The Influence of Soaking Time Variation in Different Types of Water on the Stability and Marshall Flow of Asphalt Mix Pen 60/70

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Abstract. This study analyzes the effect of immersion duration in three types of water—seawater, brackish water, and freshwater—on the stability and flow of a Marshall asphalt mix using Pen 60/70 asphalt. Test specimens were prepared using the Marshall method and immersed for 30 minutes and 24 hours to evaluate the impact of immersion time on the Marshall characteristics of the asphalt mix. The testing revealed that both immersion duration and water type significantly affect the decrease in stability and flow. A 24-hour immersion in seawater caused the largest stability reduction, at 36.40%, along with an 11.11% decrease in flow. Conversely, a 30-minute immersion in freshwater resulted in the smallest reduction, with stability decreasing by 12.34% and flow by 3.70%. These findings demonstrate that the longer the immersion duration and the more corrosive the water, the greater the negative impact on the Marshall characteristics. The implication is that coastal infrastructure exposed to seawater faces a higher risk of accelerated deterioration, necessitating strategic planning and appropriate materials to improve road durability in such environments. This study supports the importance of additional protective measures for coastal roads to enhance resilience and reduce long-term maintenance costs.

Keywords: Immersion Duration, Stability, Flow, Seawater, Brackish Water, Freshwater

1 Introduction

Road pavement is a crucial element in transportation infrastructure, serving to withstand traffic loads and distribute them to the underlying soil. In Indonesia, asphalt is widely used as the primary material for road pavement due to its flexibility, availability, and ability to withstand dynamic vehicle loads. The growth in traffic has led to an increased demand for transportation infrastructure. Roads, as essential infrastructure, play a crucial role in connecting production sources. Asphalt, as the binding material for aggregates in road pavement construction, plays a key role in determining the performance of the road pavement [1]. However, asphalt pavement is also susceptible to damage caused by environmental factors such as temperature changes, humidity, and water interaction. One of the greatest challenges in

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maintaining the durability of asphalt pavement is the effect of water, including rainwater, groundwater, seawater, and brackish water, which can degrade the mechanical characteristics of asphalt, including stability, density, flow, and Marshall Quotient.

The impact of water on asphalt pavement has been a major concern, particularly in several regions of Indonesia where asphalt pavement is frequently exposed to seawater or brackish water, especially in coastal areas and regions with high groundwater levels. Seawater and brackish water contain higher salt and mineral content compared to freshwater, which accelerates pavement deterioration. Water penetration into asphalt layers can lead to aggregate stripping, weakening the bond between asphalt and aggregate, and reducing the pavement's resistance to traffic loads. Several studies have shown that seawater has a more significant impact on asphalt damage compared to freshwater. Road pavements along coastal areas are at risk of being submerged by seawater, which has a different salinity than freshwater. The salt composition of seawater includes chloride (55%), sodium (31%), sulfate (8%), magnesium (4%), calcium (1%), and other elements (< 1%) such as bicarbonate, bromide, boric acid, strontium, and fluoride. On average, seawater contains 3.5% salt per liter [2]. The salt content in seawater accelerates the oxidation process and increases the risk of damage due to stripping, which is the loss of adhesion between asphalt and aggregate due to water infiltration. Brackish water, while containing lower salt concentrations than seawater, has similar effects but at a lesser intensity. Meanwhile, freshwater, although capable of causing pavement damage, has a less severe impact compared to seawater and brackish water. The duration of immersion is also a crucial factor in asphalt pavement testing. Long-term immersion can accelerate the degradation process, particularly in environments exposed to seawater or brackish water.

Therefore, it is essential to understand how different immersion durations in various types of water affect the Marshall characteristics of asphalt mixtures. Testing the stability and flow of Marshall specimens is one method to evaluate the performance of asphalt pavement when exposed to water for a certain period. Salt is used in civil engineering to de-ice roads in cold regions. This study examines asphalt concrete exposed to temperature changes and freeze-thaw cycles. Results show salt water improves adhesion, maintains strength, and reduces damage from frozen water despite the negative effects of temperature changes [3]. ne factor contributing to flexible pavement damage is submersion in acidic water, such as seawater. To tackle this issue, a study explored the use of Buton asphalt (as-buton), known for its superior adhesion and resistance to temperature fluctuations. This research examines how the addition of as-buton affects the modified asphalt mixture and the influence of seawater immersion on the as-buton mixture, utilizing the Marshall characteristic test. The as-buton was added in weight percentages of 5%, 7.5%, and 10%. [4]. The results of the preparation and testing of aggregate and asphalt materials indicate that the grading of the AC-WC mixture meets the requirements. The optimum asphalt content (OAC) was determined using the Marshall method, yielding a result of 5.75%. Increasing the asphalt content to 6% improved the flow, VMA, VFB, and MQ values, while the VIM value decreased. Phase II testing showed that the stability of the Laston mixture decreased as the immersion duration in saline water increased [5]. The Marshall test results show the highest stability in brackish water immersion (3259 kg),

with the highest MQ also in brackish water (821.30 kg). A salt concentration of 0.32% in brackish water yields high stability, but exceeding 0.32% leads to decreased stability. However, the flow, VIM, and VFA values do not meet specifications [6].
In this context, research on the effect of asphalt pavement immersion in seawater, brackish water, and freshwater with varying durations is highly relevant. The aim of this study is to evaluate how immersion durations of 30 minutes and 24 hours in three different types of water affect the stability and flow of asphalt mixtures. Road pavements in coastal areas, such as Jalan Kaligawe Raya in Semarang, are at risk of being submerged by seawater due to tidal flooding (ROB). Seawater can cause damage, especially when combined with repetitive traffic loads that shorten the lifespan of the road. This study examines asphalt pavement mixtures with steel slag that have been submerged in seawater for 6, 12, and 24 hours, and tested using the Marshall test to obtain density values [4]. The findings of this research are expected to provide valuable information for engineers and practitioners in designing road pavements that are more resistant to environmental influences, particularly in coastal areas and regions frequently exposed to water. Additionally, this study can offer further insights into material selection and proper pavement maintenance methods to extend the service life of roads. By better understanding how immersion duration and water type affect Marshall characteristics, more effective strategies can be developed to mitigate early pavement deterioration caused by environmental factors, ultimately improving the performance and longevity of road infrastructure in Indonesia.

2 Research Method

This research was conducted at the Material Testing Laboratory of the Civil Engineering Department at Politeknik Negeri Sriwijaya and the Construction Materials Laboratory of the Public Works and Spatial Planning Department of South Sumatra Province, following the 2018 Bina Marga General Specifications Revision 2. The research stages included preparation, material testing, specimen preparation, and specimen testing The materials used include 60/70 penetration asphalt and coarse aggregates from PT. Hakaaston UP Indralaya Prabumulih, fine aggregates from Depot Sriwijaya Maju Bersama, type 1 cement from PD. Karya Sentosa, stone dust from Batu Lingut, OKU Timur, as well as seawater, brackish water, standing water, and freshwater from various sources. The study aims to evaluate the effect of soaking time variations in different types of water on the stability and Marshall flow of 60/70 penetration asphalt mixtures. The research was conducted by creating a Design Mix Formula (DMF) to determine the Optimum Asphalt Content (OAC). The obtained OAC was then used [7].

3 Result and Discussion

3.1 Marshall Test Results to Determine the Optimum Asphalt Content (OAC)

The mix design results for the preparation of test specimens are derived from the aggregate mix design obtained through testing with asphalt content variations of 5%, 5.5%, and 6%. These asphalt content variations aim to determine the most optimal mix in achieving the desired characteristics, such as Marshall stability, flow, and density that meet technical specifications. Table 1presents the results of the Marshall test, including key parameters such as Marshall stability, Marshall flow, VIM (Void in Mix), VMA (Void in Mineral Aggregate), and VFB (Void Filled with Bitumen). Each asphalt content variation is tested to determine its effect on these parameters, helping to identify the asphalt content that yields the most optimal result, known as the Optimum Asphalt Content (OAC). This testing is crucial because the OAC significantly impacts the performance of the asphalt mix in the field. A mix with too low asphalt content can make it stiff and brittle, while too high asphalt content can result in a soft mix prone to deformation. Therefore, the 5%, 5.5%, and 6% asphalt content variations are tested to achieve the right balance between strength and flexibility of the asphalt mix.

Table 1. Recapitulation of Marshall Test Results to Determine Optimum Asphalt Content (OAC)

Mixture Characteristics	Unit	Asphalt Content			Spec.
		5	**5,5**	**6**	
Stability	kg	1096,33	1376,00	1431,50	Min.800
Flow	Mm	3,04	3,42	3,72	2-4
VIM	%	5,66	2,48	0,41	3-5
VFA	%	65,89	80,81	90,00	Min.65
VMA	%	16,64	15,25	14,91	Min. 15

Based on the graph above, the asphalt content variation that meets the 2018 Bina Marga General Specifications Revision 2 is within the range of 5.10% to 5.40%. This range is selected because it satisfies the technical criteria for several key parameters, such as stability, flow, VIM (Void in Mix), VMA (Void in Mineral Aggregate), and VFB (Void Filled with Bitumen), all of which influence the performance of the asphalt mixture in field conditions Each of these parameters is tested with careful consideration of the balance between strength and flexibility. High stability is required for the mixture to withstand traffic loads without significant deformation, while good flow indicates the mixture's ability to adapt to shape changes without damage. Additionally, an appropriate VIM value ensures there is sufficient space between aggregates to accommodate thermal expansion, and proper VMA and VFB values ensure that the mixture contains enough asphalt to bind the aggregates without too much or too little void space. From the graph analysis, the optimal asphalt content is found at the midpoint of this range, which is 5.25%. This is considered the most suitable asphalt content because it provides the best balance between strength, flexibility, and durability of the asphalt mixture, and is therefore identified as the Optimum Asphalt Content (OAC) in this study. With an OAC of 5.25%, the mixture is expected to deliver maximum performance and long-lasting durability when applied to road pavements. In conclusion, this OAC is the result of a comprehensive evaluation of several technical parameters, ensuring that the asphalt mixture can function optimally in real-world field conditions.

Table 2. Graph of Recapitulation of Marshall Test Results to Determine Optimum Asphalt Content (OAC)

No	REQUIRED MIXTURE PROPERTIES	ASPHALT CONTENT RANGE 5,0 5,5 6,0 6,5 7,0
1	V M A	
2	V F A	
3	VIM REFUSAL	
4	VIM MARSHALL STANDARD	
5	MARSHALL STABILITY	
6	UNIT WEIGHT	
7	MARSHALL LIMITATIONS	
8	MARSHALL RESULTS	5,25
9	OPTIMUM ASPHALT CONTENT	5,25%

3.2 Marshall Test Results with Various Water Variations

The Marshall test mixture in this study uses a modified Optimum Asphalt Content (OAC), previously determined to be 5.25%. This OAC serves as the basis to ensure that the asphalt mixture produced has optimal performance in field applications. To evaluate the effects of different soaking times and temperatures, tests were conducted with two soaking durations: 30 minutes and 24 hours, each at designated temperatures of 25ºC and 60ºC. Table 3 and Table 4 present the results of the Marshall test based on these variations in soaking time and temperature. Table 3 shows the test results at 25ºC with two soaking time variations. This data is expected to provide insights into how soaking duration at low temperature affects stability, flow, VIM, VMA, and VFB of the asphalt mixture. Meanwhile, Table 4 presents the test results at 60ºC for soaking periods of 30 minutes and 24 hours. This test aims to evaluate the impact of high temperature on the performance of the asphalt mixture. Higher temperatures can affect the viscosity of the asphalt and, therefore, the overall performance of the mixture. It is expected that significant differences will be observed between the test results at low and high temperatures, both in terms of stability and Marshall flow. From these two tables, a thorough analysis of the test results can help determine how variations in soaking time and temperature influence the physical properties of the asphalt mixture, as well as provide insights into optimizing asphalt mixtures for different field conditions. Thus, this information is crucial for improving the quality and durability of road pavements using asphalt mixtures.

Table 3. Recapitulation of Marshall Test Results with Various Water Variations for a Soaking Time of 30 Minutes

Characteristics of Mixture	**Unit**	**Water Variation Soaking Time 30 Minutes**						**Spec.**
		Seawater		**Brackish Water**		**Freshwater**		
		25°C	**60°C**	**25°C**	**60°C**	**25°C**	**60°C**	
Stability	kg	2066,70	1147,00	2033,75	1184,00	2087,00	1283,00	Min.1000
Flow	mm	3,14	3,61	3,06	3,39	2,87	3,14	2-4

Table 4. Recapitulation of Marshall Test Results with Various Water Immersion Variations for 24 Hours

Characteristics of Mixture	**Unit**	**Water Variation Soaking Time 30 Minutes**						**Spec.**
		Seawater		**Brackish Water**		**Freshwater**		
		25°C	**60°C**	**25°C**	**60°C**	**25°C**	**60°C**	
Stability	kg	1659,00	1026,12	1705,00	1026,12	1212,35	1152,28	Min.1000
Flow	mm	4,37	4,63	4,04	4,63	3,58	3,83	2-4

3.2.1 Analysis of Stability

Based on Figure 1, the analysis shows that the highest stability value is achieved using freshwater at a soaking temperature of 25°C, which is 2087.00 kg. This indicates that freshwater has better characteristics in supporting the strength and durability of the asphalt mixture, resulting in optimal stability at lower temperatures. High stability is crucial as it reflects the ability of the asphalt mixture to withstand traffic loads without significant deformation. In contrast, the lowest stability value was obtained from testing with seawater at a soaking temperature of 60°C, which is 1147.00 kg. This reduction in stability may be attributed to several factors, including the increased temperature affecting the viscosity of the asphalt and the chemical properties of seawater that could negatively interact with the materials in the asphalt mixture. Seawater contains salts and minerals that may impact the performance of the mixture, especially at higher temperatures where the asphalt is more susceptible to changes in its physical and mechanical propertie

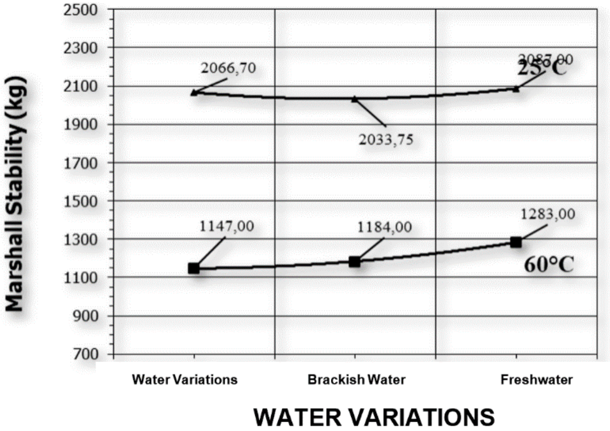

Fig. 1. Graph of Marshall Test Results on Stability for a Soaking Time of 30 Minutes

From these results, it is evident that there is an inverse relationship between soaking temperature and stability value. As soaking temperature increases, the stability values obtained for all types of water tested decrease. This suggests that higher temperatures can deteriorate the performance of the asphalt mixture, potentially due to a weakening of the bond between the aggregates and the asphalt, as well as an increased likelihood of plastic deformation occurring in the mixture. These findings emphasize the importance of selecting the type of water and regulating soaking temperature in the asphalt mixture production process. Further research is needed to explore the effects of temperature and other water types on the stability and performance of asphalt mixtures, in order to provide more comprehensive recommendations for field applications.

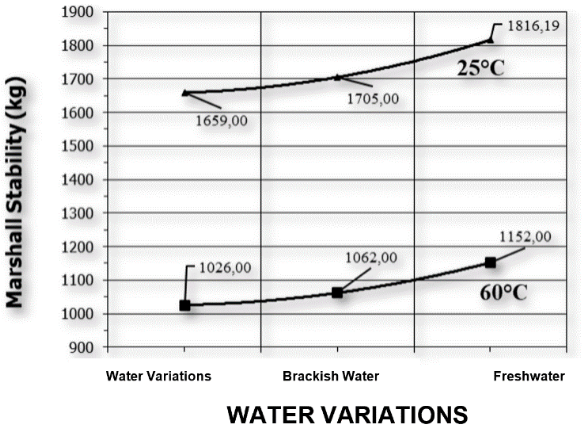

Fig. 2 . Graph of Marshall Test Results on Stability for a Soaking Time of 24 Hours

Based on Figure 2, the analysis indicates that the highest stability value is achieved using freshwater at a soaking temperature of 25°C, with a stability value reaching 1816.19 kg. This figure suggests that freshwater still provides good results in supporting the strength and durability of the asphalt mixture, although there is a decrease in stability compared to the results from the 30-minute soaking test. This indicates that while freshwater remains the best option, soaking time has an influence on the bonding strength within the asphalt mixture. Conversely, the lowest stability value was obtained from testing with seawater at a soaking temperature of 60°C, which is 1026.00 kg. The significant decrease in stability can be attributed to the effects of the higher temperature and the corrosive nature of seawater. The increased temperature can cause the asphalt to become softer and less able to withstand loads, while the salt components in seawater can damage the bond between the aggregates and the asphalt, thereby reducing the overall stability of the mixture. The results of this test once again indicate a negative relationship between soaking temperature and stability value. As the soaking temperature applied increases, the stability values obtained decrease, and this applies to all types of water tested. The reduction in stability at high temperatures suggests that the asphalt mixture becomes more susceptible to deformation, which can compromise road performance under heavy traffic conditions. By comparing the results from the 30-minute and 24-hour soaking times, we can observe that although stability generally decreases as soaking time increases, freshwater still shows better performance compared to seawater and brackish water. These findings emphasize the need for further testing to understand the mechanisms affecting the stability of asphalt mixtures, including factors such as aggregate composition, the type of water used, and soaking duration. This research can serve as an important reference in the development of more durable and efficient asphalt mixtures, as well as provide insights into how environmental conditio ns can influence the performance of asphalt materials in real-world applications.

3.2.2 Analysis of Flow

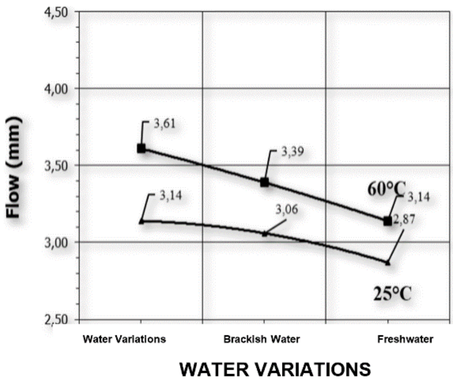

Fig. 3. Graph of Marshall Test Results on Flow Value for a Soaking Time of 30 Minutes

Based on Figure 3, the analysis shows that the highest flow value is achieved in the test with seawater at a soaking temperature of 60°C, recording a value of 3.61 mm. This figure indicates that at high temperatures, seawater enhances the flow capacity of the asphalt mixture. This condition may be due to the physical changes occurring in the asphalt when exposed to high temperatures, which lead to a decrease in the viscosity of the asphalt. With lower viscosity, the asphalt mixture becomes easier to flow, resulting in a higher flow value.

Conversely, the lowest flow value was obtained from testing with standing water at a soaking temperature of 25°C, which recorded a value of 2.78 mm. This suggests that standing water, which typically contains more contaminants, can reduce the flow capacity of the asphalt mixture at lower temperatures. The low flow value may be associated with the higher viscosity of the asphalt at lower temperatures, which limits the mobility of particles within the mixture. The results of this testing indicate a positive trend between soaking temperature and flow value, where an increase in the applied soaking temperature leads to higher flow values for all types of water tested. Increasing the temperature can enhance the mobility of asphalt particles within the mixture, thus improving its ability to flow. However, this phenomenon also indicates that at very high temperatures, the asphalt mixture could become too soft, potentially leading to unwanted plastic deformation if used under heavy traffic conditions.

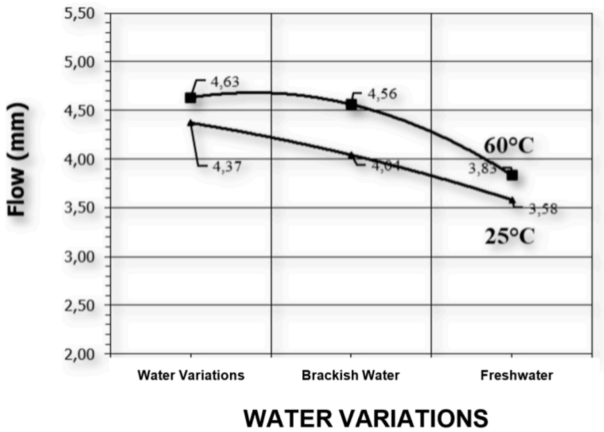

Fig. 4. Graph of Marshall test results for Flow values after 24 hours of soaking.

Based on Figure 4, the analysis shows that the highest flow value is achieved in the test using seawater at a soaking temperature of 60°C, yielding a value of 4.63 mm. This achievement reflects excellent flow capacity in the asphalt mixture under those conditions. The high temperature can reduce the viscosity of the asphalt, making it easier to flow and increasing the mobility of the particles in the mixture. This becomes particularly important in maintaining the quality of the asphalt mixture, especially in areas with high temperatures or under heavy traffic loads. On the other hand, the lowest flow value was obtained from testing with freshwater at a soaking temperature of 25°C, which recorded a value of 3.58 mm. Although freshwater is generally considered a better option in many construction applications, the lower temperature can lead to increased viscosity in the asphalt. This results in limited movement of particles in the mixture, leading to a lower flow value. This situation illustrates that temperature significantly influences the performance of asphalt mixtures, where at lower temperatures, the flow of the mixture tends to be hindered.
Interestingly, the flow value at 60°C tends to be higher compared to testing at lower temperatures, reinforcing the idea that temperature can play a key role in determining the flow properties of the asphalt mixture. Higher temperatures not only affect viscosity but may also enhance the physical interactions between aggregates and asphalt, creating better bonding within the mixture. However, it is essential to keep in mind that while higher temperatures may increase flow values, this condition can also present certain risks. For instance, using a mixture that is too soft may lead to plastic deformation when subjected to heavy traffic loads.

The difference in water types, particularly the presence of salts in seawater, has a significant impact on accelerating asphalt deterioration. Seawater contains high concentrations of salts that are hygroscopic, meaning they can attract and retain moisture more effectively than freshwater. The mechanism by which seawater accelerates asphalt damage begins when salt ions, such as sodium (Na+) and chloride (Cl-), penetrate the pores of the asphalt, causing chemical reactions with the asphalt binder and aggregate. During immersion, these salt ions increase internal moisture within the asphalt mix and trigger degradation reactions that weaken the bonds between particles. As a result, asphalt stability and durability decrease because the binding between the asphalt material and aggregate becomes weaker. Additionally, salt accelerates the oxidation process in asphalt, which leads to micro-cracks within the mix. These cracks develop more rapidly in a watery environment, causing greater structural damage over time. In real-world applications, especially on roads in coastal areas, long-term exposure to seawater accelerates the deterioration of asphalt layers, increasing the need for regular maintenance and reducing the overall lifespan of the road

4 Conclusion

This study demonstrates that immersion duration significantly influences the stability and flow characteristics of Marshall asphalt mixtures submerged in different types of water, namely seawater, brackish water, and freshwater. The results indicate that a longer immersion period adversely affects these properties, with a more pronounced deterioration observed after 24 hours compared to 30 minutes. Among the water types tested, seawater was found to have the most detrimental effect on the stability and flow of the asphalt mixture, particularly after 24 hours of immersion. Specifically, immersion in seawater resulted in a 36.40% reduction in stability and an 11.11% decrease in flow. Conversely, freshwater showed the least impact, with a stability reduction of only 12.34% and a flow decrease of 3.70% after 30 minutes of immersion.The findings emphasize the importance of considering both the type of water and the duration of immersion when evaluating the performance of asphalt mixtures. These insights are crucial for engineers and practitioners involved in road pavement design, especially in coastal regions where asphalt is frequently exposed to seawater or brackish water. Implementing appropriate material selection and maintenance strategies based on this research can help enhance the durability and longevity of asphalt pavements, ultimately improving infrastructure resilience in environments susceptible to water exposure.

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