iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VII **Month of publication:** July 2022

DOI: https://doi.org/10.22214/ijraset.2022.45730

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

A Review on Behavioural Similarity Between Marshall Stability and Indirect Tensile Strength Values for D.B.M. using VG-30 & VG-40 Grade Binder

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Abstract: ***Pavement engineers are much concerned about making bituminous layers resistant to cracking, distortion, displacement, rutting, and fatigue. Hence behaviour of bituminous layers under compressive and tensile stress is important in pavement applications. The Marshall Stability test is used to assess the compressive properties and Indirect Tensile Strength (ITS) test is used to assess the tensile properties of the bituminous mix. Many research studies have been done on Marshall Stability and ITS individually; however, a combination has not been tried yet. In this proposal, an effort has been made to study the behavioural similarity between them. Further research in this field will also ascertain correlation between Marshall Stability values and ITS values for DBM at different binder contents and for different binder grades (VG-30 and VG-40) and will interpret regarding suitability of these tests in the mix design.***
Keywords: DBM, ITS, Indirect Tensile Strength, Marshall Stability

I. INTRODUCTION

The Marshall stability of bituminous materials refers to their resistance to stresses that cause distortion, displacement, rutting, and shearing. 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 in a long period could affect the strength of an asphalt mixture showing fatigue cracks. To determine this damage the commonly used test is 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. As we know Marshall Stability Test works on compressive loading and ITS test being indirect tensile load test also is induced from 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 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.

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 dense bituminous macadam is used to prepare test specimens at the optimum bitumen content. Each specimen is tested at the temperature 25^0C 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:

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

σ_x= Horizontal tensile stress / tensile strength, N/mm^2
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. It may not be necessary that a mix that performs optimally at a specific binder content in Marshall test may also exhibit similar behaviour in ITS test as well. Therefore, it is a matter of concern to ascertain as whether behaviour of bituminous mixes in ITS test is similar with respect to Marshall Stability test.

This study is a little further of other research in a way that here it is finding behavioural similarity and identify the similar trends between Marshall stability and Indirect Tensile Strength values as it will reveal relevance of ITS test for the bituminous mixes.

Study shall be carried out to check the performance or the properties of bituminous mix with Marshall stability and Indirect Tensile Strength test. In order to evaluate the same, samples are tested for the desirable engineering properties of dense bituminous macadam.

III. OBJECTIVES OF STUDY

The following are the objectives of the study:

1) To find out the Marshall Stability value and flow value of the control mix prepared for dense bituminous macadam 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 DBM 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 DBM at different binder contents for VG-30 and VG-40 grade bitumen.
4) To interpret regarding suitability of these tests in the mix design.

IV. LITERATURE REVIEW

A literature survey helps the researchers in understanding the problems and gaps in the area of study. It contains the data and information about problems being studied and also gives the idea for future research. The review describes, summaries, evaluates and clarifies the literature.

Gupta L. & Suresh G. (2017) 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. 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 behaviour of bituminous concrete mix prepared using cement as filler material is superior in terms of mix properties, ITS and TSR.

Gupta A. & Agarwal S. (2017) did a comparative stability analysis of harder grade bitumen such as VG-30 & VG-40 by Marshall mix design method on DBM. Marshall Stability values was increased with increasing bitumen content and were achieved higher value for VG-40 grade bitumen than VG- 30 grade bitumen. Marshall stability was increased by approx. 5% with VG-40 binder grade than VG-30 grade.

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. 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. It concludes that it improves the strength and overall durability of the BC mixes by increasing its overall performance of stability.

Islam M. R. et al. (2015) made a comparison of laboratory and field aged sample to study the dynamic modulus, diametrical resilient and loss of ductility these parameters are most common to study aging by indirect tensile strength (ITS) test. The air void of the sample before conditioning ranges from 5.1% to 5.9% with an average value of 5.4%. the design binder was a performance grade binder, which was used 4.4% by weight of the mixture. Two types of sample compacted sample and loose mix sample performed indirect tensile strength of laboratory. Long term and field aged sample increase with aging period and Indirect Tensile Strength of short-term oven aged loose sample is concave down with aging period. the flow number will be decreases as aging intensity increases, that is the brittleness increases with aging.

Katman H.Y. et al. (2013) study the reclaimed asphalt pavement on Indirect Tensile Strength test of foamed asphalt mix tested in dry condition. Indirect Tensile Strength (ITS) test was conducted to analyses strength of the foamed asphalt mixes incorporating reclaimed asphalt pavement. Preparation of sample was followed closely to Marshall procedure in accordance with ASTM D6926 samples were tested for ITS after cured in the oven at 40^{o}C for 72 hours. This testing condition known as dry condition or unconditioned. Laboratory results show that reclaimed asphalt pavement (RAP) contents insignificantly affect the ITS results. ITS results significantly affected by foamed bitumen contents.

Shunyashree et al. (2013) studied 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 30^{0}C.

Gandhi T. et al. (2009) estimated 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. Used artificial neural network (ANN) models to predict the Indirect Tensile Strength (ITS) and Tensile Strength Ratio (TSR) of various mixtures. It concluded that ANN-based models are effective in predicting the ITS and TSR values of mixtures regardless of the test conditions.

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 fibres improve the Indirect Tensile Strength (ITS) and moisture susceptibility properties of asphalt concrete mixtures containing various lengths and percentages of the fibre in various aggregate sources. The results of the experiments found that, in general, the addition of the polyester fibre 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.

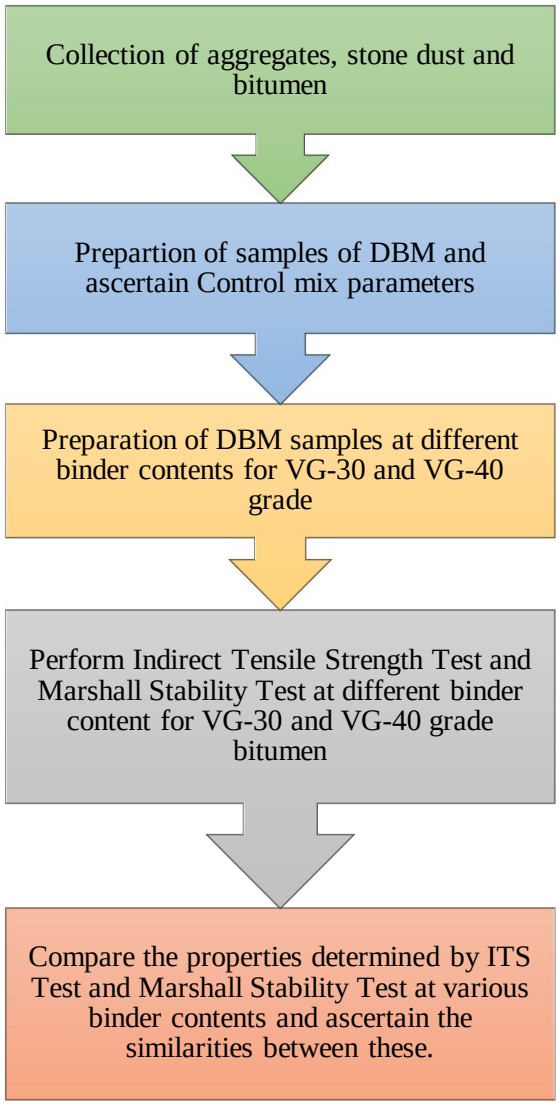
Huang B. et al. (2005) did the comparative study of semi-circular bending and Indirect Tensile Strength test for hot mix asphalt. Two types of aggregate were used (limestone and gravel) and two types of asphalt binder (PG64-22) and (PG76-22) were considered. The permanent deformation under the loading 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 LITRATURE REVIEW

1) Changes are proposed in the current bituminous mix design for improvement in them to appreciate the performance of mixes.
2) The studies were based on lab performance; no evaluation is done based on field aspects.
3) No clear guidelines are existing regarding the comparison or behavioural similarity between bituminous mixes in DBM mix in any papers.
4) Various observation on ITS test which have been used in bituminous concrete mix earlier, but very little work has been done on ITS in DBM mix.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

VI. RESEARCH METHODOLOGY



VII. EXPECTED OUTCOME

The expected outcome of this study is as given below: -

1) Suitability and efficacy of ITS 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 binder content shall be known.
3) Variation of Indirect Tensile Strength value of DBM mix prepared at different binder contents shall be known.

VIII. CONCLUSION

The study reviewed various research done on Marshall Stability Method and Indirect Tensile Strength. This study aimed to find out the behavioural similarity between the Marshall Stability and ITS test but none or very few research has been done considering both the tests together. Based on the review of various research done for the test individually it is found that both the test has been performed taking different types of variations such as addition of RAP, plastic bottles, polyester fibres, crumb rubber etc. From the above study, it is also found that for both Marshall Stability and ITS increases with addition of these additives. The study concluded that as the behaviour of both the test i.e. Marshall Stability and ITS shows similar trends, therefore there is a high need to perform the behavioural similarity between both the test and establish if there is any correlation between them. Further research in this field will also ascertain correlation between Marshall Stability values and Indirect Tensile Strength values for DBM at different binder contents and will interpret regarding suitability of these tests in the mix design.

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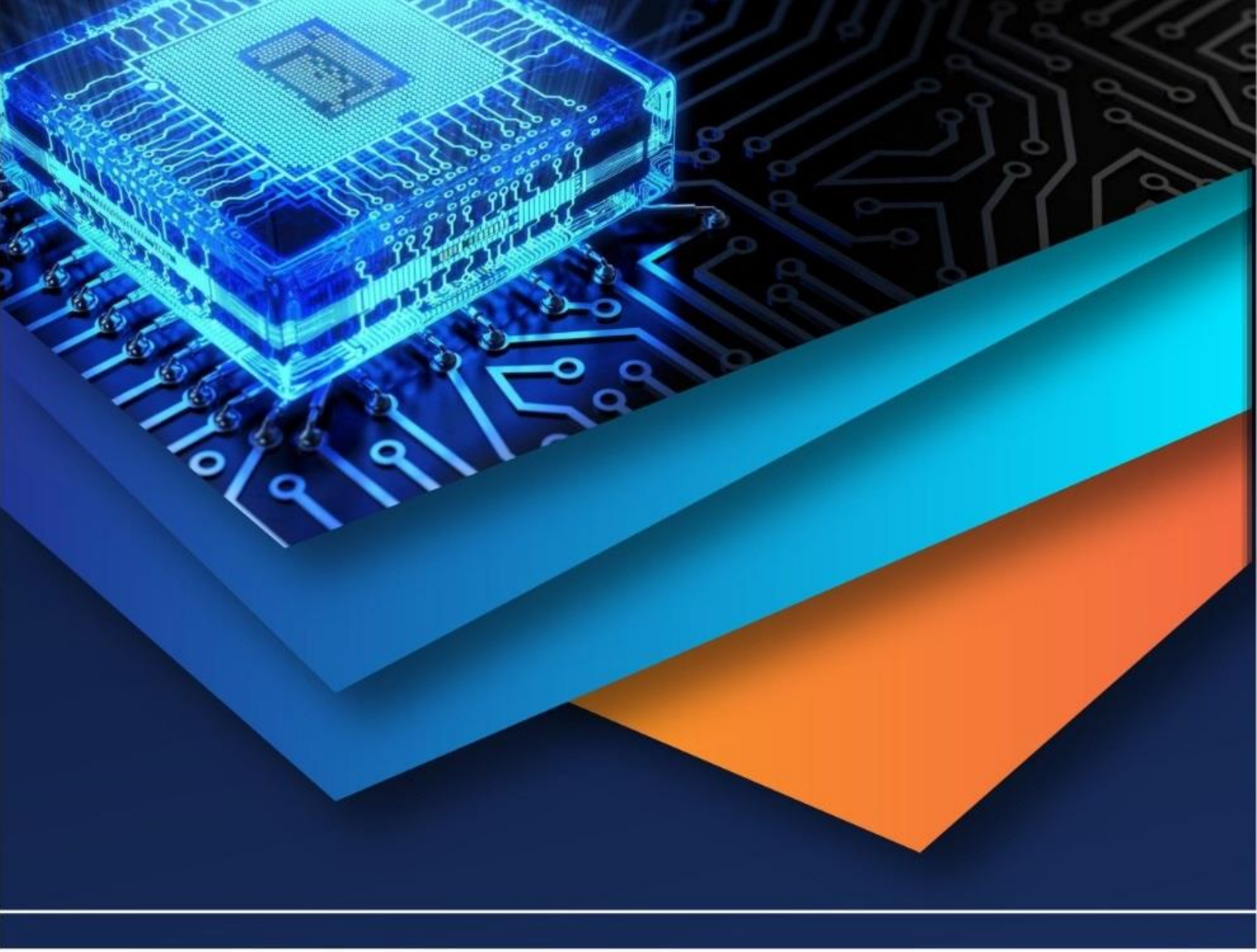

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