have been carried out by adding silica to binder with an increment of 2%.

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e) Modified bitumen:

In this study silica prepared from RHA is used as an additive, when silica is added the stability has been increased to 15.35KN. In the conventional mixture the VMA for the OBC is 14.75% but by modifying binder the voids had been reduced to 13.023%. So it will provide better durability to modified mix.

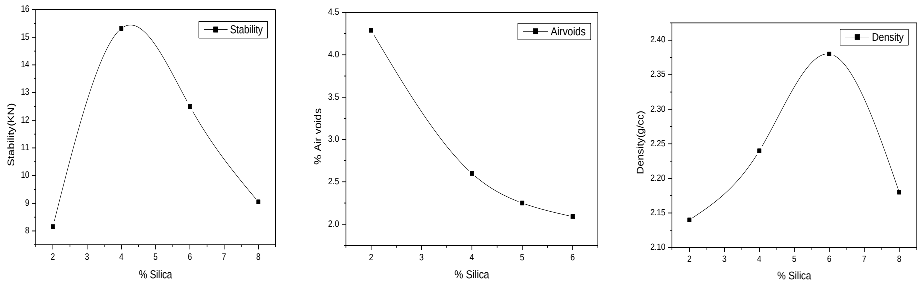

Fig 7: Stability, Air voids and Density graphs of modified binder

f) Tensile Strength Ratio

A higher TSR value typically indicates that the mixture will perform well with a good resistance to moisture damage.

Table4.Tensile strength ratio

Mixture Combination	Conditioned S_1(MPa)	Unconditioned S_2 (MPa)	TSR
Conventional	0.796	0.95	0.84
Silica	1.13	1.26	0.89

g) Immersion Wheel Test

The rutting test conducted in accordance with AASHTO – T324 and used for evaluation of rutting characteristics of the mix combinations. Two slabs were compacted in this test and silica prepared slab has given 3.15mm depth. OBC of the modified Marshall Samples percentage is taken and slab has been compacted by using slab compactor of volume of 6000cc.

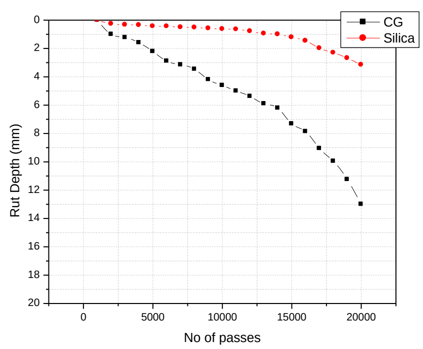

Figure 8: Rut graph

h) Silica Characteristics (X-Ray diffraction)

The crystalline structure of synthesized silica from rice husk was characterized by X-RD. The XRD pattern indicates the crystalline structure in the range of 20˚-30˚. At the remaining range disordered structure of silica was observed. The crystalline phase is evident from the sharp peaks in XRD pattern. These sharp peaks reveal the presences of cristobalite structure (7). The test has been performed as per (ASTM B761-97).

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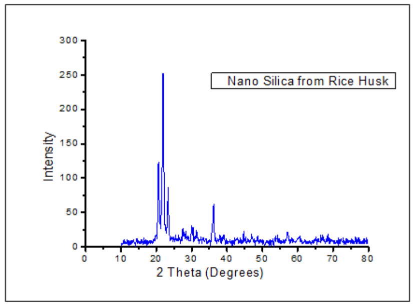

Figure 9: XRD graph

V. CONCLUSIONS

Based on the experimental observations made in Marshall Stability, immersion wheel rutting test and TSR following conclusions were made:

- The Marshall stability of silica as an additive provides effective increase in stability and density properties.
- Air voids has been decreased compared with conventional mix
- The rutting results explain that silica modified mixes has better resistance towards rutting. This is because of increase in finer properties of material results in dense mix.
- As the TSR value increased the water resistivity of the pavement increases
- Rutting and fatigue properties as enhance with addition of silica when compared to conventional binder

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