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A Review Study on Behavioral Similarity Between Marshall Stability and Indirect Tensile Strength Values for Bituminous Concrete Using VG-30 and VG-40 Grade Binder

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Abstract: ***Rutting, displacement, cracking, distortion, and fatigue are all issues that pavement engineers are concerned about. The Marshall Stability test is used to determine the compressive properties of the bituminous mix, and the Indirect Tensile Strength (ITS) test is used to analyse the tensile properties. Many studies on Marshall Stability and ITS have been conducted separately; however, these two have not been studied together. An effort has been made in this proposal to study the behavioural similarities between them. Further research on this topic will also determine the correlation between Marshall Stability values and Indirect Tensile Strength values for Bituminous Concrete at various bitumen content, as well as interpret the suitability of these tests in mix design. The study will provide guidelines to designer to established relevancy of necessity to conduct of both the test.***

Keywords: Cement, Bituminous Concrete, Marshall methods, ITS.

I. INTRODUCTION

The only mode of transportation that can provide maximum flexibility of service from origin to destination to all is the road network system. 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 effect 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.

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

B. 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 bituminous concrete mix is used to prepare test specimens at the optimum bitumen content. Each specimen is tested at the temperature 25°C to determine their Indirect Tensile Strength achieved by using breaking head under a load applied at a rate of 50 mm per minute. Guidance 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:

$$\sigma_x = \frac{2P}{\Pi Dt}$$

σ_x = Horizontal tensile stress / tensile strength, N/mm2
P =Failure load, N
D = Diameter of the specimen, mm
t = Height of the specimen, mm

II. 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 behavioural similarity between Marshall Stability and Indirect Tensile Strength values as it will tell relevance of ITS test for the bituminous mixes.

III. OBJECTIVES

Following are the objectives of present study:

1) To find out the Marshall Stability value and flow value of the control mix prepared for bituminous concrete at different binder contents and identify the optimum binder content for VG-30 and VG-40 grade bitumen.
2) To find out the Indirect Tensile Strength value for BC mix at different binder contents for VG-30 and VG-40 grade bitumen.
3) To ascertain correlation between Marshall Stability values & Indirect Tensile Strength values for BC at different binder contents for VG-30 and VG-40 grade bitumen.

IV. LITERATURE REVIEW

A literature review assists to researchers and understanding the problem and gaps in their field of study. It contains data and information about the problems being studied, as well as ideas for future research. The literature review describes, summarizes, evaluates, and clarifies it. The literature review has been classified, and the most recent literature has been summarized in the table.

1) Gupta L. & Suresh G. (2018) evaluating the Indirect Tensile Strength of bituminous concrete mix by using stone dust and cement as filler materials. Tensile strength of bituminous concrete mix is important in pavement applications. For the preparation of bituminous concrete mix specimens using stone dust and cement as filler materials, optimum bitumen content was determined by adopting Marshall Method of bituminous mix design. Bituminous mix properties were determined at optimum bitumen content. Indirect Tensile Strength (ITS) and Tensile strength ratio (TSR) of bituminous concrete mix were evaluated by varying test temperatures at 15 °C, 20 °C, 25°C, 30 °C and 35 °C. Marshall Stability and optimum bitumen content as independent variable for each filler material. As the test temperature increases the ITS and TSR values of bituminous concrete mix decreases irrespective of type of filler material. Based on the analysis of data, it was observed that at any test temperature, ITS and TSR values of bituminous concrete mix prepared using cement as filler material were higher when compared to bituminous concrete mix prepared using stone dust as filler material. It may be concluded that the behavior of bituminous concrete mix prepared using cement as filler material is superior in terms of mix properties, ITS and TSR.
2) Bansal S. et al. (2017) evaluated modified bituminous concrete mix developed using rubber and plastic waste materials. The study attempts to utilize these waste materials as partial replacement of bitumen to develop a modified binder, for making bituminous concrete mix. To simulate with the field conditions, ‘Marshall Stability Analysis’ was performed on the samples prepared by partially replacing ‘Optimum Bitumen Content’ with waste plastic. The results suggested that various materials which become waste, after their service life, like rubber tyres and plastic bottles may be utilized as partial replacement in bituminous concrete mix, which can help in satisfying the increasing bitumen demand in the road construction.

The research conclude that it improves the strength and overall durability of the BC mix by increasing its overall performance manifold. Therefore, with application of these waste materials in the fixed proportions, targeted characteristics of BC can be achieved.

3) Chandra S. & Choudhary R. (2013) studies the Performance Characteristics of Bituminous Concrete with Industrial Wastes as Filler. The physical properties of these materials meet the requirements laid for fillers in Indian specifications. This study explores the possible use of these three industrial wastes, along with hydrated lime and conventional stone dust from quartzite, as filler in bituminous construction. The results suggest that marble dust, granite dust, and fly ash have good potential for their use as filler in bituminous mixes. Among the three industrial wastes, marble dust is the most promising filler and will prove to be very economical also, as mixes with marble dust have the lowest optimum binder content (OBC).The results of various tests on bituminous concrete mixes with fly ash, marble dust, granite dust, hydrated lime, and conventional stone dust are presented and compared in this paper. The effect on OBC of filler type and filler content is explained. It is found that the OBC in a mix not only depends on the fineness of the filler but it is also controlled by the Rigid in voids of the filler. The OBC in a mix is higher if the Rigid in voids of its filler are high. The moisture susceptibility tests suggest that three industrial wastes (fly ash, marble dust, and granite dust) selected in the study can be optimally used up to 7.0% as filler in a bituminous mix.

4) 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.

5) 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 diamtral 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.

6) 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.

7) 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.

8) 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.

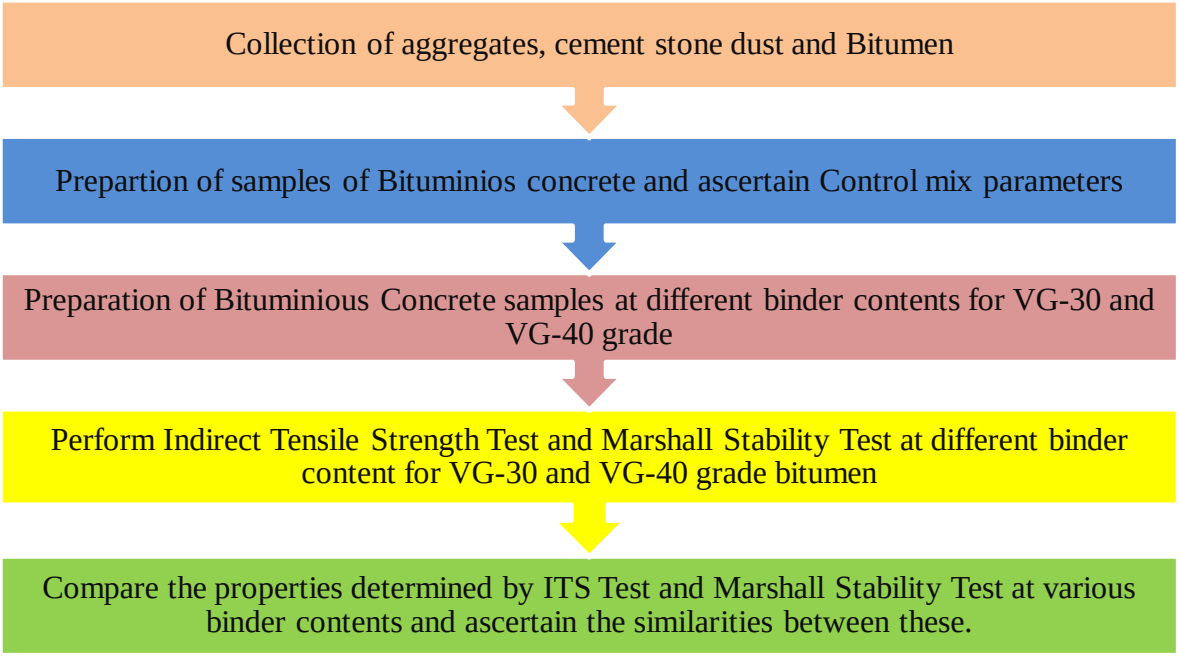
9) Huang B. et al. (2005) did the comparative study of semi-circular bending and Indirect Tensile Strength Test for hot mix asphalt. The ITS test a standard test method of AASHTO and ASTM, which is adopted by most highway agencies. Two types of aggregate are used (lime stone and gravel) and two types 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.

V. GAPS IN LITERATURES REVIEW

1) Changes to the current bituminous mix design are proposed in order to increase the performance of the mixes.
2) The studies were conducted solely on the basis of laboratory performance; no evaluation of field aspects was executed.
3) No clear guidelines exist in any papers for comparing behavioural similarities between Marshall Stability and I.T.S. mix in BC mix.
4) Various studies on I.T.S. test have been done in other bituminous mixes earlier but none or little work found on I.T.S. in Bituminous concrete mix.

VI. PROPOSED WORK AND RESEARCH METHODOLOGY

In this study, samples of BC mix will be made with different proportion of VG 30 and VG 40 Bitumen grade content. By Indirect Tensile Strength method, we will determine the tensile strength of bituminous concrete mix and with Marshall Test we will determine Stability of bituminous concrete mix. A comparative study is to be made between ITS values and Marshall Stability values to interpret suitability of these tests for the bituminous mixes.



VII. EXPECTED OUTCOMES

The expected outcomes of this study are as given below: -

1) Suitability and efficacy of Indirect Tensile Strength Test over Marshall Stability test shall be ascertained.
2) Relation between the trends of Marshall Stability and ITS values w.r.t. to binder content and grade shall be known.
3) Variation of Indirect Tensile Strength value of BC mix prepared at different binder contents shall be known.

VIII. CONCLUSIONS

The study reviewed various research done on Marshall Stability Method and Indirect Tensile Strength. This study is aimed to find out the behavioural similarity between the Marshall Stability and I.T.S. test as none or very few research has been done considering both the tests together. Although, we reviewed various research done for the test individually, it is found that both the test have been performed taking different types of variations such as addition of RAP, plastic bottles, polyester fibers, crumb rubber etc. From the above studies, it is also found that for both Marshall Stability and I.T.S. values increases with addition of above materials. The study also concluded that further research in this field will also ascertain correlation between Marshall Stability values and Indirect Tensile Strength values for B.C. at different binder contents and will interpret regarding suitability of these tests in the mix design.

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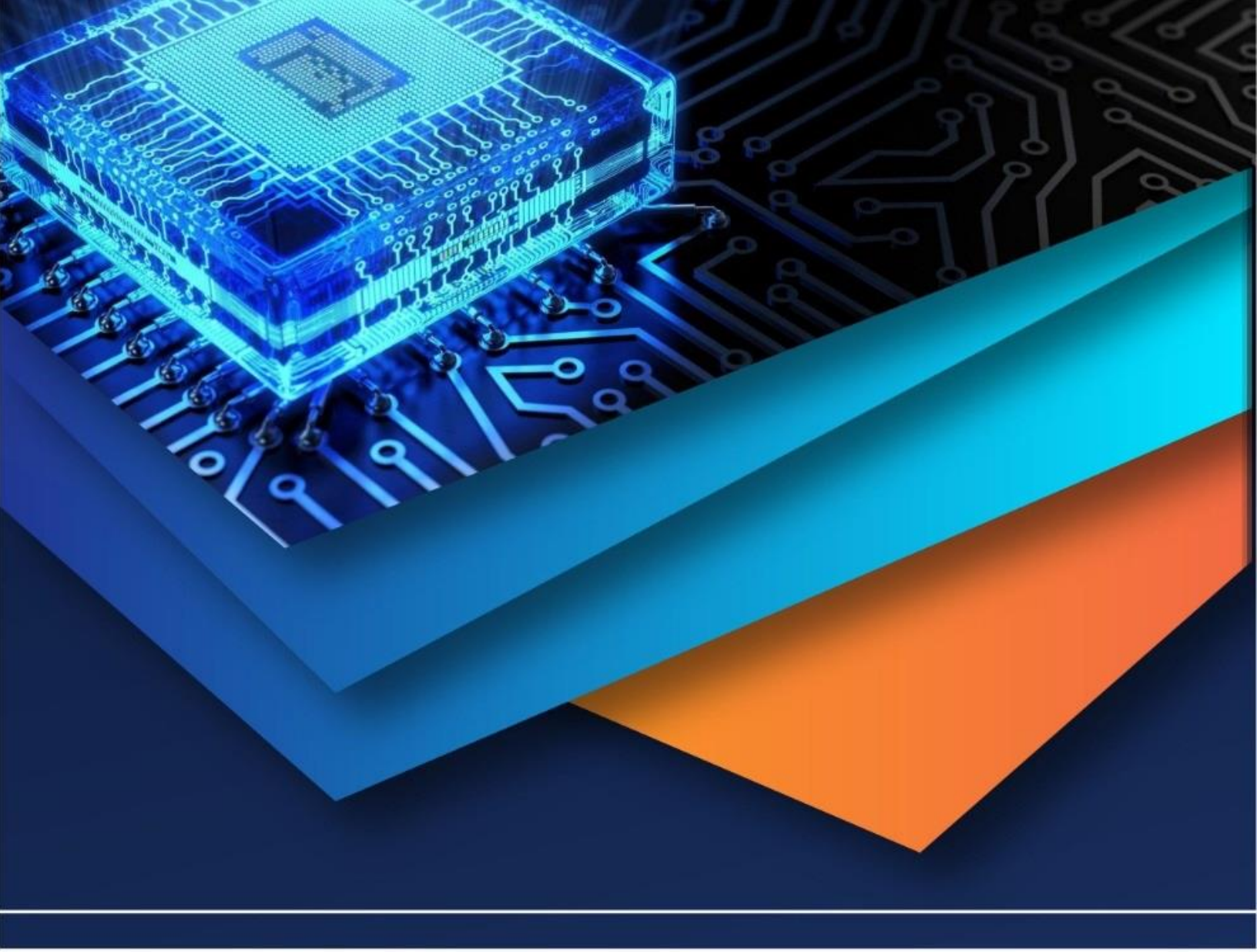

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