



Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

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ARTICLE INFO	ABSTRACT
Published:	Asbuton, a natural raw material, has significant potential for developing high-quality asphalt mixtures. However, optimizing its performance remains a challenge, particularly in enhancing flexibility, adhesion, and stability. This study addresses the problem of conventional asphalt mixtures lacking sufficient stiffness and durability by exploring the use of additives, specifically used oil and high-density polyethylene (HDPE) plastic, to improve the performance of Asbuton-based asphalt. The research aims to evaluate the effect of these additives on the mechanical properties of the mixture, particularly its indirect tensile stiffness modulus (ITSM), which better represents elastic response compared to the traditional Marshall method. The study employs an AC-BC mixture using a combination of Modified Asphalt (MO) and Oil Asphalt (MI), with Asbuton as the base material. A fixed additive content of 6.0% KAO (of total weight) is applied across three asphalt compositions: 40% MO–60% MI, 50% MO–50% MI, and 60% MO–40% MI. ITSM testing results show increasing stiffness with higher proportions of modified asphalt, yielding values of 6124 MPa, 6286 MPa, and 6738 MPa, respectively. These findings indicate that the addition of used oil and HDPE can enhance the rigidity and overall performance of Asbuton mixtures, with higher modified asphalt content producing greater stiffness. The study provides practical implications for the development of durable, flexible, and high-performance asphalt pavements using locally sourced natural materials.
Keywords: <i>Asbuton, HDPE plastic, used oil, ITSM.</i>	

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INTRODUCTION

Asbuton as a natural raw material has great potential in the development of high-quality asphalt mixtures. The distinctive characteristics of *asbuton* can improve the durability and performance of asphalt materials used in road infrastructure (Hasyir & Wasono, 2020; Hidayatulloh et al., 2021; Karyawan et al., 2021; Karyawan, Hasyim, et al., 2023; Sumiati et al., 2019). However, the challenge faced is how to optimize the *asbuton* mixture to meet the required durability and performance standards in the field (Handayani et al., 2017; Maha et al., 2015; Subagio et al., 2016; Taher & Aman, 2020).

To improve the quality of the *asbuton* mixture, the addition of additives such as used oil and high-density polyethylene (HDPE) plastic is an interesting solution. Waste oil, which is often considered industrial waste, has viscoelastic properties that can improve the flexibility and adhesion of asphalt mixtures (Lubis & Sari, 2019). Meanwhile, HDPE plastic is known for its resistance to various chemicals and environmental conditions, so it can improve the stability and service life of the mixture (Suksiripattanapong et al., 2022).

The Marshall test has long been recognized as the standard method for assessing the performance of asphalt mixtures. This method mainly evaluates the stability and fatigue of structures through the measurement of density and strength, which is considered an early indicator

of road resistance. However, performance analysis that relies solely on the Marshall test has limitations, especially in describing the stiffness characteristics experienced by road pavement layers under dynamic traffic conditions. This limitation is due to the nature of the Marshall test, which focuses more on static parameters.

Stiffness is one of the key parameters in determining the service life of asphalt mixtures. The Indirect Tensile *Stiffness* Modulus (ITSM) test serves to assess the level of stiffness of asphalt mixtures, especially related to road pavement (Iwański, 2020; Kaushik & Siddagangaiah, 2022; Zhang et al., 2016). The main purpose of this test is to determine the extent to which the asphalt mixture can withstand deformation or strain due to the load it receives. The results of the ITSM test are useful for assessing the performance of the asphalt mixture, particularly in relation to the potential for cracks in the road pavement.

Previous studies have examined the use of additives to improve asphalt mixtures. Reznadya et al. (2025) highlighted the potential of *asbuton* as a natural raw material to enhance durability and performance, but their study focused primarily on static properties and did not explore the combined effect of industrial waste additives such as used oil and plastics. Similarly, Suksiripattanapong et al. (2022) investigated HDPE-modified asphalt mixtures and found improvements in stability and chemical resistance; however, the study did not integrate viscoelastic waste materials like used oil, nor did it evaluate the mixture under dynamic loading conditions using ITSM. These limitations reveal a research gap: while prior studies confirm the individual benefits of *asbuton*, HDPE, or used oil, few have comprehensively analyzed a combined additive system under realistic stiffness and elastic response assessments relevant for pavement performance.

The objective of this research is to determine the effect of additive composition on stiffness and deformation resistance, providing a more representative evaluation of road pavement behavior. The findings are expected to guide the development of durable, flexible, and environmentally sustainable asphalt mixtures, optimizing both material performance and the utilization of industrial waste in infrastructure construction.

METHOD

The study employs an AC-BC mixture using a combination of Modified Asphalt (MO) and Oil Asphalt (MI), with *Asbuton* as the base material. A fixed additive content of 6.0% KAO (of total weight) is applied across three asphalt compositions: 40% MO–60% MI, 50% MO–50% MI, and 60% MO–40% MI. ITSM testing results show increasing stiffness with higher proportions of modified asphalt, yielding values of 6124 MPa, 6286 MPa, and 6738 MPa, respectively.

This research was carried out in the Transportation Laboratory of the Department of Civil Engineering, Faculty of Engineering, University of Mataram, West Nusa Tenggara, and the Highway Laboratory of the Civil Engineering Study Program, Udayana University, Bali.

There are two types of data used in this study, namely primary data and secondary data. Primary data are data collected directly through a series of self-conducted experimental activities with reference to manual instructions. Secondary data are data obtained indirectly or from previous

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

research that uses the same material and is still related or sustainable; in this study, secondary data come from previous research.

The equipment used is as shown in Figure 1.

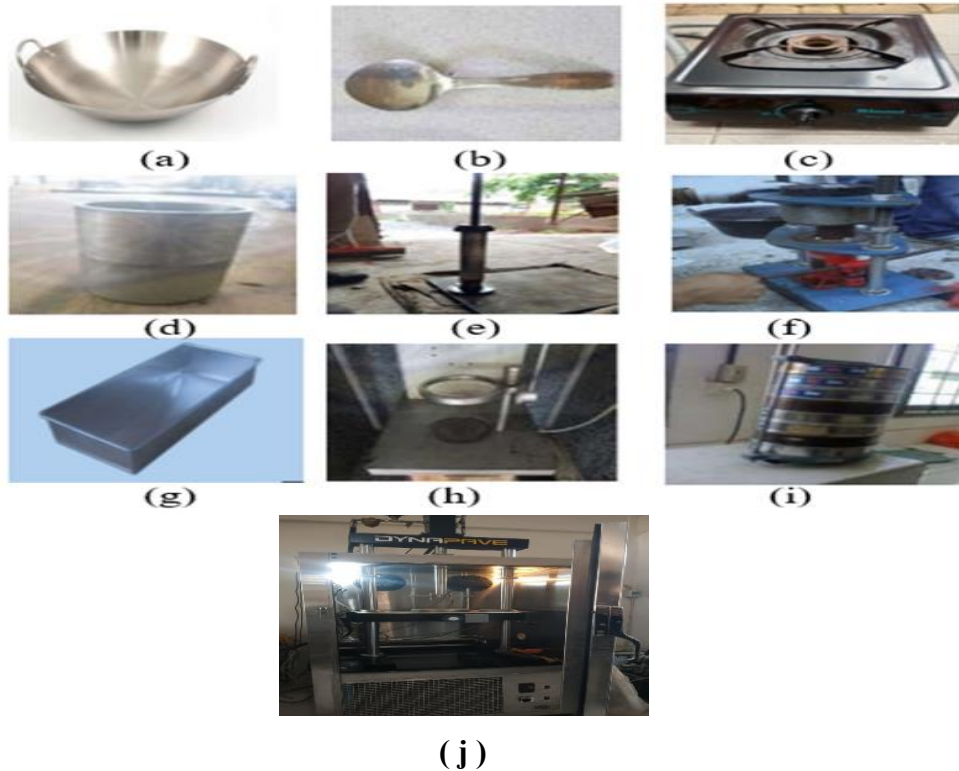


Figure 1. Equipment for making test specimens : (a) Frying pan, (b) Spoon, (c) Stove, (d) Test object mold, (e) Fist rod, (f) Ejector, (g) Zinc can, (h) Compactor substrate, (i) Aggregate filter, (j) Dynapave UTM 30

The materials used in this study are as follows:

- a. Asphalt oil Penetration 60/70
- b. Asbuton extraction from PT. The Formation of the Greek Culture
- c. Used oil
- d. HDPE plastic waste
- e. Coarse and Fine Aggregate Material from PT. Sinar Bali Pringgabaya-East Lombok
- f. Filler with the brand Semen Bosowa

Test Piece Manufacturing and Testing

At this stage, all materials have been prepared according to research needs. Manufacturing materials that have been equipped with documents in the form of test result certificates are no longer subjected to property tests; researchers only use existing data. Meanwhile, for materials

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

such as asphalt and aggregate, tests are carried out according to the 2018 *General Highway* specifications.

Asphalt testing and inspection include: *daktalicity* test, penetration, flash point, softening point, specific gravity, and oil weight loss. The test results are cited from existing data in previous research.

For coarse aggregate, fine aggregate, and filler, testing includes: aggregate wear testing, bulk specific gravity, surface dry saturated specific gravity, pseudo-specific gravity, effective specific gravity, water absorption, and gradation. The results of these property tests are taken from secondary data, namely from the results of previous research.

At this stage, all property test results that meet the *general* specification standards of *Bina Marga 2018* are used as a reference to make a mix design. This mix design also takes data from secondary sources, including the results of Agustin's research (2023). The mix design is derived from the value with the best K.A.O, which is 6%, and the best Marshall value using a mixture of 50% oil asphalt and 50% modified asphalt. Therefore, the composition of the mixture is tested as follows.

Composition of the test object mixture:

Table 1. Composition of test specimen mixture I

Material	Sum	Details
Asphalt (modified asphalt + oil asphalt)	6 %	40% Modified asphalt (MO) 60% Oil Asphalt (MI)
Coarse Aggregate	42%	100% Natural aggregate
Fine Aggregate	46 %	100% Natural aggregate
Filler	6 %	100% Natural aggregate

Table 2. Mixed composition of test specimen II

Material	Sum	Details
Asphalt (modified asphalt + oil asphalt)	6 %	50% Modified asphalt (MO) 50% Asphalt Oil (MI)
Coarse Aggregate	42%	100% Natural aggregate
Fine Aggregate	46 %	100% Natural aggregate
Filler	6 %	100% Natural aggregate

Table 3. Mixed composition of test specimen III.

Material	Sum	Details
Asphalt (modified asphalt + oil asphalt)	6 %	60% Modified asphalt (MO) 40% Oil Asphalt (MI)
Coarse Aggregate	42%	100% Natural aggregate
Fine Aggregate	46 %	100% Natural aggregate
Filler	6 %	100% Natural aggregate

Before the manufacture of the test piece, the first thing done is to make a modified asphalt mixture. The manufacture of modified asphalt is carried out by the hot asphalt-plastic mixture method. Asphalt and plastic are heated in different containers. After both have melted, the asphalt

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

is poured into a plastic container that has melted. Then stirring is carried out during mixing until the modified asphalt becomes homogeneous and the mixing temperature when a homogeneous mixture is obtained is recorded. Likewise, used oil is added when the asphalt melts (Karyawan, Kencanawati, et al., 2023).

The comparison of mixing asphalt and modified materials (used oil and HDPE) used was 100 grams of asphalt extracted from asbuton plus 5 grams of used oil and 6 grams of HDPE plastic (Karyawan, Kencanawati, et al., 2023).

After the modified asphalt mixture is completed, the test object begins to be made. The stages of making the test specimen are as follows:

- a. Weigh HDPE plastic according to the measurement, then heat until it melts at a temperature of 200 °C - 280 ° C;
- b. Weigh the extracted asbutone according to the dose, then heat it until it melts at a temperature of 140° C - 160° C;
- c. Mix the heated extraction asbuton with the melted HDPE plastic, stir until homogeneous, then add the used oil according to the measurement. Mix the three ingredients until homogeneous, after looking homogeneous, this mixture is cooled.
- d. Heat coarse aggregates, fine aggregates and fillers according to the available amount, heated to 170°C.
- e. Mix 60/70 oil asphalt with modified asphalt according to the dosage in composition I (40% oil asphalt and 60% modified asphalt). Composition II (50% oil asphalt and 50% modified asphalt) and composition III (60% oil asphalt and 40% modified asphalt) stir until it looks homogeneous at a temperature of 140° C - 160° C.
- f. Put the coarse aggregate, fine aggregate and filler into the oil asphalt and modified asphalt that has been mixed, stirring until homogeneously mixed at a temperature of 140° C - 160° C.
- g. For the mixture, 3 test pieces are made for each composition, so the total test pieces are 9 pieces.
- h. Once the mixture looks homogeneous, place it in the test specimen mold, by coating it with the paper bottom of the mold.
- i. Pierce the mixture with a spatula inside the mold 25 times, then the top layer of the mold is coated with paper, then the test specimen is mashed 2 x 75 bumps on the top and bottom of the mold.
- j. After finishing the mash, the test specimen is removed from the mold using an ejector device.
- k. After that, the test specimen is cooled for 24 hours and each sample is named.

Based on the Indirect Tensile Stiffness Modulus (ITSM) test procedure manual for road pavement samples using the Dynapave Universal Testing Machine (UTM) prepared by I Nyoman Arya Thanaya, Civil Engineering study program, Faculty of Engineering, Udayana University in 2017, the following is the testing method (ITSM) used.

The test procedure is carried out as follows:

1. Suitable transducer set on IMAC channel

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

2. Open the test menu, select the UTS003- Indirect Tensile Stiffness Modulus (ITSM) menu, select New Test. It can use the available test templates or new test sets.
3. Open and set up the Virtual Pendant Menu
4. Mains, show the power supply
5. Warning, reminding if the test table (cross head) has not been locked
6. Fault, if there is damage.
7. ITSM Data Input and Set Up Parameters
8. Set the sample and set the Load Actuator/Piston and transducer level
9. Start test
10. Before the test starts, select the Test Result Menu, to view a graph of the test results. In the initial stage, 5 conditioning pulses were applied. It will appear on the screen.
11. The test results can be in the form of pdf or as a csv file that can be opened and processed using excel.

RESULT AND DISCUSSION

Asphalt, Aggregate and Filler Test Results

The 60/70 penetration asphalt test aims to find out the characteristics of asphalt as a binding agent in the mixture. This study uses asphalt from PT. Kresna Karya, Pringgabaya District, East Lombok Regency. This test refers to the 2018 General Specification of Bina Marga Revision 2 which consists of several parameters in the study. For test results, see Table 4.

Table 4. 60/70 Penetration Asphalt Test Results

Yes	Types of Testing	Asphalt Pen 60/70	Specifications
1	Penetration at 25oC (0.1 mm)	63,5	60 - 70
2	Soft Spot oC	53	≥ 48
3	Flash Point oC	300	≥ 232
4	Ductility at 25oC (cm)	149,1	≥ 100
5	Specific Gravity	1,04	≥ 1,0
6	Oil Weight Loss, %	0,29	≤ 0,8

Based on the test results contained in Table 4, all test results meet the standards of the 2018 General Specification of Bina Marga Revision 2 (2020). So that the asphalt can be used in this study as a binding material in the pavement mixture.

Testing of modified asphalt from asphalt extraction of Asbuton, 5% waste oil and 6% HDPE aims to find out the characteristics of asphalt as a binding agent in the mixture. This study uses asphalt from PT. Sustainable Nature Performance Gresik, East Java. This test refers to the General Specification of Highways which consists of several parameters in the study. For test results, see Table 5.

Table 5. Modified Asphalt Test Results

No	Types of Testing	Modified Asphalt	Specifications
1	Penetration at 25oC (0.1 mm)	63,1	50 - 60

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

2	Soft Spot oC	96	≥ 50
3	Flash Point oC	232	≥ 232
4	Ductility at 25oC (cm)	9,55	≥ 100
5	Specific Gravity	1,498	$\geq 1,0$
6	Weight Loss, %	0,045	$\leq 0,8$

Based on the test results contained in Table 5, the test results obtained penetration, soft spots, flash points, specific gravity, and weight loss meet the standards of the 2018 General Specification of Bina Marga Revision 2 (2020), only the ductility test does not meet the standards of the General Specification of Bina Marga 2018 Revision 2 (2020). The "Findings" section gives a concise explanation of the result of the researcher's data collection. Meanwhile, the "Discussion" section displays the researcher's analysis of the obtained data, which also includes citations from relevant, supporting sources.

The purpose of testing aggregates and fillers is to determine whether the characteristics of aggregates and fillers meet the General Specifications of Bina Marga 2018 Revision 2 (2020) or not. The aggregate used consists of coarse and fine aggregates derived from PT. Sinar Bali Binakarya, Pringgbaya, East Lombok Regency. As for the filler, it uses Bosowa brand portland cement. For test results, see Table 6.

Table 6. Aggregate and Filler Test Results

No	Aggregate Testing	Result	Specifications
Coarse Aggregate			
1	Bulk Specific Gravity	2,73	$\geq 2,5$
2	Surface Dry Saturated Specific Gravity	2,78	
3	Pseudo-Gravity	2,88	
4	Effective Specific Gravity	2,8	
5	Keausan Impact (%)	20	$< 30\%$
6	Absorption (%)	0,02	$< 3\%$
Fine Aggregate			
1	Bulk Specific Gravity	2,75	$\geq 2,5$
2	Surface Dry Saturated Specific Gravity	2,83	
3	Pseudo-Gravity	2,98	
4	Effective Specific Gravity	2,87	
5	Absorption (%)	0,03	$< 3\%$
Filler (Semen Portland Bosowa)			
1	Bulk Specific Gravity	2,3	$\geq 2,5$
2	Surface Dry Saturated Specific Gravity	2,3	
3	Pseudo-Gravity	2,31	
4	Effective Specific Gravity	2,3	
5	Absorption (%)	0,06	$< 3\%$

Based on the test results in Table 6, all test results of coarse aggregates, fine aggregates, and fillers have met the standards of the 2018 Bina Marga General Specification Revision 2 (2020). So that aggregates and fillers can be used as pavement mixing materials in this study.

Determination of Mixed Warranty of Test Specimen and KAO.

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

The purpose of this determination is to determine the characteristics of the AC – BC laston using the middle limit of the aggregate gradation according to the standards of the General Specification of Bina Marga 2018 Revision 2 (2020).

Table 7. Aggregate Gradient in Mixtures.

No	Size Ayakan (mm)	AC - BC	Middle Value	Pass Percentage (%)	Percentage Held (%)
1"	25	100	100	100	0
3/4"	19	90 - 100	95	95	5
1/2"	12,5	75 - 90	83	83	12
3/8"	9,5	66 - 82	74	74	9
No.4	4,75	46 - 64	55	55	19
No.8	2,36	30 - 49	40	40	15
No.16	1,18	18 - 38	28	28	12
No.30	0,6	12 - 28	20	20	8
No.50	0,3	7 - 20	14	14	6
No.100	0,15	5 - 13	9	9	5
No.200	0,075	4 - 8	6	6	3
Filler					6
Total					100

From Table 7, the aggregate gradation for laston AC – BC is obtained in Figure 3.

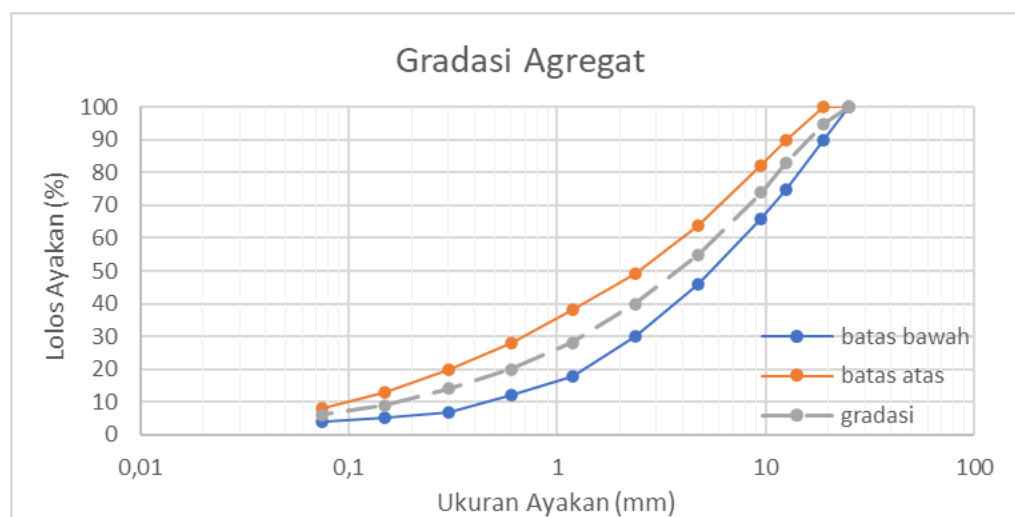


Figure 3. Aggregate gradation graph for Laston AC – BC.

In Table 7, the proportional value of each aggregate fraction and filler is known. For the percent of the coarse aggregate expressed in the formula as (%CA), the percent of the fine aggregate with the symbol (%FA), the percent of the filler with the symbol (%FF), and 0.75 is the constant (K) for the laston. So that the value of the planned asphalt content (Pb) can be determined as follows:

Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

$$Pb = 0.035 (\%CA) + 0.045 (\%FA) + 0.18 (\%FF) + K$$

$$Pb = 0.035(45) + 0.045(49) + (0.18(6) + 0.75$$

$$Pb = 5.6\% \approx 6\% \text{ (rounded result)}$$

The value of $Pb = 6\%$ was obtained from the calculation results, so that for the value of other variations it could be determined, namely $Pb-1 = 5\%$, $Pb-0.5 = 5.5\%$, $Pb = 6\%$, $Pb+0.5 = 6.5\%$, and $Pb+1 = 7\%$. After determining the value of each variation in the planned asphalt content (Pb), the next stage calculates the optimal asphalt content value (KAO).

By Previous research conducted by (Karyawan et al., 2024), the recapitulation of mechanical and volumetric values is obtained, namely Stability, Flow, MQ, VMA, VIM, and VFB, as shown in Table 8.

Table 8. Recapitulation of the results of Mechanical and Volumetric calculations

Parameter	Specifications	Up to Asphalt (%)				
		5,0%	5,5%	6,0%	6,5%	7%
Stability (kg)	≥ 800 kg	2305.146	2060.109	1672.599	1519.655	1368.206
Flow (mm)	2 - 4 mm	1.990	1.997	3.747	3.910	3.993
SQM (Kg/mm)	≥ 250 Kg/mm	1338.539	1152.677	459.829	394.809	341.301
VMA (%)	$\geq 14\%$	14.445	14.660	14.774	14.789	14.908
VIM (%)	3 - 5 %	5.272	4.327	3.275	2.111	1.068
VFB (%)	≥ 65 %	63.631	70.801	78.262	85.984	92.868

Based on the results of Table 8, the asphalt content is 6% that meets the General Specification of Bina Marga 2018 Revision 2 (2020), so that the Optimum Asphalt Content (KAO) is used at 6%.

Indirect Tensile Fatigue Test (ITFT) Test Results.

Indirect Tensile Stiffness Modulus (ITSM) is a parameter used to measure the stiffness of a material, especially in asphalt or asphalt concrete, in resisting indirect tensile loads. The modulus of indirect tensile stiffness is measured through laboratory testing using the Indirect Tensile Test method. This test is performed by applying a load to the material sample in the diametrical direction, thereby causing an indirect tensile stress on the sample. The results of the Indirect Tensile Stiffness Modulus (ITSM) test can be seen in Table 9.

Table 9. Indirect Tensile Stiffness Modulus (ITSM) test results

Up to Asphalt (%)	ITSM Value (MPa)
40% MO:60% MI	6124
50%MO:50%WED	6286
60%MO:40%WED	6738

From Table 9, a graph of the relationship between asphalt content and *Indirect Tensile Stiffness Modulus* (ITSM) is obtained in Figure 4.

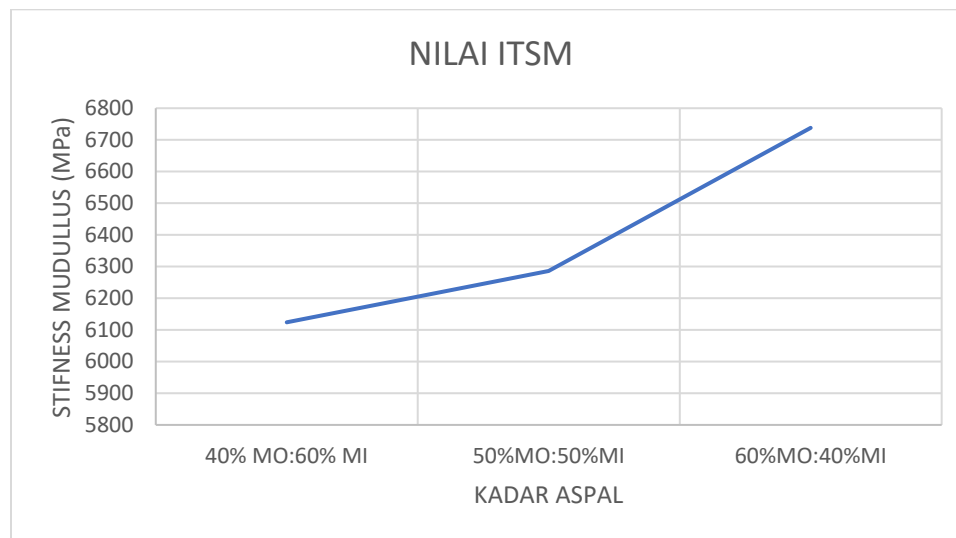


Figure 4. Graph of the Relationship of Asphalt Rate with ITSM Value

Based on Figure 4, the Indirect Tensile Stiffness Modulus (ITSM) value obtained varies. In the composition of 40% MO: 60% MI the ITSM value is 6124 Mpa, while in the composition of 50% MO: 50% MI the ITSM value becomes 6286 Mpa, and finally in the composition of 60% MO: 40% MI becomes 6738 Mpa. This suggests that further modification asphalt increases the stiffness of the mixture. The rigidity of the material (ITSM) is directly proportional to the addition of modified asphalt. This is due to the characteristics of modified asphalt materials that contain HDPE Plastic which increases rigidity, where Modified Asphalt (MO) begins to provide a strengthening effect as the number of compositions increases. According to Aschuri & Woodward (2007), the addition of HDPE to bitumen significantly increases the stiffness modulus value (ITSM), in line with the increase in the proportion of HDPE. The findings of Reza et al. (2022) also show that the mixture of HDPE and RAP contributes to the improvement of ITSM despite the decrease in high test temperatures. In addition, Nawir & Mansur (2021) prove that the addition of HDPE to asphalt increases rigidity as seen from the Marshall parameters.

CONCLUSION

The stiffness performance of the AC-BC mixture using 60/70 (MI) penetration asphalt adhesive coupled with *asbuton* modified asphalt with used oil additives and HDPE plastic (MO), combined with natural aggregates in ratios of 40% MO: 60% MI, 50% MO: 50% MI, and 60% MO: 40% MI, was obtained as follows: the composition of 40% MO: 60% MI yielded an ITSM value of 6124 MPa; the composition of 50% MO: 50% MI resulted in an ITSM value of 6286 MPa; and finally, the composition of 60% MO: 40% MI showed an ITSM value of 6738 MPa. This suggests that increased modified asphalt content increases the stiffness of the mixture. The rigidity of the material (ITSM) is directly proportional to the addition of modified asphalt.

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Indirect Tensile Stiffness Modulus (ITSM) Analysis of Asbuton Mixture with Used Oil Additives and HDPE

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