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The Performance of Stone Mastic Asphalt Incorporating Iron Ore

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Abstract The high traffic load often appears for its resilient module and dynamic creep to affect the efficiency of the asphalt mixture. A typical way to resolve these problems is to change the properties of the asphalt binder by incorporating iron ore (IO) and stone mastic asphalt (SMA). Given that we use Iron ore to boost the asphalt properties in this research, this study aims to promote IO as an asphalt binder to strengthen asphalt mixture properties. This study aims to evaluate the mechanical performance of stone mastic asphalt 20 incorporating iron ore and to access the optimum iron ore content in the SMA. Iron ore is utilised to increase asphalt binding characteristics and ground paving performance. High freight weights, which increase road use owing to a variety of issues, including fatigue cracking and other deformations caused by stress on roadways, are one of the primary problems affecting thick-grade asphalted surfaces and quality performance. In this study, six different percentages of IO content were employed, which are as follows: (0%, 1%, 2%, 3%, 4%, and 5% from the total weight of aggregate). Furthermore, in this study, a 60/70 asphalt penetration grade was selected. The study compares modified and conventional bitumen specimens using the Marshall stability, resilient modular testing, dynamic creep, and LA abrasion tests. According to the results of this study, using a ranking of performance tests, the Optimum Iron Ores Content was determined to be 5 % iron ore. Therefore, we may conclude that there is improvement in incorporating additive IO into SMA.

Keywords Iron Ore, SMA, Volumetric Properties, Resilient modulus, Dynamic creep, Abrasion

1. Introduction

Stone Mastic Asphalt (SMA) was first created for high abrasion resistance by stumped tires and was used in Europe for around 40 years. This combination was later found to be very resistant and not just beneficial for its original function. This technique continued to advance even after the application of a resistant tire was halted in several European nations [1, 2]. SMA may be better described as an asphalt mixture, which is a two-component hot mix: a rough skeleton of the aggregate and high-asphalt mortar. The extraordinary rut resistance of SMA is primarily attributed to the ground skeleton component, which is contacted "stone to stone" due to the gradation of its lacuna. Together these two components address all issues. SMA has good fatigue resistance, great deformation, and durability characteristics. The skeleton of interlocking stone ensures stability and minimum rutting for heavy road loads. The high content of the mortar's asphalt binder facilitates longevity. Furthermore, the mortar properties are essential to prevent drainage and to help the stone skeleton avoid rutting at mixing and placing temperatures [3-5]. The SMA stone skeleton consists of the coarse aggregate, characterized in the 4.75 mm strand as the aggregation fraction. The shapes are used to differentiate between relative raw and fine aggregates. The stone skeleton must have a "stone-by-stone" contact to provide adequate rolling strength load-bearing capacity [6-8]. Utilising iron ore to enhance the performance of asphalt mixtures is not a fresh industrial practice. New materials such as hematite ore, magnet ore, limonite ore, siderite ore and so forth are constantly being implemented in industry. The stone mastic asphalt was added to improve the efficiency of the iron ore. The combination's stabilized mastic asphalt had a significant impact on the stone mastic asphalt or open-friction process during material transport and paving, resulting in a reduction in binder outflow. Before testing the modified and control versions, it is essential to specify the inclusion of additives to improve the asphalt mixture's properties.

Iron ores are the materials and minerals, from which metallic iron can be economically extracted. Iron oxides predominate in the ore, which varies in color from dark grey to bright yellow to dark purple to rusty red. Examples of iron-containing particulates include magnetite, hematite, goethite, limonite, and siderite. "Natural ore" or "direct shipping ore" refers to iron-producing ores that can be directly transported into blast furnaces [9-12]. The incorporation of iron ore into densely graded asphalt has been found to enhance the structural integrity and mass of the material while simultaneously reducing its flow and susceptibility to water infiltration. To improve SMA with increased binder material, iron ore is used as a stabilizer in the blending phase, the combined film thickness is improved, the stable mix is improved, the ores clamps are enhanced, and the aggregates' strength is increased. In 2013, China accounted for approximately 65% of the global seaborne iron ore market, followed by Japan (11%), the European Union (9%) and Korea (6%), meaning that the Asian nations dominate the global iron ore field. From approximately 50 Mt/a in 2000 to approximately 745 Mt/an in 2012, China's iron ore imports have increased in volume. In 2013, imports were approximately 820 Mt/a. The primary suppliers were Australia, Brazil, South Africa, Canada, and India, with three of the world's largest iron ore manufacturers being Vale in Brazil, Rio Tinto, and BHP Billiton with assets located primarily in Australia [6]. In addition to avoiding issues in paving and maximizing the life of the SMA, efforts were made to enhance various features of typical asphalting blends, such as permanent deformation, rutting, resiliency, and tiredness cracking. In recent decades, scientists and paving technicians have been concentrating on developing modified asphalt blends and subgrade improvement to increase the performance of various layers of flexible pavement especially its surfacing layer [13-15].

Thus, this study contributes and promotes the utilization iron ore as an asphalt binder to strengthen asphalt mixture properties.

2. Methodology

This research included test and clarified in detail how iron ore is effectively applied to asphalt mixtures and analyzed its strength, toughness, and consistency. Furthermore, the results of this investigation will be analysed, and the attributes and traits of diverse SMA blends will be differentiated through experimental procedures. In that approach, the construction of the Marshall mix was carried out to demonstrate the difference between the two asphalt varieties, iron ore asphalt and unmodified asphalt blended. In Malaysia, the Marshall Mix design is a guideline for designing mixed asphalt. This technique will be used by measuring the fatigue breaking, rutting, and other aetiologies to examine and measure the pavement strength.

2.1. Aggregate Characterizations and Properties

In general, the measurement of the total gradient will be characterized. In this analysis, the aggregate form was SMA 20 [10]. Multiple particulate sizes are dispersed throughout the gradient. The gradient substantially affects the efficacy of SMA paving, including its rigidity, permeability, operability, and stress resistance [11, 12, 16, 17]. For instance, excessively small sizes can lead to fragile SMA pavements. At the same time, too big ones may cause alienation and desperation for such thermal, packing, material, and conditions of the requested SMA sheet, and asphalted mix designs need a fair distribution of the aggregate sizes. Although the gradation resulting in maximum density can be good for stability, it has always been desired to provide sufficient vacuums for asphalted binder needed between aggregate arrangements. The asphalt mixtures are usually thick, angular, intense, and solid aggregates. In comparison, in this experiment, seven analyses were used according to ASTM requirements beginning at 20mm and finishing at 0.075mm, each sieve sized with a variation in weight. Although in the sample, a total of 1200g was used after a sieve analysis [18, 19].

2.2. Iron Ore

The mixture asphalt SMA was combined with Iron Ore (IO) and grew by 0%,1%,2%,3%, 4%, and 5%. By weight of the asphalt mixture, the quantity of each additive was chosen. The IO utilized in this experiment is acquired through a series of processes from its origins in the mountains.

2.3. Asphalt

Asphalt is popular for the stability and longevity of the pavement. This strength makes asphalt flooring the best choice for most paved surfaces. Because of their stability and durability, federal and state authorities promote asphalt flooring vehemently. It does not need to be replaced for 20 to 25 years if it is appropriately placed. Asphalt flooring is also the favourite choice for applications such as highways, car parks, roads, airstrips and much more [20]. In this research, asphalts were 6% of the mixture weight, and the bitumen grade was extracted from the University of Malaysia Pahang's 60/70 grade, a widely used grade in

Malaysia.

2.4. Specimen Preparation

The Marshall Stability and Flow tests required the specimen to be compacted to determine its real mass and height accurately. Compaction was an essential factor in these tests. When the mixture was being poured into the mould, it was spaded ten times in the inner part of the mould and 15 times around the outside edges. After placing the mould on the pedestal, the material was immediately pressed down with the allotted number of strokes, which came to fifty blows [21]. After that, the mould was flipped over as quickly as it could be removed, and the same amount of blows was delivered to the remaining mixes. Experiments on bulk specific gravity, Marshall Stability, and flow, in addition to abrasion, robust modulus, and dynamic creep, were carried out after samples had been compacted, pushed out, and allowed to return to room temperature.

2.5. Mechanical Properties

The tests involved in evaluating the overall performance of the modified mixture are resilient modulus, dynamic creep, and abrasion resistance. First, the specimens were compacted using a Marshall compactor and tested with 25°C for resilient modulus and 40°C for both resilient modulus and dynamic creep. As for the abrasion resistance test, the specimens underwent 300 number of revolution (no steel ball) to encounter the abrasion loss. Then, the results for all tests were further analysed to indicate the overall performance of the modified asphalt mixture.

3. Results and Discussion

3.1. Volumetric Properties

As shown in the obtained Figure 1 to Figure 6, there was a significant effect of adding Iron Ores with different percentages capacities. It is noteworthy that the stability demonstrates an upward trend as the iron filings content increases until it attains its peak value, after which it commences to decline. Simultaneously, there is a reduction in flow rate as the percentage of iron filings increases. Consequently, a reduced flow value suggests inadequate bitumen content in the asphalt, resulting in stiffer asphalt pavement. The ratio of calculated stability to flow represents the rigidity of the pavement, which indicates the strength, quality, consistency, and durability of asphalt pavement, and that meets the objectives of this research in terms of this test for the strength.

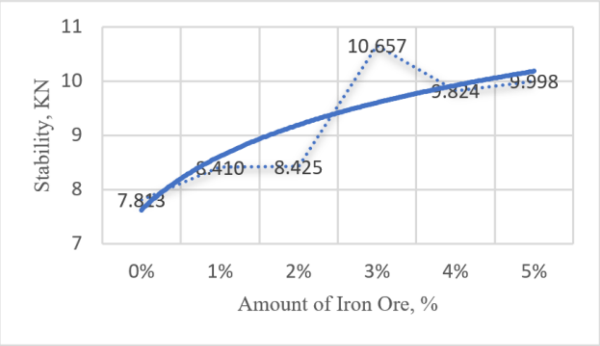

Figure 1. Stability

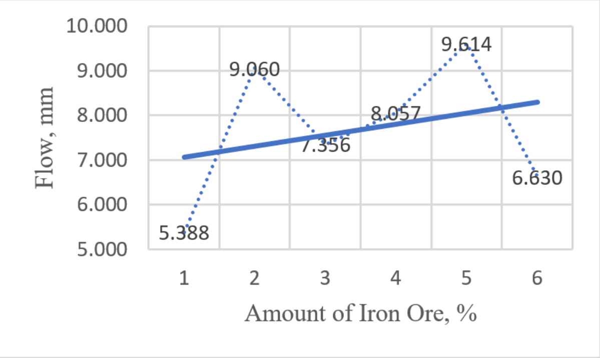

Figure 2. Flow

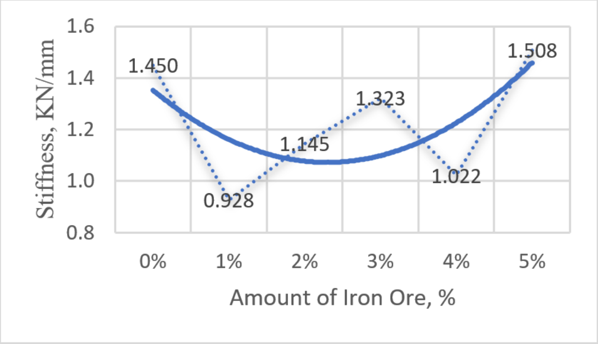

Figure 3. Stiffness

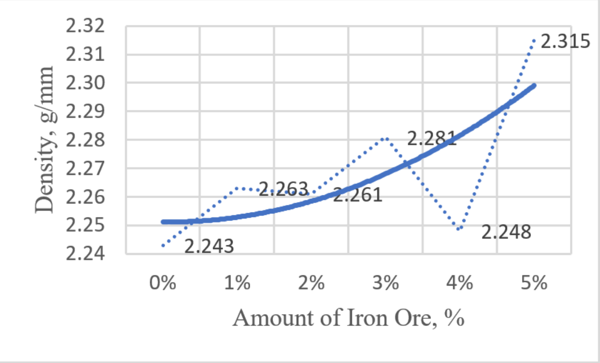

Figure 4. Bulk density

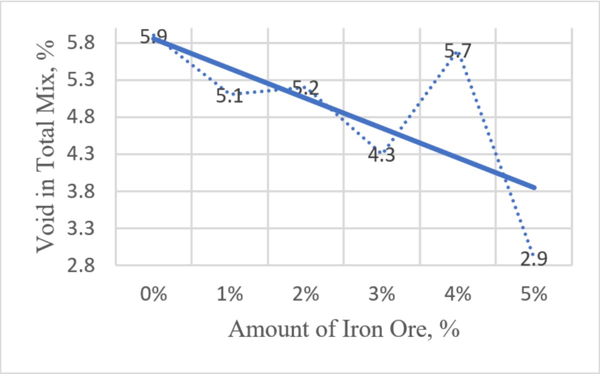

Figure 5. VTM

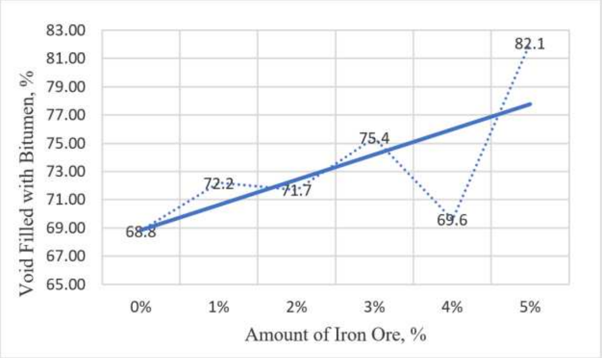

Figure 6. VFA

3.2. Resilient Modulus

The resilient module test is a ratio between the elements of stress and strain. The weight of automobiles on the asphalt surface is referred to as stress, and the strength-to-area ratio is referred to as the strength-to-area ratio. The strain in the toughness modular test is the capability of the asphalt or substance, without deformities such as rutting or cracking, to return to its original form after load applied by heavy vehicles. As a result, the test was performed in the laboratory employing vertical load sequences in the specimen to produce accurate, robust modulus data. The object of the vertical loads was not only to distort the specimens but also to get the specimen back to their original form, called the horizontal and vertical deformation retrievable that happens during repeated loads. In this experiment, a total of 25°C and 40 °C is applied to all 12 samples, with two directions of 0 and 90o and three separate pulses repeating (1000m, 2000ms, and 3000m), in line with ASTM D 4123. The result of a resilient module and maximum strength are shown in Figure 7 and Figure 8.

3.3. Dynamic Creep

The Universal Test Machine (UTM) is used to perform destructive dynamic creep testing. The test was done to see if the asphalt mix was getting ruts. At a temperature of 40°C, the cycle and strain for an unaffected and altered sample is shown in Figure 9. Based on the result, the modified sample with Iron Ores of (0,1,2,3,4 and 5%) in SMA is the lower strain compared to the unmodified sample. The graph's lowest dynamic creep result was at an IO level of 1%. However, when compared to a changed specimen, the highest dynamic creep result from the graph was at an IO level of 2%.

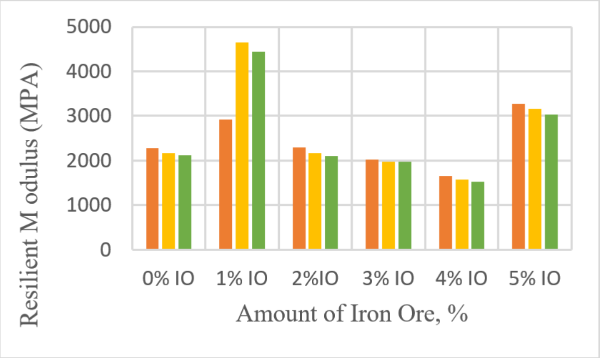

Figure 7. Resilient modulus 25°C

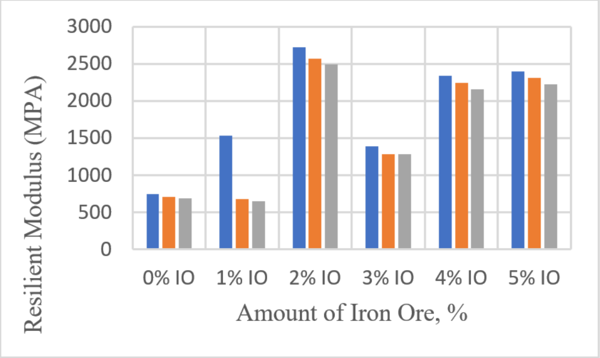

Figure 8. Resilient modulus 40°C

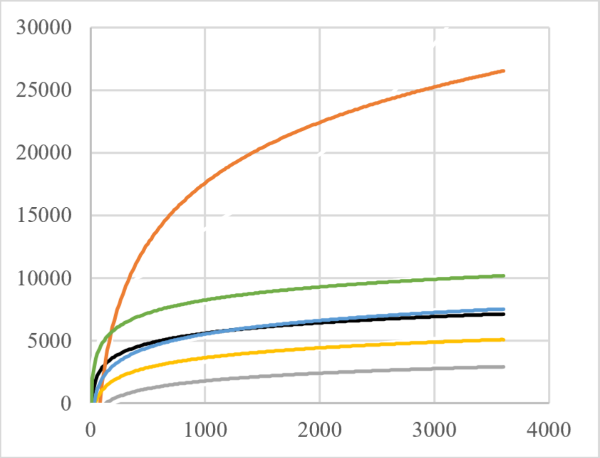

Figure 9. Dynamic creep test

3.4. Abrasion Resistance

From Figure 10, 4% of the Ore material reported being the highest abrasion value in 300 revolutions, and the lowest abrasion rate was 0% of the Ore content. The SMA tensile power increases with decreasing abrasion. Iron Ore helps increase the hardness and consistency of improved asphalt binder SMA. The lowest loss abrasion, 0% ore content was determined to be the optimal value to increase the effectiveness of the SMA combinations. The modified asphalt Iron Ore binder performs well over a long term in pavement, dam construction, and slope stabilization and is sufficiently resistant to the abrasive impact.

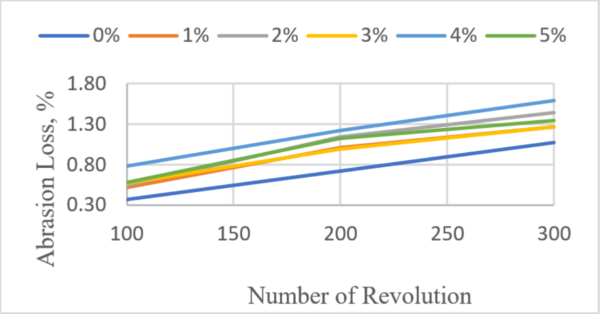

Figure 10. Los Angeles Abrasion

4. Conclusions

At the end of the tests that were carried out in this study, it can be concluded that the mechanical characteristics of asphalt pavement may differ noticeably upon the amount of iron ore added to the asphalt mixture. Additionally, the results unmistakably demonstrated that 5% iron ore was the ideal amount to add to the asphalt mixture to have the greatest impact on the mechanical characteristics of the modified asphalt and to produce improvements in the Marshall, resilient modulus, dynamic creep, and abrasion tests.

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