COMPARATIVE STUDY ON ASPHALT MIXTURE WITH NANO MATERIALS AND POLYMER

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ABSTRACT: Pavement materials are crucial factors affecting pavement durability. Now-a-days, 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, its original form it has been modified using Nano-materials known as modified asphalt. In this paper we are gone 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.

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

1. 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 laying of road, the bitumen and coarse aggregate are mixed together providing good bonding and friction between 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.

Due to this, when the traffic loads are heavy, the pavement will get deteriorated. During winter rainy seasons,
due to presence of moisture content, the pavement may be damaged. To prevent this, Polyester (Recron-3S) fiber is added at certain proportions (3%, 6%, 9%, and 12%) to the bitumen mix. Generally, asphalt pavements can absorb water and lose its strength. But, with the addition of this fiber to these pavements, the strength is not decreased even with the absorption of water and also it with stands to abrasion. Polyester (Recron-3S) fiber in bitumen protects from the fatigue, flow value, cracking and deformation on flexible pavements.

In recent years, nanotechnology has gradually been incorporated into the field of modified asphalt with various kinds of nanomaterials being used to modify asphalt. There are various nanomaterials which have potential to be used in asphalt modification; such as Nano clay, Nano silica, Nano-hydrated lime, Nano-sized Nano-silica powders, or polymerized powders, fibers, and nanotubes. The recent practices of nanotechnologies are those using Nano-sized particles in so-called nanomaterials and nanometer-size features on integrated circuits. These materials frequently show properties that are completely different from those demonstrated by the same products with larger dimensions. A reason for this can be found in the increased relative surface area of minute particles.

GENERAL:

In 2013, M. Faramarzi et al. Attempted to promote technical characteristics of asphalt mixture using carbon nanotubes as an additive material for bitumen. In this study, marshal test parameters of hot mix asphalt, modified with 0.1, 0.5, and 1% carbon nanotubes, are investigated and compared to conventional asphalt mix. Wet and dry process methods are most practical ways of mixing CNF in AC. It was decided that the best method to adopt for this investigation was dry process. According to the results, the more carbon nanotubes increase, the better asphalt concrete specifications will be. Thus sample containing 0.01 carbon nanotubes by weight of bitumen, has the best results. This sample regarding Marshal Stability 32.53 percent and Marshal Ratio 44.71 percent is higher than the control sample. Also Marshal Flow 8.4 percent and specific gravity 0.68 percent is lower than control sample. It should be noted that despite the decrease in flow, it is still within the permitted regulation. The initial cost of both samples 0.005 and 0.01 is higher than the control sample but for total cost, the amount and type of work should be investigated. When using modified mix, due to its high stability, the lower layer thickness will be less than the control mix and then the amount of total costs will decrease.

Yadykina, V.V et al. made a guess based on theoretical researches that inserting CNT into bitumen will make a positive impact on its stress-strain properties. In researchers’ opinion it may be possible because of aromatic compounds presence in bitumen connected with π-conjugated links system. It will cause the CNT and carbon amorphous particles dispersing improvement and forming theirs Table suspensions in organic solvents. These suspensions will consist of separated carbon amorphous particles and carbon nanotubes, this will cause forming a grid from nanotubes and carbon nanoparticles at asphalt-concrete and asphalt binder with improved stress-strain properties.

Ziari Hasan et al. discussed the mixing conditions of CNT with asphalt and the effect of various mixers on the CNF mixing with asphalt cement (AC). In the first stage, multi wall carbon nanotube, which its weight proportion to asphalt is three percent, and asphalt are mixed together. This mixture is divided into three smaller mixtures (samples). Each sample is mixed by using a different mixer and in different conditions. These mixers are mechanical, high shear and ultrasonic mixers similar results were observed in almost all samples mixed by the mechanical mixer. While there was a concentration of Nano materials in some parts of samples there was almost no Nano materials concentration in some other samples. This indicates that the use of the mechanical mixers, to mix Nano materials, leads to forming a heterogeneous mixture based on the materials dispersion in asphalt. In addition, it cannot prevent Nano materials from becoming agglomerated. In contrast to the provided samples by the mechanical mixer, the dispersion of Nano materials in the whole sample mixed by the high shear mixer was homogeneous. But unfortunately, this mixer, like the previous one, could not disperse Nano materials in Nano scale and these materials were dispersed in micro scale. Therefore, agglomeration of Nano materials in the sample was observed. Consequently, they normally become agglomerated and approach micro scale. Therefore, this mixer cannot separate these Nano materials from each other. For samples mixed by an ultrasonic mixer, Nano materials are observed homogeneously and separately dispersed in asphalt (without agglomeration). Also, CNT particles are separated from each other and easily recognizable.
Mojtaba Ghasemi et al. reported the potential benefits of nano-SiO2 powder and SBS for the asphalt mixtures used on pavements. Five asphalt binder formulations were prepared using various percentages of SBS and Nano-SiO2 powder. Then, Marshall Samples were prepared by the modified and unmodified asphalt binders. The results of this investigation indicated that the asphalt mixture modified by 5% SBS plus 2% nano-SiO2 powder could give the best results in the tests carried out in the current study so that this modification can increase physical and mechanical properties of asphalt binder and mixtures. The modified bitumen’s were prepared by a high shear mixer. The physical properties of the modified bitumen (such as softening point, penetration and ductility) were measured. The obtained optimum bitumen content for the control mixtures was 6.3% which was used for preparing all other modified mixes in order to maintain consistency throughout the study.

Vangari Manikunta, Gopi Sai Reddy (2018), states that, the permeable Asphalt Pavements are suited for environment in order to percolate the water into the ground for raising the ground water table which is suited for India. In this process, the pavement loses its strength. Further, it is mentioned that, in such cases, addition of fibers to asphalt mix may give the efficient results like additional strength, resistance to shrinkage splits and stability to the pavement.

P. Rajendra Kumar & P. Archana (2017), got good results on the performance of expansive soils while adding the Recron-3s fiber. By adding this fiber, there is a reduction in maximum dry density & optimum moisture content and increase in the tensile strength.

G. Pradeep Reddy, G. Tarun Krishna (2017), presented a paper giving clear information about the nature of bitumen with the addition of Recron fibers. And they show the comparison of nominal bitumen and bitumen with Recron fiber based on strength, flow value, voids filled with mineral aggregates, bulk density and unit weight.

G. Jenitha, M. Shenbagavalli (2016), in their work gave the clear information about properties of Recron fiber and advantages. They analyzed that with the addition of Recron, there is a change in strength and workability of concrete.

Muhammad Nawazish Husain, Praveen Agarwal (2015), explained about the effect of adding recron fiber to the silty soils which is situated in Kurukshetra. By adding 0.15% of Recron fiber, the CBR value had increased by 3.5% to 20.2% and with further addition of Recron fiber of 0.3%, 0.4%, and 0.6%, there is a little improvement in CBR value. With 0.15% fiber the UC value also has been increased.

Farhad Zafari, Mohammed Rahi (2014), exposed their results about by adding Nano silica to the asphalt pavement. This improves the resistance of pavement by the effect of rutting and rheological properties of asphalt binder.

Kishan Khunt (2013), concluded about the strength of the soil which may increase to certain extent by using additive materials. Especially, Recron-3s mixed with soil & fly ash mixture gave a wonderful result. Fiber absorbs everything and keeps the road surface intact and many problems are solved like pot holes, cracking and failure of pavement. Fiber plays an important role in increasing the efficiency of pavement and helps to bind the soil under the road.

2. OBJECTIVES

- To study the properties of bitumen by adding different proportions of Polyester (Recorn-3S).
- To modify the strength of the bitumen mix by using Polyester (Recorn-3S) Fiber.
- To obtain the optimum value of Recron fiber to be mixed with the nominal bitumen.

3. MATERIALS USED

Aggregate
It is a term for the mineral materials, for example, sand, rock and pulverized stone that are utilized with a coupling medium for such as water, bitumen, Portland Concrete, lime and so forth to shape compound materials. The properties of the aggregates are shown in the Table: 1

| S.NO | Test                  | Results | Acceptable value |
|------|-----------------------|---------|-----------------|
| 1    | Aggregate crushing value | 17.95%  | 30% (maximum)   |
| 2    | Impact value          | 12.725  | 10-20(strong)   |
|      |                       |         | 20-30(good)     |
| 3    | Specific gravity      | 2.91    | 2.5-3.0         |

### Polyester (Recron-3S) Fiber

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.

**Properties:**
- Tensile Strength: 4000 – 6000 kg/cm²
- Cut Length: 6mm or 12mm
- Melting Point: >250°C
- Color: White
- Source: Reliance Industries
- Cross section: Triangle
- Diameter: 35-40 micron
- Ignition temperature: >450°C

**Advantages:**
- Improves homogeneity of the concrete by reducing segregation of aggregates.
- Reduces shrinkage cracks/microcracks
- Abrasion resistance increases by more than 25%.
- Impact and shatter resistance increase by 100%.
- Increases ductility, compressive, flexural and tensile strength.
- Reduces water permeability which helps to prevent corrosion of primary steel.
- Increases energy absorption capability of concrete.
- Replaces or reduces non-structural steel in floors, roads and pavement.

### Bitumen

The bitumen used in this study is 80/100. This grade is mainly used for good flexible pavements design mixes with chips. This bitumen type has good properties. The main property of this grade is that this has more viscosity as compared to other grades.
Table 2. Bitumen Test Results & Accepted Values

| S. No. | Tests       | Results | Acceptable Values |
|--------|-------------|---------|-------------------|
| 1      | Ductility   | 74      | 65(min)           |
| 2      | Softening point | 47      | 46(min)           |
| 3      | Penetration | 80/100  | 80/100            |
| 4      | Fire        | 325     | 235(min)          |
| 5      | Flash       | 315     | 205(min)          |

Nano-Material

The extremely small things which are studied by Nano technology are known as Nano-materials. Materials with the size of $10^{-9}$m order are termed as Nano-materials. They can be of various states such as liquid form and solid. Nano-material used is Nano-silica it is of liquid form and it is brought from the Silica Ceramic Pvt Ltd, a tiles manufacturing company in DubacherlaneareaChebrolu, Eluru, Krishna district and there Nano-silica is used for fine polishing given to the tiles during manufacturing to make it glossy and give texture to the tiles and helps in increasing the service life of them.

Properties:

- A Nano-fluid is intended for use in high voltage engineering is a heat transfer fluid, containing small fraction of Nano-sized fillermaterials.
- These nanoparticles exhibit unique properties, compared to those of the same material at the bulk scale.
- The term Nano-fluid is defined as to a colloid fluid, composed of a liquid phase and dispersed Nano particles insuspension.
- The thermal conductivity was measured in the temperature range 10°C to 80°C with up to 0.1% silica Nano particles.

4. METHODOLOGY:

4.1 Using Polyester (Recron-3S) fiber

The Polyester (Recron-3S) fiber is collected and made into pieces of 2 cm length. Then aggregates properties are obtained by conducting various tests such as crushing test, impact test, specific gravity, water absorption and abrasion test.

4.2 Aggregate Impact Test

The aggregates that pass through 12.5 mm and 10 mm with pan below the sieves are taken and the aggregate which retained on 10 mm sieve is collected. 1/3rd of the cylinder is filled with aggregate and tampered with tamper rod for 25 times. Again the cylinder is filled up to 2/3rd level with aggregate and tampered. The cylinder is placed at the bottom of the impact machine and hammer is lifted up to 300 mm and it was dropped freely until 15 blows. After this, the aggregate is passed through 2.36 mm sieve and readings are noted.
4.3 Crushing Test
Aggregates which retain on 10 mm sieve are collected and the cylinder is filled by 1/3 proportion giving tampering of 25 times. Then it is placed in the crushing machine and the load of 50 tonnes, 5 tonnes per minute is applied. Then, the aggregates are sieved on 2.36 mm sieve and readings are noted.

Specific Gravity
Aggregates are collected and placed in the wire basket and the aggregates are immersed into water and kept for 24 hours. After that, the aggregates are cleaned by using cloth and readings are noted.

4.4 Penetration Test
The bitumen sample is heated and then cooled for 24 hours. The bitumen mould is placed on the bottom base of penetration machine and the time is set. The reading is noted from the instrument.

4.5 Softening Point
The bitumen is placed in the rings and fixed well and the ball is placed and the whole apparatus is put in to the water bath and temperature is switched on. At certain temperature, the ball penetrates through the bitumen and touches the bottom the lid.

4.6 Marshall Mix Design
Marshall Mix design is used to find the optimum binder content of the bitumen, Stability, flow value and bulk density for the bitumen content.

- Different types of aggregates are selected for grading by using MORTH table.
- First, we need to assemble the mould with a base plate and we need to apply sum lubricate.
- Before that we need to sieve the aggregate as per the MORTH table.
- Then, sample of aggregate is taken as per the MORTH table and heated up to certain temperature by using pan.
- The bitumen content is added to the sample and mixed thoroughly and taken into the mould immediately.
- 75 blows are given on both sides of the sample mechanically or manually.
- The sample is ideally put for 24 hours and then removed from the mould.
- The water bath is taken at 60 degrees for the sample and the surface of the sample is cleaned.

Then marshal stability test is done and readings are noted down. Using Nano-silica

- This project aims to study the improvement in properties of modified bitumen, by adding nanomaterial as a percentage of weight.
- The effect of Nano-materials (Nano-silica) is examined. To Examining the Performance of Hot Mix Asphalt Using Nano-Materials achieve the optimum content, five different percentages of Nano-silica (1, 3, 5, 7, and 9%) will be mixed with bitumen.
- Nano-silica will be mixed with bitumen using two different methods: (i) using the mechanical mixer and/or (ii) using the hand mix as shown in Figure (1); the better method later determined through results.
- A variety of tests are carried out on all samples to study potential improvement. Tests that will be conducted are the penetration test, viscosity test and softening point, ductility test and flash and fire point test. The Marshall test will be carried out on specimen prepared by finding the optimum bitumen content of modified bitumen of dry aggregate weight.
- Unconfined compression tests are also carried out on the optimum percent of the Marshall specimen to obtain the stress-strain curve, accordingly.
- The test procedure will be carried out after mixing bitumen with Nano material (Nano-silica) and filling it in the mould and the properties will be checked.
- Then the results will be compared for that of normal asphalt to modified bitumen and properties that are enhanced and useful to increase the service life of bituminous pavements will be known.
5. RESULTS AND DISCUSSION:

Using Polyester (Recron-3S) fiber

5.1.1 Nominal Mix

With the utilization of various proportions of aggregates of various sizes, the voids in the mix got reduced giving more stability to the mixture. The various sieve sizes taken for getting the required quantity of aggregate and weights are as follows: e.g.: for 5% of bitumen.

Table 3. Sieve Sizes & Aggregate

| Sieve sizes | Aggregate weight taken |
|-------------|------------------------|
| 5% of       | 5.5% of                | 6% of                |
| 10          | 60                     | 120                  | 60       |
| 8           | 120                    | 120                  | 120      |
| 6.3         | 240                    | 180                  | 120      |
| 4.75        | 240                    | 180                  | 240      |
| 2.36        | 300                    | 300                  | 360      |
| Filler      | 240                    | 300                  | 300      |
| Total weight| 1200                   | 1200                 | 1200     |

5.1.2 Weights of Material

The bitumen content is taken as per the total weight of the aggregate 1200 grams.

5% of Bitumen = (1202.327*5)/100 = 60 grams.

5.5% of Bitumen = (1200*5.5)/100 = 66 grams.

6% of Bitumen = (1200*6)/100 = 72 grams.

The fiber % is taken as per the total bitumen for each sample that is:

Table 4. Fibre % and weights taken

| S.NO | BITUMEN (%) | FIBER (%) | WEIGHT OF FIBER TAKEN (gms) |
|------|-------------|-----------|-----------------------------|
| 1.   | 5           | 3         | 1.80                        |
|      |             | 6         | 3.60                        |
|      |             | 9         | 5.40                        |
|      |             | 12        | 7.20                        |
| 2.   | 5.5         | 3         | 1.98                        |
|      |             | 6         | 3.96                        |
|      |             | 9         | 5.94                        |
|      |             | 12        | 7.92                        |
| 3.   | 6           | 3         | 2.16                        |
|      |             | 6         | 4.32                        |
|      |             | 9         | 6.48                        |
|      |             | 12        | 8.64                        |

5.1.3 Marshal Tests on Various Mixes

Various Mix types, their propositions and the obtained values of unit weight, stability, flow, percentage of air voids and percentage of voids filled by bitumen are as follows:

Table 5. Mix Types and the Values Obtained

| Mix | Bitumen (%) | Flow (mm) | Marshal stability (KN) | Unit wt. (g/cm²) | % of Air Voids | % of voids filled |
|-----|-------------|-----------|------------------------|------------------|----------------|------------------|
| C   | 5           | 4         | 10.35                  | 2.56             | 5.72           | 68.39            |
5.2.1. Nominal mix:
The various sieve sizes required for the mix are taken as follows..

| Materials    | Aggregate weight taken (gms) |
|--------------|------------------------------|
|              | 5%  | 6%  | 7%  |
| 12mm         | 336 | 336 | 336 |
| 6mm          | 336 | 336 | 336 |
| Stone dust   | 480 | 480 | 480 |
| Cement       | 48  | 48  | 48  |
| Bitumen      | 60  | 72  | 84  |

5.2.2. Nano-silica addition:
In this project we had followed wet process i.e. Nano-silica is binded or mixed with the bitumen content at different proportions. The Nano-silica content is increased by decreasing the bitumen content. For 1200 grams, the 5.55% OBC = 66.6 grams

For 1% Nano-silica content

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

| Requirements | Sam 1 | Sam 2 | Sam 3 | Avg |
|--------------|-------|-------|-------|-----|
| Height (cm)  | 6     | 6.1   | 6     | 6   |
| Diameter (cm) | 10.0 | 10.2 | 10.1 | 10.1 |
|--------------|------|------|------|------|
| Volume       | 471 cc | 498.19 cc | 480.46 cc | 483.21 cc |
| 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 | 2.30 | 2.27 |
| Vv (%)       | 4.18 | 6.27 | 3.76 | 4.73 |
| Vb (%)       | 12.10 | 11.84 | 12.15 | 12.03 |
| VMA          | 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

_For 3% Nano-silica content:_

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

| Requirements | Sample 1 | Sample 2 | Sample 3 | Average |
|--------------|----------|----------|----------|---------|
| Height       | 5.9 cm   | 6.1 cm   | 6.0 cm   | 6.0     |
| Dia          | 10.1 cm  | 10.1 cm  | 10 cm    | 10.05   |
| Volume       | 472.45 cc | 488.47 cc | 471 cc  | 477.3   |
| Air weight   | 1240 gm  | 1253 gm  | 1249 gm  | 1247    |
| Weight in water | 725gm      | 706gm      | 712gm      | 714    |
| Unit weight  | 2.62 g/cc | 2.56 g/cc | 2.65 g/cc | 2.61 g/cc |
| Gt           | 2.40     | 2.40     | 2.40     | 2.4     |
| Gm           | 2.35     | 2.29     | 2.32     | 2.33    |
| Vv           | 2.08%    | 4.58%    | 3.33%Z   | 3.33%   |
| Vb           | 12.17%   | 11.86%   | 12%      | 12.01%  |
| VMA          | 14.25%   | 16.44%   | 15.33%   | 15.34%  |
| VFB          | 85.4%    | 72.14%   | 78.28%   | 78.60%  |
| Marshall value | 395 div | 360 div | 390div | 381.66div |
| 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

For 5% Nano-silica content:

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

| Requirements    | Sample 1  | Sample 2  | Sample 3  | Average |
|-----------------|-----------|-----------|-----------|---------|
| Height          | 5.9 cm    | 6.2 cm    | 6.1 cm    | 6.1     |
| Diameter        | 10.2 cm   | 10 cm     | 10 cm     | 10.06   |
| Volume (cc)     | 481.86    | 486.7 cc  | 478.85 cc | 482.47  |
| Air weight (gm) | 1256 gm   | 1240 gm   | 1250 gm   | 1248.66 |
| Weight in water | 725 gm    | 730 gm    | 709 gm    | 721.33  |
| Unit weight (g/cc)| 2.60 g/cc| 2.54 g/cc| 2.61 g/cc| 2.58 g/cc|
| Gt              | 2.39      | 2.39      | 2.39      | 2.39    |
| Gm              | 2.36      | 2.38      | 2.31      | 2.33    |
| Vv              | 1.25%     | 0.418%    | 3.34%     | 1.67%   |
| Vb              | 12.09%    | 12.19%    | 11.83%    | 12.03%  |
| VMA             | 13.34%    | 12.60%    | 15.17%    | 13.70%  |
| 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

For 7% Nano-Silica Content

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

| Requirements    | Sample 1  | Sample 2  | Sample 3  | Average |
|-----------------|-----------|-----------|-----------|---------|
| Height          | 6.1 cm    | 6.1 cm    | 6.0 cm    | 6.05    |
| Diameter        | 10.1 cm   | 10 cm     | 10.1 cm   | 10.05   |
| Volume (cc)     | 488.47    | 478.85    | 480.46    | 482.5   |
| Air weight (gm) | 1242      | 1256      | 1240      | 1246    |
| Weight in water | 698       | 715       | 705       | 706     |
| Unit 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      | 2.30    |
| Vv %            | 2.98      | 1.30      | 1.82      | 2.03    |
| Vb %     | 11.55 | 11.75 | 11.07 | 11.67 |
|----------|-------|-------|-------|-------|
| VMA%     | 14.53 | 13.05 | 13.52 | 13.70 |
| 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

For 9% Nano-Silica Content

Required Nano-silica content = 5.69g and bitumen content = 63.27

| Requirements | Sample 1 | Sample 2 | Sample 3 | Average |
|--------------|---------|---------|---------|---------|
| Height       | 6.1 cm  | 6.1 cm  | 6.2 cm  | 6.133   |
| Dia          | 10.2 cm | 10.2 cm | 10.1 cm | 10.1    |
| Volume       | 498.19 cc | 498.19 cc | 496.48 cc | 497.62 |
| Air weight   | 1291gm  | 1285gm  | 1280gm  | 1285.33 |
| Weight in water | 720gm | 727gm | 732gm | 726.33 |
| Unit weight  | 2.59 g/cc | 2.57 g/cc | 2.57 g/cc | 2.57 g/cc |
| Gt           | 2.40    | 2.40    | 2.40    | 2.4     |
| Gm           | 2.26    | 2.30    | 2.33    | 2.296   |
| Vv           | 5.83%   | 4.16%   | 2.91%   | 4.30%   |
| Vb (%)       | 10.78   | 10.97   | 11.11   | 10.95   |
| VMA(%)       | 16.61   | 15.03   | 13.88   | 15.17   |
| VFB(%)       | 64.90   | 72.98   | 80.04   | 72.64   |
| Marshall value (div) | 480 | 465 | 500 | 481.66 |
| Flow value (div) | 390 | 334 | 382 | 368.66 |

For Marshall Value 481.66 div = 2116.16 kg
Flow value for 386.66 div = 3.68 mm

5.2.3: Marshall Stability test

The average values that are obtained are...

| Nano-silica (%) | 1  | 3  | 5  | 7  | 9  |
|-----------------|----|----|----|----|----|
| Marshall stability (kg) | 1588.58 | 1676.84 | 2152.80 | 2782.52 | 2116.16 |
| Flow value (mm) | 3.8 | 4.26 | 2.77 | 2.55 | 3.68 |
| Air voids (%) | 4.75 | 3.33 | 1.67 | 2.03 | 4.30 |
| Unit weight (g/cc) | 2.59 | 2.61 | 2.58 | 2.62 | 2.57 |
6. CONCLUSION:

1. The unit weight is more for nominal mix as compared to the modified bitumen whereas in modified bitumen, the unit weight is least for the mix-3 proportion.

2. The void percentage is more for the nominal bitumen mix when compared to the modified bitumen mix. The least percentage value of voids is 2.66%.

3. Void in the nominal mix is mostly filled by bitumen where as in modified bitumen; the voids are filled by bitumen and fiber. Hence, the bitumen percentage for filling voids is less when compared to nominal mix.

4. The flow value is more for the nominal mix whereas the modified bitumen is having much lesser flow value. In nominal mix, the maximum flow value is 4.1mm whereas in modified bitumen mix flow value is 3.1mm.

5. 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.

6) The optimal percentages for Nano-silica is 7%.

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 shear mixing.

8) A 7% Nano-silica increases softening by 9.52% in case of mechanical mixing and by 11.9% in case of high shear mixing. 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.

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

10) Mixing Nano-silica using a mechanical mixer or hand mixer gives the same results a homogenous mixture with no agglomeration of Nano.

Among the 2 materials that are added, Nano-silica gave the more stability when compared to the fiber. The optimum Bitumen content obtained is 5.55%. For this OBC, different proportions of Nano-silica is added and compared with the bitumen specimens. Nano-silica will increase the melting point of the bitumen. The use of the innovative technology not only strengthens the road construction but also increases the road life as well as help to improve the environment and creating a source of income. Use of Nano-silica in pavement construction would be a boon for India’s hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes.

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