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Influence of TiO_2 nanoparticles blends on properties of Asphalt

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ABSTRACT

Nanotechnology is the most versatile field because its application covers science, research and technology. Nanomaterial's enhanced surface to volume ratio has shown different properties from bulk materials. The aim of this study to investigate the properties of asphalt by blending it with TiO_2 nanoparticles. TiO_2 nanoparticles are fabricated by hydrothermal method and well characterized by X-ray diffraction technique.Tio_2 nanoparticles (1.0 % by weight) were added in asphalt. The mixture was homogeneous by stirring mechanically at 163^0C. The following rheological properties like penetration, softening point and ductility of asphalt were measured with and without doping of TiO_2 nanoparticles at laboratory scale. The results of the experiments indicated that the addition of TiO_2 nanoparticles was helpful in increasing the hardness, viscosity grade and ductility of the binder.

KEYWORDS

Hydrothermal method;
Penetration properties;
Softening point;
Ductility;
Viscosity grade.

INTRODUCTION

Asphalt (or bitumen) usually is a byproduct of crude oil refining process in petroleum refineries, and it is a complex heterogeneous mixture of hydrocarbons[5]. It is used in road pavements as the binder of aggregates in a great extent all around the world. Asphalt pavements must undergo heavy loads and unfavorable environmental conditions for an acceptable period of time. High-temperature rutting and low temperature cracking are the most considerable limitations of unmodified and pure asphalts[4]. Therefore, modification and reinforcement of asphalt binder is necessary.

Nanotechnology is a relatively new field in science dealing with structures that are on the nano-scale. Nano-sized particles have been used innumerous applications to improve various properties. However, due to many reasons including the cost of production and purification, nano-sized particles have seen very little use in the construction field. One of the nano-material is TiO_2 nanoparticles which is very versatile compound used in photo-voltaic cell, photo-catalyst and water-treatment[1].

This present work, report the effect of TiO_2 nanoparticles blends on properties of asphalt. Basically we are finding the binding property of the TiO_2 nanoparticles.

EXPERIMENT SECTION

Synthesis of TiO_2 nanoparticles

TiO_2 powder (99.9% purity) were purchased from Merck. Sodium hydroxide (Sodium Hydroxide pellets) from Merck and Hydrochloride acid (HCl, 37%) were used to prepare TiO_2 nanowires. In this experiment TiO_2

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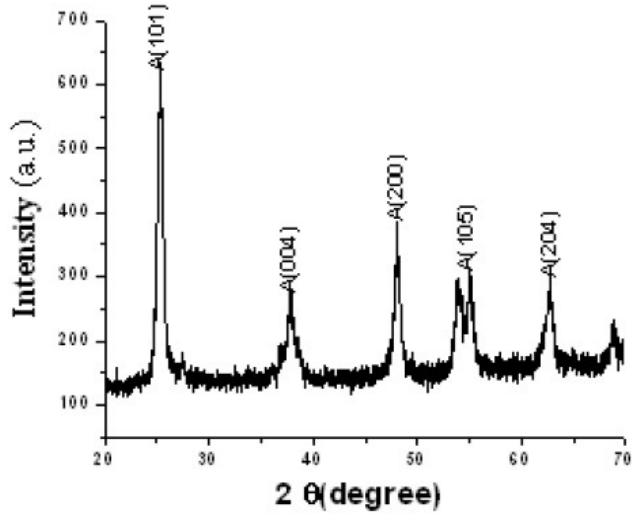

Figure 1 : XRD Pattern of TiO_2 nano particles

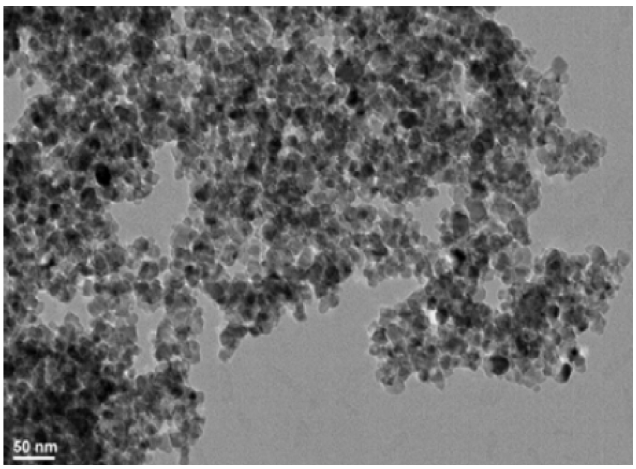

Figure 2 : TEM Images of TiO_2 nano particles

nanoparticles were fabricated by hydrothermal method. The precursors was prepared by adding of 4 gram of TiO_2 powder to 400 ml of 10M NaOH aqueous solution and stirring of 10 min. The solution beaker was tightly closed by aluminum foil and heated at 150 °C for 6 hour without stirring. Now solution was allowed to cool at room temperature. The whiteprecipitates was collected by centrifugation and thoroughly neutralized with 0.1 M HCl and maintained the pH approximately near 7 by using the deionized water then samples were dried at 120°C for 2 hour. The as-prepared nanoparticles were annealed at temperature 550°C in heat oven for 2 hour.

Characterization of TiO_2 Nanoparticles

The crystallite phase and lattice of TiO_2 nanoparticles were determined by X-ray diffraction spectroscopy using an X-ray diffractometer with CuKα radiation in the range of 20-90° by step scanning with 2r increment of 0.02° (λ=0.154nm) and a fixed counting time of 5sec/ step. The morphologyand size of particles were determined by transmission electron microscopy (TEM.JEOL, JEM-2010)with an accelerating voltage of 200kV.Crystallite size was obtained by Debye-Scherrer's formula and found average size of TiO_2 nanoparticles was 13nm.

Method of blending of TiO_2 nanoparticles in asphalt

Virgin Asphalt binders was used to blend with TiO_2 nano particles in this study. The Dosage Percentages (1.0% by weight of binder) ofTiO_2nano particles were employed and these particles was blended with virgin asphalt binder. Approximately 100 grams of asphalt binder were poured into a 140 ml glass beaker, and

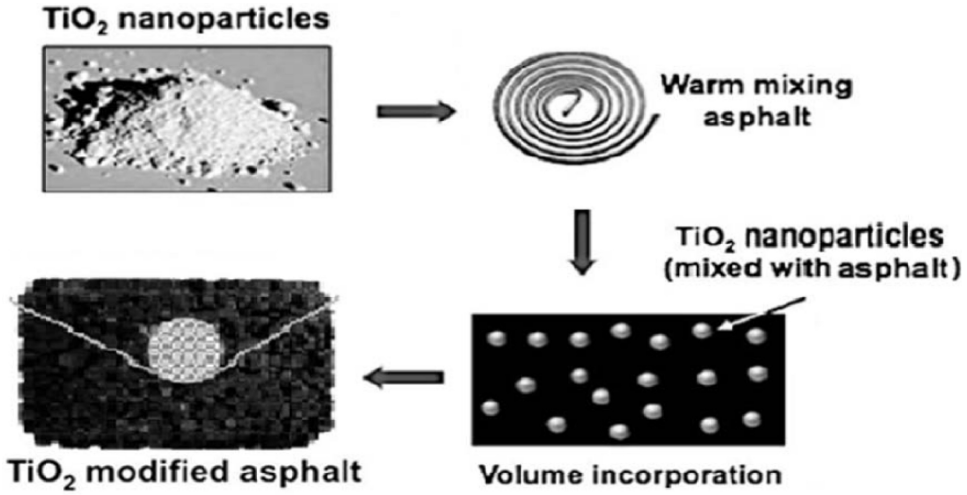

Figure 3 : Image of blending of TiO_2 nanoparticles in the virgin asphalt

then TiO_2 nano particles was added into beaker. And then these materials were heated to 163°C (325 °F) on a hot plate and were blended homogenous manually up to 30 min in the laboratory.

Penetration test

Penetration test is the most commonly adopted test on bitumen to determine the grade of the material in term of its hardness because of its simplicity. The penetration grade of bitumen binder are generally denoted as 80/100, 60/70 or 30/40 grade bitumen. The apparatus is used in the penetration is penetrometer. The penetration unit contain of a straight, polished cylindrical stainless steel needle and range of this needle is 0 to 40mm. Figure 4. Illustrated, the value of penetration is increase of TiO_2 nanoparticles modified binder in compare to unmodified binder.

Softening point test

Softening point is essentially the temperature at which the bituminous binder material have an equal viscosity. The softening point of the asphalt is therefore related to the equi-viscous temperature (e.v.t). The softening point found by the ring and ball apparatus is approximately 20°C lower than the e.v.t. The ring and ball unit contain steel balls,ball centring guides, ring holder, bottom plate and beaker cover with support rods thermometer and heater separately. Figure 5. Illustrated, the value of penetration is increase of TiO_2 nanoparticles modified binder in compare to unmodified binder.

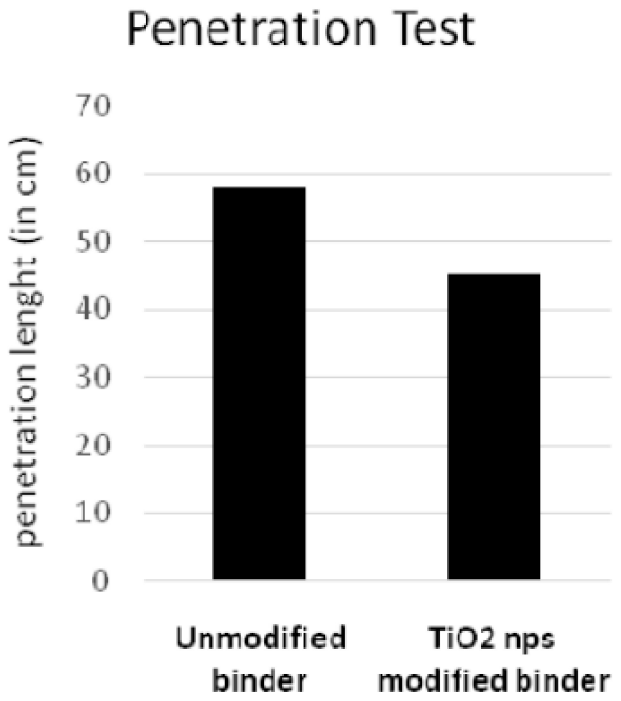

Figure 4 : Graphically comparison of penetration value of binder with or without TiO_2 nanoparticles

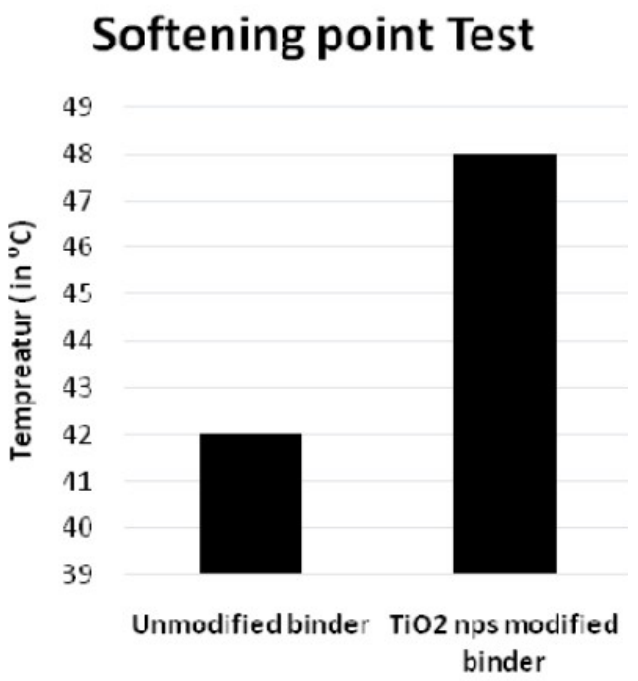

Figure 5 : Graphically comparison of softening point value of binder with or without TiO_2 nanoparticles

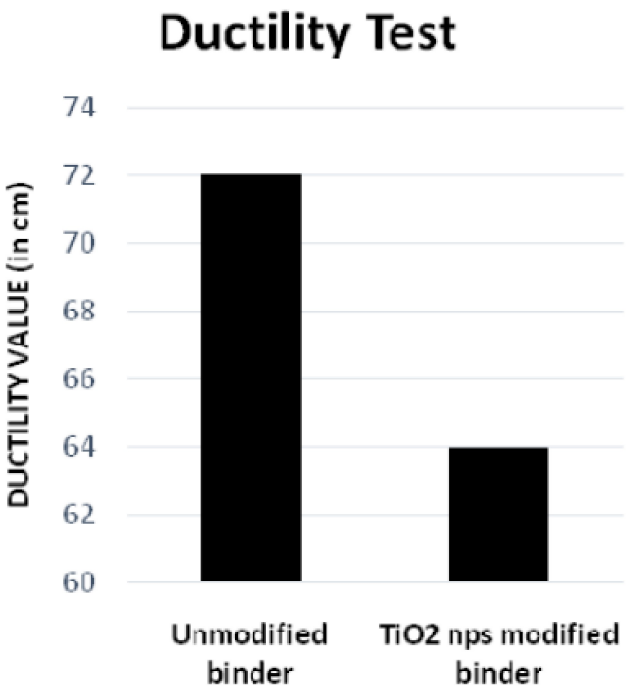

Figure 6 : Graphically comparison of ductility value of binder with or without TiO_2 nanoparticles

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Ductility test

Ductility test is the test which determine the ability of a material to stretch before breaking. It is desirable that the bitumen binder used in the bituminous mixes from ductile thin film around the aggregates. This serves as a satisfactory binder in improving the physical interlocking of the aggregates. Ductility test apparatus consist of items like sample (briquette) moulds water bath square-end trowel or putty knife sharpened on end and ductility machine. The test conducted at 27±0.5°C. The maximum travel length is 150 cm. and maximum traction speed is 5 cm/min. Figure 6. Illustrated, the value of penetration is increase of TiO_2 nanoparticles modified binder in compare to unmodified binder.

CONCLUSIONS

In this limited study, the penetration test results indicate that, as expected, the addition of TiO_2 nano particles increased the penetration values of asphalt binders, tested in this research work, Penetration grade were changed from 50/60 to 40/50 its means property reduced by 12% which shows the hardness has increased. And hardness property of asphalt is used in the heavy traffic volume road and airport runways.

The addition of TiO_2 nano particles has a significant effect on Softening point of the binder and it is increase by 12% which shows degree of softening has increased which is beneficial in warmer region.

Ductility test results show that the addition of a TiO_2 nano particles results in a decrease the ductility of asphalt binder. Ductility decreases by 9.3% which shows the minimum deformation, so minimum cracking of road surface will occur.

In summary, the research findings show that the addition of TiO_2 nanoparticles in asphalt binders tested in this research program improves some of the rheological properties such as penetration values, Softening point and Ductility value because it fill the void of asphalt due to its nano-size and create a bond between oxygen and emulsion of asphalt. This technology may be used for further research in asphalt pavement area.

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