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A Review on Correlation between Marshall Stability and ITS values for Bituminous Mixes with RAP

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Abstract: ***Utilization of recycled materials in DBM mixes is gaining popularity due to environmental concerns and the potential for cost savings. The performance of DBM is influenced by several factors, including the choice of binder grade and the incorporation of recycled materials. However, the impact of recycled materials on the mechanical properties of the mix, as measured by Marshall stability and indirect tensile strength, needs to be thoroughly understood. Although the effect of RAP addition in DBM has been studied in relation to the Marshall test but not much is known about its effect on Indirect Tensile Strength. Marshall Stability and ITS have alone been the subject of several research investigations, but their combination has received far less attention. The correlation between Marshall Stability and ITS was researched to some extent for virgin mixes but not with recycled material. An effort has been made to examine their correlation in this study. This study aims to explore the potential benefits of incorporating RAP in DBM mixes and how it affects the correlation between the two parameters.***
Keywords: Marshall Stability, Indirect Tensile Strength (ITS), DBM, RAP.

I. INTRODUCTION

Recycled materials, such as Reclaimed Asphalt Pavement (RAP), play a significant role in Dense Bituminous Mix (DBM) production and have a notable impact on the Marshall stability and Indirect Tensile Strength (ITS) of the mix. The inclusion of RAP in DBM offers environmental benefits by reducing the demand for virgin materials and promoting sustainability in road construction and rehabilitation projects.

When RAP is incorporated into the DBM mix, it introduces aged binder and aggregates from the reclaimed pavement. These aged materials can affect the overall performance characteristics of the mix, including its Marshall stability and ITS values. The impact of RAP on these properties depends on various factors such as the percentage of RAP used, the quality of the reclaimed material, and the compatibility between the RAP and the new binder.

The impact of RAP on Marshall stability and ITS values is often assessed through laboratory testing and analysis. Marshall stability tests measure the load-carrying capacity and resistance to deformation of the mix, while ITS tests evaluate its tensile strength and resistance to cracking. By conducting these tests on DBM samples with varying RAP content, engineers can evaluate the effect of RAP on the mechanical properties of the mix.

Many research investigations on Marshall stability and indirect tensile strength have been done separately using different agents and recycled materials, but no comparative studies have been done utilizing recycled material. It is uncertain if the Indirect Tensile Strength test is more appropriate in relation to Marshall Stability given that both tests, Indirect Tensile Strength and Marshall Stability, operate under compressive load.

A. Marshall Stability Test

The Marshall Stability test is a widely used method in the field of asphalt engineering to determine the resistance of a bituminous mix or an asphalt mixture to plastic deformation under loading conditions. It involves subjecting a compacted cylindrical specimen to a gradually increasing load on curved surface at the deformation rate of 5cm per minute until failure occurs. The maximum load sustained by the specimen at a temperature of 60°C is known as the Marshall Stability value. This test is an indicator of the mixture's ability to resist rutting and deformation. This test provides valuable information for assessing the structural integrity and performance of asphalt pavements.

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B. Indirect Tensile Strength Test

This test is carried out in the lab by applying a single compressive force that acts parallel to and along the vertical diametric plane to a cylindrical specimen. Using the Marshall technique of mix design, test specimens for dense bituminous macadam mix are created at the optimum bitumen content. Each specimen's indirect tensile strength was measured at a temperature of 25 °C achieved by applying a load @ 50 mm per min while utilizing a breaking head. For the indirect tensile strength test, use the ASTM D6931 and ASTM D1074 standards.

In order to determine the ITS, use the formula 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

Comparison between Marshall Stability and ITS test is shown below through diagram:

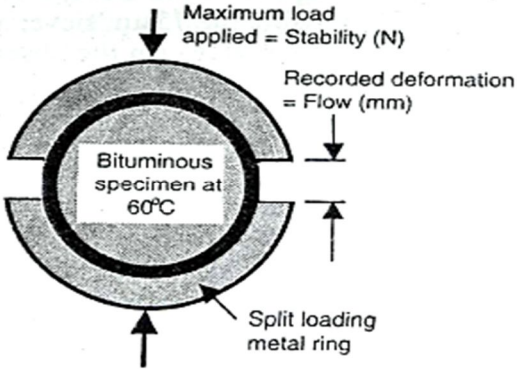


Figure 1: Marshall Stability test

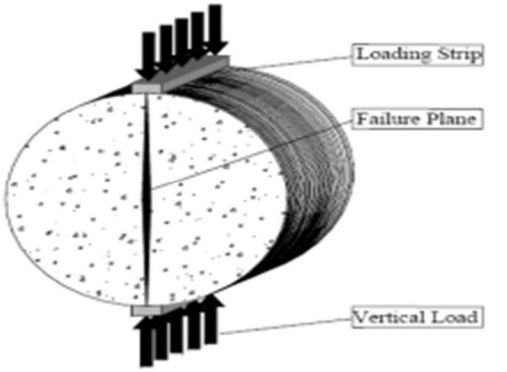


Figure 2: ITS test

II. REVIEW OF LITERATURE

The researchers can better comprehend the issues and knowledge gaps in their field of study with the use of a literature review. It provides the concept for future development as well as data and information about the issues being researched. There has been a lot of research done on Marshall Stability and Indirect Tensile Strength separately utilizing different agents, recycled materials, and fillers. Here are several research projects that are presented.

Gupta S. and Duggal A. K. (2022) examined how Marshall stability and indirect tensile strength parameters for conventional DBM utilising VG-30 and VG-40 grade binder behaved similarly. Finding a correlation between Marshall stability and ITS values for DBM at various binder contents for VG -30 and VG-40 grade bitumen was the main aim of this research. For DBM mixes, the Marshall stability test and indirect tensile strength test were conducted in this study with varied binder content percentages: 4.5%, 4.65%, 4.80%, and 4.95%. Based on the test results, it was concluded that the Marshall stability value can also serve as an indicator of ITS values because both the tensile strength and stability are at their highest levels at the same binder concentration, or at 4.65% for both VG-30 and VG-40 grade binder. The study found that both tests' behaviour exhibited similar trends, thus it was highly recommended that behavioural comparisons be made between them to see whether there was any correlation.

Gupta L. & Suresh G. (2018) utilizing cement and stone dust as filler materials to test the indirect tensile strength of a bituminous concrete mix. When applying bituminous concrete mix on pavement, tensile strength is crucial. pertaining to the making of bituminous concrete by employing the Marshall technique of bituminous mix design on mix specimens made using cement and stone dust as filler materials, the optimum bitumen content was found. At this bitumen concentration, the properties of bituminous mixes were established. Different test temperatures at 15 °C, 20 °C, 25 °C, 30 °C, and 35 °C were used to assess the indirect tensile strength (ITS) and tensile strength ratio (TSR) of bituminous concrete mix. For each filler material, consider stability and optimum bitumen content as independent variables. Regardless of the kind of filler material used, the ITS and TSR values of bituminous concrete mix fall as the test temperature rises. Based on the data analysis, it was found that bituminous concrete mixes made using cement as the filler ingredient had greater ITS and TSR values than those made with stone dust.

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This was true for all test temperatures. On the basis of mix characteristics, ITS, and TSR, it can be said that the behaviour of bituminous concrete mixes made using cement as a filler ingredient is preferable.

Koteswara Rao et al., (2018) conducted laboratory tests to assess the suitability of RAP materials for the preparation of DBM by partial replacement with natural aggregate, and the Marshall Stability Tests were used to determine the strength qualities of the blended RAP material. Trial Marshall-mix samples of the planned DBM were created by mixing varied amounts of RAP material (35%, 40%, 50%) with fresh aggregates (65%, 60%, 50%). Each sample was then mixed with bitumen (VG-30) containing 3%, 3.5%, 4%, 4.5%, and 5%. The optimal ratio was found to be 40% RAP material to 60% virgin material based on the test findings. The engineering properties of this RAP replacement mix have been found to be acceptable and comparable to those of 100% virgin material, and it has been concluded that RAP materials can be used effectively in combination with virgin material in an energy- and environmentally-friendly manner.

Islam M. R. et al. (2015) describe the comparison in 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. The maximum size of the aggregate was 19mm. In this aged in the field and laboratory and then loaded diametrically to determine indirect tensile strength value and flow number. 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. Sample prepared using a super pave gyratory compactor following the AAHTO T 312-07 test protocol. Overall, 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 indirect tensile strength of the dry foamed asphalt mix evaluated on the reclaimed asphalt pavement. The strength of the foamed asphalt mixes containing reclaimed asphalt pavement was examined using an indirect tensile strength (ITS) test. The sample was prepared according to the Marshall process in accordance with ASTM D6926 and evaluated in accordance with ASTM D6926-07. Following a 72-hour cure in an oven set at 40°C, samples were examined for ITS. Dry condition or unconditioned refers to this testing circumstance. Reclaimed asphalt pavement (RAP) ingredients don't significantly influence the ITS outcomes, according to laboratory studies. Foamed bitumen contents had a substantial impact on ITS performance.

Shunyashree et al. (2013) researched the impact of recycling materials on the asphalt concrete mixtures' indirect tensile strength. For the laboratory tests, recycled asphalt pavement (RAP) from NH-4 and crumb rubber modified binder (CRMB-55) were utilized. Instead of using traditional filler, foundry waste was employed. On asphalt concrete mixtures with RAP replacement levels of 30, 40, 50, and 60%, laboratory experiments were done. These test outcomes were compared with those of standard mixtures and asphalt concrete mixtures containing fully removed RAP aggregates from the binder. The Marshall Method was used to create the mix. The asphalt concrete (AC) mixes with 60% RAP showed the highest stability values according to the Marshall Tests. When RAP in AC mixtures was raised, the optimal binder content (OBC) decreased. At 300°C, it was discovered that AC mixes with RAP had higher indirect tensile strengths than standard AC mixes.

Navarro F. M. & Gamez M. C. R. (2012) researched into how crumb rubber affects the stiffness modulus and indirect tensile strength of hot bituminous mixes. The mixes used in the study were closely graded, with an air void percentage of 4-6%, a continuous coarse grain maximum aggregate size of 22mm, and a bitumen component of 3.5–5.0% of the mix's total weight. Road engineering has become more and more dependent on the usage of rubber from recycled tyres to alter the mechanical qualities of bituminous mixes. This study examines the effects of crumb rubber incorporation on the cohesiveness and bearing capacity of bituminous mixtures, using both the dry and wet processes. According to the results, crumb rubber improved the stiffness and stability of mixes while only marginally lowering their indirect tensile strength. In addition to the obvious environmental advantages, including this material into asphalt mixtures enhances the durability of road surfaces by minimising the impact of traffic loads on the pavement. Al-Baiti H.K.A. (2012) examined how additives and other elements affect the tensile strength of asphalt paving mixtures. The tensile strength and flexibility of asphalt concrete determine how resistant it is to cracking. Low tensile strength has been identified as a significant cause of other performance issues. With a reduction in tensile strength, the fatigue life of the mixture is reduced exponentially. The main goal of this study is to examine how external factors affect tensile strength and to forecast an indirect tensile strength model for asphalt concrete paving materials under the local climate. It also looks at how much polystyrene resin and hydrated lime should be added to the mixture to increase its resistance to distresses. The principal influencing parameters—soaking, asphalt content, compaction, maximum aggregate size, and temperature - are provided through a statistical analysis model for tensile strength in asphalt mixture. These factors have an impact on the indirect tensile strength.

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Anurag K. et al. (2009) investigated the indirect tensile strength of hot mix asphalt using roofing polyester waste fibres in a lab setting. In recent years, it has been demonstrated that using these components to improve the asphalt mixture's performance attributes is cost-efficient, ecologically friendly, and effective. The main goal of this study was to ascertain whether polyester fibres made from roofing waste that have been uniformly dispersed in asphalt concrete mixtures can increase the mixtures' indirect tensile strength (ITS) and moisture susceptibility properties. According to the experiment's findings, adding polyester fibre generally improved the modified mixture's wet tensile strength and tensile strength ratio (TSR), increased toughness in both dry and wet conditions, and increased void content, asphalt content, unit weight, and Marshall stability.

Huang B. et al. (2005) conducted a comparison of the indirect tensile strength test and semi-circular bending for hot mix asphalt. The majority of transportation authorities use the IDT test, which is a common test method recommended by AASHTO and ASTM. Limestone and gravel are the two forms of aggregate that are employed, and PG 64-22 and PG76-22 were the two asphalt binders that were taken into consideration. When estimating the cracking potential of asphalt mixes, the permanent deformation under the loading strips is both undesirable and intolerable. The indirect tensile test that uses semi-circular bending to measure the tensile properties of hot mix asphalt mixtures is more appropriate since it considerably reduces the permanent deformation caused by loading strips. The findings of this investigation demonstrated complete comparability and conversion between the indirect tensile strength test and semi-circular bending.

III. FINDINGS DRAWN FROM LITERATURE REVIEW

1) Use of Recycling materials in asphalt mixtures, such as RAP and CRMB-55, increased stability and indirect tensile strength while reducing binder content.
2) There is behavioural similarity between I.T.S. & Marshall stability of virgin mixes of dense bituminous macadam.
3) In both laboratory and field-aged samples, the dynamic modulus, diametrical resilient modulus, and loss of ductility increased with aging. The indirect tensile strength also increased with aging in long-term laboratory and field-aged samples, while the short-term oven-aged loose sample showed a concave-down trend. The flow number decreased as aging intensity increased, indicating increased brittleness with aging.
4) Bituminous concrete mixes using cement as a filler showed higher indirect tensile strength (ITS) and tensile strength ratio (TSR) compared to stone dust mixes, across all test temperatures.
5) Recycling old tyres improves stiffness, stability, and durability when recycled crumb rubber is added to bituminous mixtures.
6) The study on dry foamed asphalt mix with reclaimed asphalt pavement found that the foamed bitumen content significantly affects the indirect tensile strength (ITS) performance, while RAP ingredients have no significant influence.
7) RAP materials can be effectively used with virgin material, 40% RAP and 60% virgin material blend exhibited comparable engineering qualities.

IV. GAPS IN LITERATURE REVIEW

1) Changes may be feasible in the current practices of bituminous mix design for improvement in the performance of mixes.
2) The studies were based on lab performance; no evaluation is done on the basis of field aspects.
3) There isn’t any clear comparison research regarding the behavioural similarity between Marshall Stability and ITS values in the DBM mix employing recycled material.
4) Various studies had been done on ITS test in bituminous mixes specified earlier but none or little work has been done on ITS in DBM mix.

V. PROPOSED STUDY

Further research in this field involves the preparation of DBM specimens with different binder grades (VG-30 and VG-40) and varying percentages of bitumen content along with RAP. Marshall Stability tests shall be conducted to assess the resistance of the mixtures to rutting, while ITS tests shall be performed to evaluate the tensile strength of the specimens. The results obtained from these tests will be statistically analysed to determine the correlation between Marshall Stability and ITS values.

VI. CONCLUSION

A review of prior studies on the Marshall Stability technique and indirect tensile strength was conducted. This study aims to investigate the possible advantages of using RAP in DBM mixtures and how it influences the correlation between Marshall Stability and Indirect Tensile Strength values.

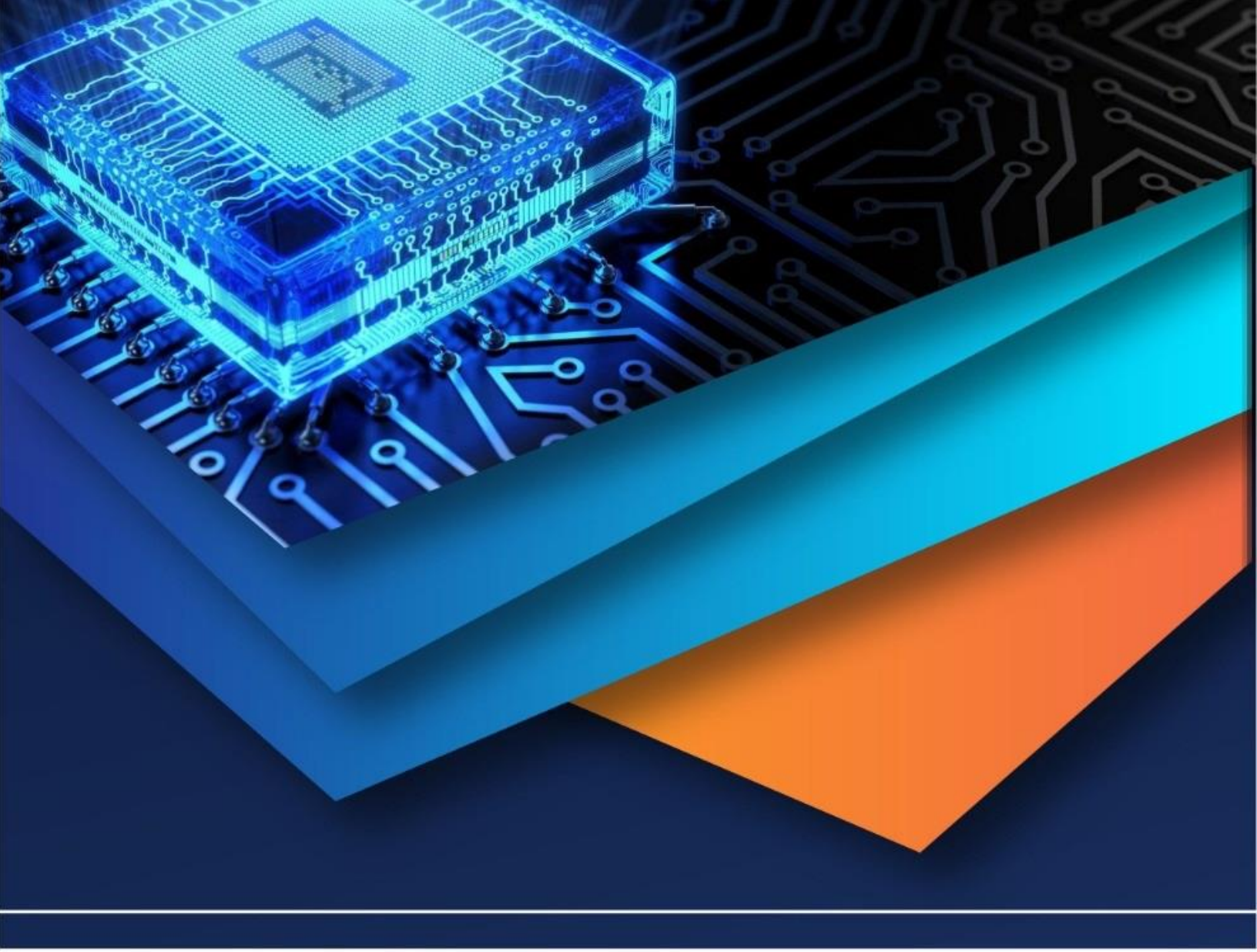
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A number of research studies have focused on Marshall Stability and ITS separately, but far less emphasis has been paid to their combination. Based on a review of the many studies conducted on each of these tests separately, it has been determined that the tests have been carried out with various additives, including RAP, plastic bottles, polyester fibres, crumb rubber, etc. According to the study, adding these substances results in higher values for both Marshall Stability and Indirect Tensile Strength. This study also concluded that both the tests operate under compressive loads and showing similar trends so there is high need to study the similarity between them and establish if there is any correlation between them. Further research in this field involves the preparation of DBM specimens with different binder grades (VG-30 and VG-40) and varying percentages of bitumen content along with RAP. Marshall Stability tests to be conducted to assess the resistance of the mixtures to rutting, while ITS tests will be performed to evaluate the tensile strength of the specimens. The results obtained from these tests will be statistically analysed to determine correlation between both the tests and whether ITS is more appropriate than Marshall Stability in terms of suitability and effectiveness.

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