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A Review on Study of the Behavioral Similarities Between Marshal Stability and Indirect Tensile Strength Values in Bituminous Concrete Containing Carbon Black and Cement

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ABSTRACT: *The problems of rusting, displacement, cracking, distortion, and fatigue concern pavement engineers. ITS is used to determine the tensile properties of bituminous mixes as well as Marshall Stability tests to determine their compressive characteristics. For preparation of bituminous concrete samples using aggregates, carbon black and cement as filler material. There have been several studies on Marshall Stability and ITS separately, but they have not been studied together. In this proposal, an effort is made to examine their behavioral similarities. Research on this topic will also determine if Marshall Stability values correlate with Indirect Tensile Strength values for Bituminous Concrete. In this research were determine stability values as well as tensile values at temperature 60^{0}C for Marshall technique and 25^{0}C for ITS. It will also determine if these tests are appropriate for mix design. In the study, guidelines will be provided to the designer to establish the relevance of conducting both tests*.

Key Words: Carbon Black, Cement, ITS, Marshal Stability and Bituminous Concrete

1. INTRODUCTION

India is the second largest country in the world which has largest developing economy. Due to the increase in traffic, wear and tear of the pavement is increasing day by day. "The life of bituminous pavement and quality of riding surface get decreased. Durability of roads also decreases if there are extreme changes in weather, high rainfall intensity, adverse terrain condition and poor subgrade of soil conditions. Attempts are therefore being made to make durable pavements. Therefore, for increasing the pavement life, different types of stabilizing additives like carbon black, cement, fibers, rubbers, polymers, fly ash, artificial silica, and brick dust or a combination of these materials and modifiers such as polymers and fibres can be used. So, in present days, for enhancing the durability of roads, different types of fillers are using in bituminous mix at very fast rate. A good and long-lasting road network requires proper planning, designing, construction and maintenance approach. India has the world's second largest road network. According to the National Highways Authority of India, roads carry approximately 64% of freight and 79% of passenger traffic. National Highways carry approximately 40% of total road traffic, despite covering only about 2% of the road network. With the country's cities, towns, and villages having better connectivity over time, road transportation has gradually increased. Average growth of the number of vehicles per annum has also been increasing over recent years affecting the performance of the pavement. Research activities are continuously carried out in order to enhance the properties of bituminous mix enable flexible pavements to meet the present challenges. In a developing country like India, it is necessary to provide cost-effective solutions. Therefore, there is vast scope and need to improve the properties of bituminous pavement. The Marshall Stability of bituminous materials refers to their resistance to stresses that cause distortion or displacement. Bituminous pavement occasionally experiences heavy traffic loads, so it's important to use bituminous material with good stability and flow. The effect of traffic load over long period could affect the strength of an asphalt mixture showing early signs of fatigue cracks. To determine this damage is commonly used the Indirect Tensile Strength (ITS). Though much research has been done on Marshall Stability and Indirect Tensile Strength using various agents and filler materials, but no comparative study has been done in this regard. Marshall Stability Test works on compressive loading and ITS test being Indirect Tensile load also works on compression load. Therefore, it is a matter of concern if ITS test is relevant with respect to Marshall Stability".

1.2 Marshall Stability Test

"In this method, a compacted cylindrical specimen of bituminous mixture is loaded diametrically at a deformation rate of 50 mm per minute and the

resistance to plastic deformation of the specimen is measured. The Marshall stability of the mix is determined by the maximum load that the specimen can support at a standard test temperature of 60 °C. The corresponding deformation at maximum load is the flow value. Finding the optimum binder content for the type of aggregate mix being used while satisfying other criteria is the prime objective of this test".

1.3 Indirect Tensile Strength Test

"In the laboratory, a cylindrical specimen is loaded with a single compressive load that acts parallel to and along the vertical diametric plane. The Marshall method of mix design for dense bituminous macadam is used to prepare test specimens at the optimum bitumen content. Each specimen is tested at the temperature 250C to determine. Their Indirect Tensile Strength achieved by using breaking head under a load applied at a rate of 50 mm per minute. Guidelines in ASTM D6931and ASTM D1074 code for indirect tensile strength test are applicable". The load at failure recorded and ITS is computed by using this formula which is given below:

$$\sigma x = 2P/\pi Dt$$

σx = Horizontal tensile stress / tensile strength, N/mm2

P = Failure load, N

D = Diameter of the specimen, mm

t = Height of the specimen, mm

2. NEED AND SCOPE OF STUDY

"Though much research has been done on Marshall Stability and Indirect Tensile Strength using various agents and filler materials, but no comparative study has been done in this regard. Marshall Stability Test works on compressive loading and ITS test though being Indirect Tensile load, also is derived from compression load. Therefore, it is a matter of concern if ITS test results have correlation with respect to Marshall Stability. This study is a advancement of earlier research in a way that here it is finding behavioral similarity between Marshall Stability and Indirect Tensile Strength values as it will tell relevance of ITS test for the bituminous mixe"s.

3. OBJECTIVES OF STUDY

1. To determine the optimum binder content of the bituminous mixes namely Bituminous Concrete (BC).
2. To evaluate the behavioral similarities of addition of Carbon black and Cement on Stability, Flow, Density and other Properties of mixes e.g., VMA, VFB, and Air Voids for BC.
3. To determine the changes if any in optimum binder content BC on account of addition of Carbon black and Cement in BC.
4. To find out the Indirect Tensile Strength value for BC for VG-30 grade bitumen.

4. LITERATURE REVIEW

Galooyak Saeed Sadeghpour (et.al) "studied the effect of carbon nanotube on the rheological properties of bitumen. In this study, different contents of carbon nanotube are used for the modification of the conventional bitumen. For the samples prepared by the ultrasonic mixer, it is observed that the agglomerated Nano-materials are peeled off and uniformly dispersed in bitumen. Then classical experiments of bitumen, x ray analysis, and rheological tests using Dynamic Shear Rheometer, were conducted on the modified bitumen. Master curves are plotted, and the results depicted that addition of 1.2 % by weight of carbon nanotubes to the bitumen have improved rheological properties of bitumen at high and low temperature service, significantly. Also, addition of nanotube increased the stiffness and reduced the phase angle of base bitumen. So, the use of carbon nanotubes as additives has significantly improved the classical properties of bitumen (softening point, penetration, etc.) and performance of modified bitumen compared to base binder" [1].

Khodary Farag (et.al) "explained the mechanical properties of modified asphalt concrete mixtures using $Ca(OH)_2$ as nanoparticles. $Ca(OH)_2$ nanoparticles were synthesized by sol.gel method and analyzed by XRD and TEM. The effect of Ca $(OH)_2$ nanoparticles on the mechanical properties of unmodified and modified asphalt concrete mixtures was investigated. The results showed significant improvement on both physical and mechanical properties of modified asphalt concrete mixtures. The addition of 5% Ca $(OH)_2$ nanoparticles decreases the penetration grade of the blend by nearly 30 %. Softening point was increase by 15 °C (45 %) and the viscosity was decreases by 7%. Unmodified specimens had the lowest value of indirect tensile strength, while $Ca(OH)_2$ nanoparticles modified asphalt concrete mixtures has the highest value of indirect tensile strength specially at modification level 4%. The modified asphalt concrete mixtures with 5% have a higher increase of compressive strength. Finally the modified asphalt concrete mixtures with Ca $(OH)_2$ are preferable to be used in hot climate as well as heavy

traffic load area. From the results of various test using Ca (OH) $_2$ nanoparticles can improve road mechanical properties, including rutting resistance and enhance bitumen performance to resist high traffic loads" [3].

Kumar M. Veerendra (et.al) "did the comparative study of wet and dry blending of plastic modified bituminous mix used in road pavements. Utilisation of waste plastics in bituminous road pavements have been investigated currently under two types of blending namely wet mix and dry mix. In this study engineering properties of WM & DM is evaluated. The optimum bitumen content determined in terms of Marshall Stability test was found to be 4.98%. The enhancement in the performance was obtained at 8% partial replacement by waste plastic in both WM & DM. In comparative study of WM & DM, DM is better option to improve the performance of road pavements in terms of its fatigue, strength, stiffness by utilization of waste plastics. Utilization of plastic waste is found to be an eco-friendly solution for waste disposal and economy in pavement construction".[5].

Patil S.B (et.al) "studied the influence of imperial smelting furnace slag aggregate on properties of bituminous mixes**.** He investigated the feasibility of using this slag aggregate in bituminous binder course mixes. The Marshall method was used to design control bituminous mixes and evaluate the potential performance of these ISF slag aggregate bituminous mixtures. The investigation of different bituminous mixes including DBM and BC was done with replacement of natural aggregates by ISF slag from 5% to 25%, at different binder contents. The properties of these mixes such as bulk density, stability, void content, void in mineral aggregate and voids filled with bitumen were determined. Leachate analysis was also done on bituminous mixes containing ISF slag. The result indicates that ISF slag aggregate can successfully employed in bituminous binder course mixes. Replacement of 20% sine aggregates by ISF slag in bituminous concrete and dense bituminous macadam mixes satisfies all the requirements of MORTH Specifications. Economy is achieved in saving the crusher broken fine stone aggregates to the extent of fuel, electricity, mechanical energy etc. The disposal problem of waste is also minimized in an environmentally acceptable manner".[6]

Raghuram K.B. (et.al) "studied the performance evaluation of stone matrix asphalt using low cost fibres. SMA is hot mix asphalt which provides better resistance to rutting. SMA is coarse aggregate skeleton with higher binder content, even though the use of higher binder content improves the durability of the mix, it will also lead to asphalt draindown. Cellulose fibre has been used to reduce the draindown of asphalt from SMA mixes. This investigation considers the use of various low-cost stabilizers & also high viscosity binders as draindown retarders. The performance of mix is evaluated in terms of stability & the resistance to rutting. The stability of SMA is checked by using the standard Marshall procedure. The rut depth is captured using wheel track test setup where rut depth achieved after 20,000 repetitions is used to evaluate the performance of SMA mixes. SMA mixes stabilized with FERP exhibit lower draindown than the SMA mixes with other fibres. FERP & jute fibres resulted in higher stability values when compared to other fibres. Jute fibres are effective in resisting the permanent deformation when compared to all other fibres used in this study. Jute & FERP might replace the high-cost cellulose fibres in SMA mixes".[7].

Ranadive M.S. (et.al) "studied the enhancing stability of flexible pavements using plastic waste and fly ash. The use of national thermal power plant by product fly ash instead of mineral filler and waste plastic from solid waste in DBM was investigated. The Marshall stability and flow values have been determined to evaluate the strength and deformation characteristics. Marshall Properties of mix with fly ash are on lowering side as compared to mix with fly ash and plastic. Marshall test conducted on bituminous mix with 5% fly ash have maximum stability value of 1560 kg, correspondingly the values of flow is 2.3, Percentage air voids is 4.2%, VMA is 13.4% & VFB is 68.2%. Also Marshall test conducted on bituminous mix with combination 5% fly ash & 2% plastic waste have higher value of stability 1700 kg, correspondingly the values of flow is 2.4, percentage air voids is 3.9%, VMA is 13.1% & VFB is 70.0%. Marshall Test conducted on bituminous mix with the combination of 2% plastic & 5% fly ash have the values of stability, flow, percentage air voids, VMA & VFB are within the limits of specifications given by MORTH. But these results are based on lab performance; field studies in future will substantiate the result".[8].

Satyakumar M. (et.al) "determined the texture depth for sand mix asphalt modified with sulphur, slurry & flyash. The safety & riding quality depends on surface texture (macro texture), which influences water dispersal & ability of tire to contact the road surface. This paper deals with the texture depth contribution to tire pavement contact. Three test stretches, each having a length of 275m was made for study by adding mineral fillers such as flyash, slurry & sulphur with beach sand & bitumen at different combination. A stepwise regression analysis was used, to indicate the separate & distinct effect of several mixture properties such as percentage of air voids, flow value & unit weight on the texture depth of the experimental surface mixtures along with the skid resistance. The result of investigation showed that sand mix asphalt mix modified with mineral fillers

such as sulphur, slurry & flyash exhibits superior surface characteristics compared to conventional dense mix. The texture depth has not much significant effect on skid resistance of sand asphalt mixes, which are considered for the investigation".[9].

Tewari Y.C. (et.al) "studied the role of nanotechnology in highway engineering. It deals with understanding, controlling & manipulating matter at the level of individual atoms & molecules in the range of 0.1-100nm & creating materials, devices & system with new properties and functions. In this study the innovation of relevant nanotechnology and its impact on highway engineering practice is introduced for broadening vision and inspiring the creativity of highway engineering. Addition of nano scale materials into cement could improve its performance. Carbon nano tubes may be applied to improve mechanical properties of cement. The addition of nano particles in asphalt improves mechanical performance, durability, reflectivity & skid resistance, better binding, quicker curing, better maintenance & sustainability. Although the cost of nanotechnology-enabled materials and devices may hinder their widespread application for highway engineering at the current stage, their price is expected to drop in the near future. In addition, the benefits from nanotechnology's application could justify the additional cost. However, the useful improvements that nanotechnology might bring highway infrastructure could be minimized if there is lack of appropriate vision and awareness".[10]

Shunyashree et al. (2013) "study of the effect of use of recycled materials on Indirect Tensile Strength of asphalt concrete mixes. For the laboratory investigations reclaimed asphalt pavement (RAP) from NH-4 and crumb rubber modified binder (CRMB-55) was used. Foundry waste was used as a replacement to conventional filler. Laboratory tests were conducted on asphalt concrete mixes with 30, 40, 50, and 60 percent replacement with RAP. These test results were compared with conventional mixes and asphalt concrete mixes with complete binder extracted RAP aggregates. Mix design was carried out by Marshall Method. The Marshall Tests indicated highest stability values for asphalt concrete (AC) mixes with 60% RAP. The optimum binder content (OBC) decreased with increased in RAP in AC mixes. The Indirect Tensile Strength for AC mixes with RAP also was found to be higher when compared to conventional AC mixes at 300C" [11].

Erarslan N. & Williams D.J. (2011) "investigated the effect of cyclic loading on the Indirect Tensile Strength of rocks. This paper presents the results of laboratory experiments during the investigation of the stress–strain characteristics of Brisbane tuff disc specimens under diametral compressive cyclic loading. The ITS of Brisbane tuff disc specimens was measured using the Brazilian tensile strength test. The reduction in ITS was found to be 33% with sinusoidal loading tests, whereas increasing cyclic loading caused a maximum reduction of 37%. It is believed that the fracturing under cyclic loading starts at contact points between strong grains and weak matrices and that contact points at grain boundaries are the regions of stress concentration (i.e., indenters). Trans granular cracks emanate from these regions and inter granular cracks sometimes pass through the contact points. Once cracking begins, there is a steady progression of damage and a general 'loosening' of the rock, which is a precursor to the formation of inter granular cracks".[12].

Anurag K. et al. (2009) "did laboratory investigation of Indirect Tensile Strength using roofing polyester waste fibres in hot mix asphalt. The use of these materials was proved to be economical, environmentally sound and effective in increasing the performance properties of the asphalt mixture in recent years. The primary objective of this research was to determine whether homogeneously dispersed roofing waste polyester fibers improve the Indirect Tensile Strength (ITS) and moisture susceptibility properties of asphalt concrete mixtures containing various lengths and percentages of the fiber in various aggregate sources. The results of the experiments found that, in general, the addition of the polyester fiber was beneficial in improving the wet tensile strength and tensile strength ratio (TSR) of the modified mixture, increasing the toughness value in both dry and wet conditions, and increasing the void content, the asphalt content, the unit weight, and the Marshall Stability".[13].

Gandhi T. et al. (2009) "estimating the Indirect Tensile Strength of mixtures containing anti- stripping agents using on artificial neural network (ANN) models to predict the Indirect Tensile Strength (ITS) and Tensile Strength Ratio (TSR) of various mixtures considering five input variables such as asphalt binder source, aggregate source, anti-striping agents (ASA), conditioning duration, and asphalt binder content. The results indicate that ANN-based models are effective in predicting the ITS and TSR values of mixtures regardless of the test conditions. In addition, the developed ANN models can be used to predict (or estimate) the ITS values of the mixtures used in other research projects. Furthermore, the results also show that the asphalt binder source, aggregate source, and asphalt binder content are the most important factors in the developed ANN models while the conditioning duration is relatively unimportant (i.e., it has less effect on the ITS values in comparison with other variables). In addition, the sensitivity analysis of input variables indicated that the

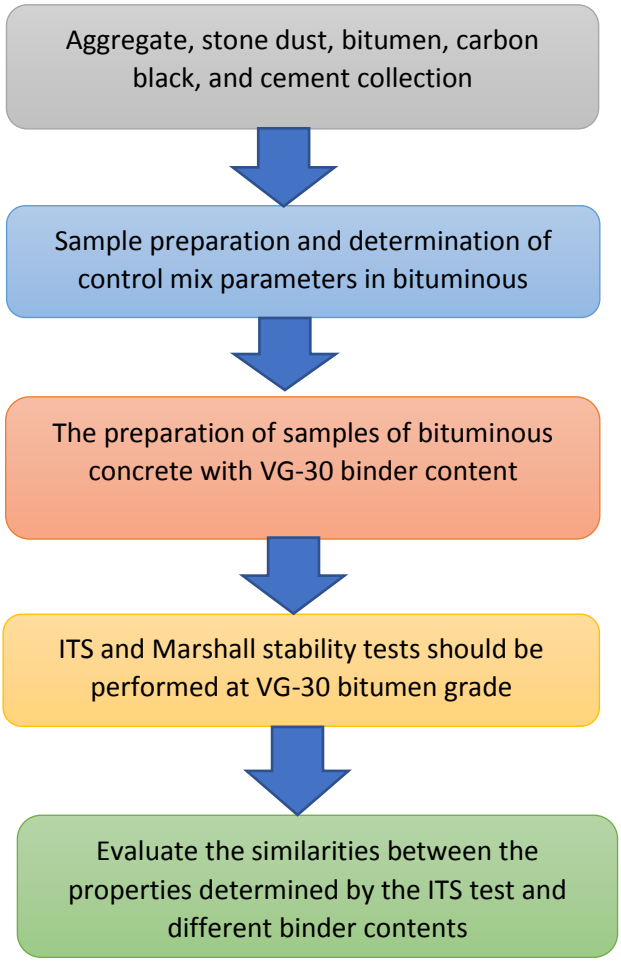
changes of ITS values are significant as the changes of the most important independent variables".[14].

Chen X. & Huang B. (2008) "evaluation the performance of moisture damage in hot mix asphalt (HMA) and Superpave Indirect Tensile Test. Evaluate the moisture damage of dense-graded surface HMA mixture using simple performance test (SPT) and super pave Indirect Tensile Test (IDT). Asphalt binders (PG 64-22) with and without amine-based antistrip additive (ASA) were used to make mixtures for laboratory moisture damage evaluations. The dynamic modulus, Superpave IDT creep, resilient modulus and strength tests were performed on conditioned and unconditioned specimens. The results from this study indicated that the SPT dynamic modulus test and the Superpave IDT with F-T were effective to characterize lab-measured moisture susceptibility of HMA mixtures. Increasing F-T (freeze-thaw) cycles would increase moisture damage in HMA mixtures. Amine-based antistrip additive was effective to decrease the moisture damage in HMA mixtures. Increasing coarse aggregate angularity (CAA) levels could increase dynamic modulus; however, it seemed that CAA had no significant effects on the lab-measured moisture resistance of HMA mixtures".[15].

Huang B. et al. (2005) "did the comparative study of semi-circular bending and Indirect Tensile Strength Test for hot mix asphalt. The ITS test a standard test method of AASHTO and ASTM, which is adopted by most highway agencies. Two types of aggregate are used (lime stone and gravel) and two types of asphalt binder (PG64-22) and (PG76-22) were considered. The permanent deformation under the loading strips is undesirable and in same case unbearable for the calculating of the cracking potential of asphalt mixes. Semi-circular bending test could significantly reduce the loading strip-induced permanent deformation and thus is more suitable Indirect Tensile Test for calculating tensile properties of hot mix asphalt mixtures. The results from this study indicated that semi-circular bending and Indirect Tensile Strength Test were fully comparable and convertible" [16].

5. RESEARCH METHODOLOG

Samples of BC mix will be made with bitumen grade VG-30 in this study. "The Indirect Tensile Strength method will be used to determine the tensile strength of bituminous concrete mixes. The Marshall Test will be used to determine the stability of bituminous concrete mixes. A comparative study is to be made between ITS values and Marshall Stability values to interpret the suitability of these tests for bituminous mixes".



6. EXPECTED OUT COMES

i. Various properties of mix with filler gives better results.
ii. Optimum binder content is batter in addition of carbon black as compare to other mixes.
iii. Stability value is more after addition of carbon black as compare to control mix
iv. Density is nearly same in Marshall stability test and ITS test.

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