The effect of sea water soak on asphalt porous characteristics with and without waste of rubber tire waste as an asphalt addictive

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Abstract. The use of rubber tire scrapped in the development of porous asphalt technology as a part of flexible pavement aims to minimize the adverse effects of transportation facilities. The use of rubber tire scrapped as an asphalt modifier in the pavement can provide several benefits, including reducing reflective cracking on overlays, reducing maintenance cost, increasing resistance to new pavement cracking and rutting, increasing skid resistance and pavement age.

This paper presents laboratory investigation on the effect of seawater immersion on porous asphalt performance using rubber tire scrapped. Method used in laboratory investigation is based on AAPA 2004 and Bina Marga 2010. The results showed the permeability all types of mixture indicator "moderate drainage". The results of testing the Marshall characteristics showed a decrease in the value of stability, flow, and MQ in the porous asphalt mixture with Pen 60/70 asphalt and rubber asphalt as the duration of sea water immersion increased. The porous asphalt mixture using Pen 60/70 asphalt and rubber asphalt has Index of Retained Strength values which tend to decrease with increasing sea water immersion duration. Indirect Tensile Strength test results due to seawater submersion indicate a decrease in ITS value in porous asphalt mixtures with Pen 60/70 asphalt and rubber asphalt. The Cantabro test results showed an increase along with the increasing duration of seawater immersion.

1. Introduction

Transportation is an important part of a country’s infrastructures. Hence, road infrastructure requires special attention in terms of safety and comfort. Some coastal areas in Indonesia often experience tidal flood that cause the sea water to inundate the land, causing losses and disturbing community activities. Roads located in coastal areas have problems with seawater inundation. Seawater is a solition that has a coarsional nature and can cause damage to pavement. Porous asphalt is a mixture that is designed to have a higher porosity than other types of pavement. Porous asphalt is planned to have a large cavity so that water can permeate freely, so that it can provide a level of safety for road users, especially when it rains. Porous asphalt can also reduce glare from the road surface during the day or night. In addition to using porous asphalt as a solution to reduce road pavement damage, the use of added material rubber tire powder in pavement can provide the advantage of reducing reflective cracking on overlays, reducing maintenance costs, increasing resistance to new pavement cracking and rutting, increase skid resistance and pavement life.

Based on the description above, there is desire to continue the research that has been carried out by Harmadana [1], which uses porous asphalt mixture and added ingredients of rubber tire powder with a...
level of 3.5%, 4.5%, 5.5%, and 6.5%. From the result of these studies, the use of rubber tire powder as an added material can increase stability so that it can meet existing requirements [1]. The proportion of the addition of rubber tire powder at a value of 5.5% produces the best effect. Therefore, the authors plan to conduct research using porous asphalt mixture with ingredients plus rubber tire powder by (0% and 5.5%) and soaking in the form of seawater. This research was conducted to see the effect of seawater on porous asphalt by using added rubber tire powder materials with the aim of analyzing the extent of the influence of seawater on porous asphalt durability and the effect of adding rubber tire powder as added ingredients.

2. Research methodology
The method used in this study is an experimental research method that is a research method that is carried out by conducting experiments to obtain data and then the data is processed to obtain a comparison with the specification and requirements used. The specifications and procedures carried out refer to the Australian Asphalt Pavement Association, the Indonesian Nasional Standard, and the General Specifications of Bina Marga 2010. The aggregates used came from Clereng, Kulonprogo, DIY. Asphalt used is Pertamina Pen 60/70 asphalt. The rubber tire powder used was obtained from Gulon, Salam, Magelang, Central Java. The seawater used is obtained from the North Coast of Kaliwage, Semarang.

The test begins with an examination of the physical properties of the material, then the proceed with the making of a specimen to determine the optimum asphalt content (OAC). The next step is making test specimens using Pen 60/70 asphalt and asphalt mixed with rubber tire powder and assembled in seawater for testing Marshall Standard, IRS, ITS, Asphalt Flow down, Permeability and Cantabro test.

3. Results and discussion
Marshall, IRS, ITS, Asphalt Flow Down, and Cantabro test were conducted at the Highway Laboratory, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. Permeability testing is carried out at the Transportation Laboratory, Faculty of Engineering, Universitas Gajah Mada. The test carried out refer to the AAPA 2004, SNI, and Bina Marga 2010.

3.1. Physical Properties of Material and Seawater
Testing the physical properties of material includes testing the characteristics of coarse aggregates and fine aggregates, filler testing, asphalt testing and seawater testing. The test results can be seen in Table 1, Table 2, Table 3, Table 4, and Table 5 below.

| NO | Test Type       | Specification | Result  |
|----|----------------|---------------|---------|
| 1  | Specific Gravity| ≥ 0,1         | 1,0751  |
| 2  | Penetration     | 60 - 70       | 65,6    |
| 3  | Ductility       | ≥ 100         | 157     |
| 4  | Flash Point     | ≥ 232         | 280     |
| 5  | Fire Point      | ≥ 232         | 281     |
| 6  | Solubility TCE  | ≥ 99          | 100     |
| 7  | Softening point | ≥ 48          | 49,5    |
Table 2. Examination Result of Rubber Tires Asphalt 5.5%

| NO | Test Type                  | Specification | Result |
|----|----------------------------|---------------|--------|
| 1  | Spesific Gravity           | ≥ 0,1         | 1,0277 |
| 2  | Penetration (0,1 mm)       | Min. 50       | 51,3   |
| 3  | Ductility (cm)             | ≥ 50          | 63     |
| 4  | Flash Point (°C)           | ≥ 232         | 259    |
| 5  | Fire Point (°C)            | ≥ 232         | 274    |
| 6  | Softening Point (°C)       | ≥ 54          | 55,5   |

Table 3. Examination Result of Rough Aggregate

| NO | Test Type                                | Specification | Result |
|----|------------------------------------------|---------------|--------|
| 1  | Spesific Gravity                         | > 2,5         | 2,6447 |
| 2  | Water Absorbtion on Aggregate (%)        | < 3,0         | 1,54648|
| 3  | Adhesion Test (%)                        | > 95          | 99,5   |
| 4  | Abrasion Test (%)                        | < 40          | 26,6   |

Table 4. Examination Result of Smooth Aggregate

| NO | Test Type                                | Specification | Result |
|----|------------------------------------------|---------------|--------|
| 1  | Spesific Gravity                         | > 2,5         | 2,6271 |
| 2  | Water Absorbtion on Aggregate (%)        | < 3,0         | 2,35   |
| 3  | Sand Equivalent (%)                      | > 50          | 71,2409|

Table 5. Examination Result of Sea Water

| No | Parameter | Unit | Result A.003 | Test Method             |
|----|-----------|------|--------------|------------------------|
| 1  | pH        | -    | 6,82         | SNI 06-6989.11-2004    |
| 2  | Chloride (Cl) | mg/L | 12,240      | SNI 6989.19:2009       |
| 3  | Sulfate (SO) | mg/L | 20,9        | SNI 6989.20:2009       |

3.2. Optimum Asphalt Content (OAC)

Determination of optimum asphalt content in porous asphalt mixture is calculated based on planning criteria from the Australian method, by means of a 35% cantabro loss value set to obtain the minimum bitumen content, then the 18% VITM value is set to obtain the maximum asphalt content, then both values plotted on the asphalt flow down graph. The optimum bitumen level is the sum of the average asphalt rough value with the asphalt flow down value as follows.
3.2.1. Cantabro Value
Cantabro Loss testing is carried out to determine the weight loss in the mixture carried out an abrasion test with a Loss Angeles machine and also as a parameter to determine OAL as required by AAPA. Test specimens which are left idle for 48 hours at room temperature and at least 6 hours before testing the temperature must be kept at room temperature. Before the test object is inserted into the Los Angeles drum machine. The image of the Cantabro test results can be seen in Figure 1 below.

![Figure 1. Relation between Asphalt Level and Cantabro Loss Value](image_url)

From Figure 1 it can be seen that the cantabro value decreases with increasing proportion of bitumen content. The decrease in weight loss means that it is resistant to impact. This is caused by the increasing percent of bitumen content because with increasing asphalt content the binding strength of the mixture between aggregate and asphalt is getting better so that it increases the ability of porous asphalt mixture to withstand impact.

3.2.2. VITM Value
VITM is the percentage of air cavity in the mixture against the total volume of aggregate and asphalt mixture. Based on the results of the test, it is obtained a graph of the VITM value at various asphalt levels as shown in Figure 2 below.

![Figure 2. Relation between Asphalt Level with VITM Value](image_url)

The results of testing the VITM value in Figure 2 show that the value of VITM gets smaller with increasing asphalt content, because the air cavity is filled with asphalt and increases the volume of the air cavity and the mixture becomes more dense.

3.2.3. Asphalt Flow Down Value
Asphalt Flow Down testing is carried out to determine the maximum asphalt content that can be homogeneously mixed with aggregates without the separation of asphalt separation and also as a
parameter to determine KAO as required by AAPA (2004). The picture of the Asphalt Flow Down test results can be seen in Figure 3 below.

![Figure 3. Relation Between Asphalt Level with Asphalt Flow Down Value](image)

Based on Figure 3, it can be seen that the value of Asphalt Flow Down increases along with the addition of asphalt levels, however the increase in the value of Asphalt Flow Down is not significant. The increase in the results of the Asphalt Flow Down test shows that the separation between asphalt and aggregate increases with increasing asphalt content, this is due to the film enveloping the aggregate thicker with increasing percentage of bitumen so that the asphalt attached to the outside will melt and separate from the mixture.

The value of the test results of Cantabro, Marshall and Asphalt Flow Down that meet the requirements of the above parameters, obtained optimum asphalt content from porous asphalt mixtures using Pen 60/70 asphalt, which is 5.18%.

3.3. Overview of Characteristic of Permeability

Permeability testing graph can be seen in Figure 4. below.

![Figure 4. Relation of Rubber Asphalt Bonds to the Permeability Coefficient](image)

Based on Figure 4, it can be seen that the two porous asphalt mixes that use Pen 60/70 asphalt and rubber asphalt are of moderate drainage. This is because the addition of rubber tires fills the cavity between the bitumen and the aggregate of small cavities in the mixture (VITM) causes the water to become difficult to seep into the porous asphalt mixture. Thus, the use of rubber tires is quite capable of producing a watertight mixture.

The research conducted by Juliansyah [2] also mentions that the addition of rubber tire waste as an additive to overcome the decline in the performance of superpave mixtures due to rainwater immersion, by using a mixture of added rubber tires becomes more impermeable so it is more difficult to get away
with water[2]. The difference with the research conducted by Juliansyah [2] is that the type of mixture used is included in a tight gradation, so that by adding rubber tires it produces a mixture of poor drainage.

In contrast to the research conducted by Bahtiar [3] which examined the porous asphalt mixture using oil sludge substrates, the permeability value increased with increasing oil sludge. Permeability value with oil sludge substitution has a higher permeability value than the research conducted by researchers using added rubber tire material, which means that the asphalt mixture with oil sludge has a better permeability value[3]. The highest permeability of porous asphalt mixture with oil sludge is $4.33 \times 10^{-2}$ cm / second while the porous asphalt mixture with rubber tires is $1.19 \times 10^{-3}$ cm / second. The equation from Bahtiar's research (2018) is that the type of mixture used is included in the category of open gradations that easily pass water.

3.4. Overview of Marshall Characteristics in OAC
Based on the test results of Marshall, Cantabro, and Asphalt Flow Down, the value of OAL is 5.18%. Samples were made using OAL which had been obtained and then immersed using sea water with variations in immersion duration of 48 hours and 96 hours. For comparison, some samples are made without sea water immersion. The results obtained can be seen in the following discussion.

3.4.1. VITM
The results of laboratory tests on porous asphalt mixes soaked in sea water can be seen in Figure 5 below.

![Figure 5. Relation between Immersion Duration with VITM Value](image)

In Figure 5, it can be seen that the porous asphalt mixture with rubber asphalt binding material has a smaller VITM value compared to the 60/70 Pen bond mixture. This condition is caused by the air pores that have been filled with bitumen and other fine minerals. The small VITM value causes the mixture to be more waterproof, so it can reduce the bitumen oxidation process and increase the asphalt durability.

Based on graph 5 it can be seen that the more immersion time, the value of VITM decreases, this is because the minerals contained in seawater can fill the cavity to be smaller. From the test results, the value of VITM with Pen 60/70 asphalt is 19.50%, 19.13%, and 19% while rubber asphalt is 18.81%, 18.36% and 17.96%. The test results meet the requirements of AAPA which is 18%, but in mixtures using added rubber tire material with a duration of 96 hours bathing falls below the minimum requirements.

The same can be seen in the study of Bahtiar [3] which examined the porous asphalt mixture using oil sludge substitution, the increasing oil sludge substitution the value of VITM decreased. This is because the asphalt that has been substituted with oil sludge has a more watery nature compared to Pen 60/70 asphalt and has a high mineral content, causing the minerals contained to fill the cavity to be smaller. The difference from Bahtiar's research is the type of substitution used.
3.4.2. Stability

The results of the laboratory test on porous asphalt mixes soaked in sea water can be seen in Figure 6 below.

In Figure 6, it can be seen that the value of the stability of the mixture decreases with the duration of immersion that is getting longer. This shows that there is an effect of decreasing the bond between aggregate and asphalt due to sea water entering the mixed cavity containing various kinds of chemical compounds. Based on the graph above, it can be seen that the use of rubber asphalt in the mixture has a better performance in resisting the load under conditions of seawater tendam.

The stability value of porous asphalt mixture using material added to rubber tires larger than the mixture using Pen 60/70 asphalt. This is caused by the stiffer nature of rubber asphalt Pen 60/70, indicated by the smaller penetration value of rubber asphalt from Pen 60/70 asphalt.

In a study conducted by Juliansyah [2] who examined superpave mixtures using added rubber tire materials, also stated that the addition of rubber tires in the mixture caused the value of stability to increase. The difference from Juliansyah's research (2017) is that the porous asphalt mixture with added rubber tire material has a lower value of stability. This is because the porous asphalt mixture has a bitumen cavity (VITM) which is larger than the superpave mixture.

In a study conducted by Yusuf [4] which examined the performance of a mixture of Stone Matrix Asphalt with Pen 60/70 and Starbit E-55 due to the long seawater immersion, it can be seen that the stability value decreased with increasing sea water immersion duration. This happens because sea water can reduce the ability of asphalt to bind to the aggregate [4]. The stability value of the mixture of porous asphalt using material added by rubber tires soaked in seawater has decreased in accordance with the research conducted by the researcher.

3.4.3. Flow

Flow is a state of change in the shape of a mixture that occurs due to a load to the collapse limit expressed in units of length (mm). The value of the flow to sea water bath can be seen in Figure 7. In Figure 7, it can be seen that the porous asphalt mixture with Pen 60/70 asphalt and rubber asphalt has decreased due to seawater immersion. This shows that under conditions of submerged seawater, porous asphalt using rubber asphalt binding material has good ability to withstand vertical deformation. Mixtures that use rubber asphalt have better resistance to vertical deformation than mixtures that use Pen 60/70 asphalt, this is because the rubber asphalt is more rigid.

The same thing can be seen from the study of Yusuf [4] who examined the performance of the mixture of Stone Matrix Asphalt with Pen 60/70 and Starbit E-55 due to sea water immersion, flow value decreased with increasing sea water immersion duration. the value of flow of porous asphalt mixtures with added rubber tire material meets the requirements of AAPA.

In a study conducted by Juliansyah [2] the addition of rubber tire waste as an additive to overcome the decrease in the performance of superpave mixtures due to rainwater immersion, the flow value decreased slightly as the duration of rainwater bathing increased. The addition of rubber tires can also
affect the flexibility of the asphalt mixture, the more the rubber content increases the flow value will decrease.

![Flow vs Immersion Duration Graph](image)

**Figure 7.** Relation between Immersion Duration with Flow Value

#### 3.4.4. Marshall Quotient (MQ)

The Marshall Quotient value is the result of the stability between flow and flow. Marshall Quotient value for seawater immersion can be seen in Figure 8. below.

![MQ vs Sea Water Immersion Duration Graph](image)

**Figure 8.** Relation between Sea Water Immersion Duration with MQ Value

In Figure 8, it can be seen that the MQ value has decreased, obtained from the comparison of the value of stability and the value of flow decreasing due to seawater immersion. The decrease in the MQ value in the porous asphalt mixture shows that the longer the mixture is soaked in seawater, the more flexible the mixture in accepting the load will be. The porous asphalt mixture using rubber asphalt has a higher MQ value than the mixture using Pen 60/70 asphalt, this is because rubber asphalt has a more rigid nature than Pen 60/70 asphalt.

The same can be seen in the study of Juliansyah [2] that the addition of rubber tire waste as an additive to overcome the decrease in the performance of superpave mixtures due to rainwater immersion, ie Marshall Quotient values will decrease with increasing duration of rainwater bathing. The addition of rubber tires also affects the decrease in the MQ value because of the effect of decreasing the bond between aggregate and asphalt after rainwater bathing.

This research is slightly different from Yusuf [4] who examined the mixture of Stone Matrix Asphalt with Pen 60/70 binding material which experienced an increase in MQ value before being held up to 96 hours of holding, then decreased after being immersed for 96 hours. In contrast to the mixture of Stone Matrix Asphalt that uses Starbit E-55 asphalt, the results have similarities to what the researchers did, namely the MQ value has decreased with increasing duration of sea water immersion.
3.5. Overview of Retained Strength (IRS) Index

The index of retained strength was obtained from the immersion process, to determine the strength and agility of the mixture after experiencing a 24-hour immersion process at a temperature of 60°C for soaking for 0.5 hours at 60°C. The IRS value graph can be seen in Figure 9. below.

![Figure 9. Relation between Immersion Duration and IRS Value](image)

Based on Figure 9, it can be seen that the IRS value decreases with increasing duration of seawater immersion, this is influenced by a decrease in the value of stability caused by the amount of water entering the mixture causing the mixture to become weak in accepting the load. The graph above shows that the mixture using rubber asphalt has a higher IRS value than the mixture using Pen 60/70 asphalt, this is because the rubber asphalt is stiffer than Pen 60/70 asphalt.

In a previous study conducted by Juliansyah [2] the addition of rubber tire waste as an additive to overcome the decline in the performance of the superpave mixture due to rainwater immersion, as the duration of rainwater increased, the IRS value increased. These results occur because of the chemical influence of the superpave mixture soaked for 96 which increases the value of stability. In addition, in the same study showed that the IRS value using rubber asphalt was higher than the mixture using Pen 60/70 asphalt due to changes in the characteristics of the mixture due to the effect of adding rubber tires.

In a study conducted by Yusuf [4] who examined the mixture of Stone Matrix Asphalt using Pen 60/70 binding material and Starbit E-55 asphalt has different results from research conducted by researchers where IRS values increased with increasing immersion duration.

3.6. Overview of Indirect Tensile Strength (ITS) Characteristic

Indirect Tensile Strength is the ability of the pavement layer to withstand the tensile strength caused by the vehicle load. Based on the test results obtained the value of the relationship between the length of immersion and the Indirect Tensile Strength value can be seen in Figure 10 below.

![Figure 10. Relation between Immersion Duration and ITS Value](image)

Based on the graph in Figure 10, the value of ITS tends to decrease with increasing immersion duration in sea water with a mixture of Porus made from asphalt Pen 60/70 and rubber asphalt. This is because the longer the duration of immersion causes the asphalt to soften and the bond between the asphalt and aggregate becomes reduced which causes the strain strength of the mixture to be reduced so...
that the mixture is easily cracked. The mixture using rubber asphalt has a lower ITS value than the one using rubber asphalt.

In a study conducted by Julainsyah [2] the addition of rubber tire waste as an additive to overcome the decrease in the performance of the superpave mixture due to rainwater immersion, also stated that as the soaking time increases the ITS value decreases and with the addition of rubber tires to make the mixture stable. The difference from the research of Julainsyah [2] with research conducted by researchers is on the type of mixture used and the type of soaking water used.

3.7. Overview of Cantabro Characteristics
Cantabro Test is a test conducted to determine the resistance of the test object to wear by using the Loss Angeles machine. This test aims to determine the weight loss of the test object after an abrasion test. The image of the Cantabro test results can be seen in Figure 11 as follows.

![Figure 11. Relation between Immersion Duration and Cantabro Value](image)

Based on the graph in Figure 11, it can be seen that the Cantabro value tends to increase with increasing immersion duration in seawater with a porous mixture of Pen 60/70 asphalt and Rubber asphalt. This means that the increasing duration of seawater immersion makes the mixture less resistant to impact. The mixture with rubber asphalt binding material is more resistant to impact or abrasion compared to the mixture with Pen 60/70 binding material.

The same can be seen from the research of Julainsyah [2] the addition of rubber tire waste as an additive to overcome the decrease in the performance of superpave mixtures due to rainwater immersion, namely the value of cantbro loss increases with increasing rainwater immersion. The addition of rubber tires also has an effect on the value of cantabro loss, the increasing the rubber tire level the lower the cantabro loss value. This shows that the addition of rubber tires can withstand heavy losses due to collisions.

In a study conducted by Bahtiar [3] which examined porous asphalt mixtures using oil sludge substitution, namely the value of cantabro decreased with increasing levels of oil sludge substitution, the decrease in cantabro test results showed that the resistance of the mixture to impact tended to increase, this was due the loss of weight in the mixture is getting smaller with the percentage of addition of oil sludge substitution.

4. Conclusion and suggestion

4.1. Conclusion
Based on research and analysis of porous Asphalt mixture performance data using ingredients added by rubber tire waste to the effect of seawater immersion, the following conclusions are obtained.

- The results of testing the physical properties of Pen 60/70 asphalt and rubber asphalt show insignificant density values, while the results of testing ductuality, concentration, solubility in TCE, flash point, and burn point show significant results.
Rubber tires can be used as an ingredient to add Pen 60/70 asphalt. This can be seen from the tests of Marshall, Cantabro and AFD whose results meet the requirements of AAPA (2004). Porous Asphalt mixture which has been added to rubber tires has changed the Marshall characteristics, namely the value of stability, flow, and MQ which has increased. The percent weight loss (cantabro) decreases with the addition of rubber tires.

The permeability value of porous asphalt mixtures using 60/70 pen asphalt and asphalt using 5.5% rubber tire material indicates the results of the "moderate drainage" indicator. The mixture using rubber asphalt has a higher tightness than the mixture using Pen 60/70 asphalt.

Effect of seawater immersion on Marshall characteristics, namely a decrease in the value of stability, flow and MQ in porous asphalt mixtures with Pen 60/70 asphalt and rubber asphalt as the duration of seawater immersion increases. The longer the porous asphalt mixture soaked in sea water causes a decrease in the mix ability to accept the load.

The porous asphalt mixture using Pen 60/70 asphalt and rubber asphalt has an Indirect of Retained Strength value which tends to decrease with increasing sea water immersion duration.

Indirect Tensile Strength test results due to seawater immersion indicate a decrease in ITS value in porous asphalt mixtures with Pen 60/70 asphalt and rubber asphalt. This is because the longer the duration of soaking causes the bitumen to soften and the bond between the asphalt and aggregate decreases so that it is easy to crack.

The Cantabro test results show an increase along with the addition of sea water immersion duration. The mixture with rubber asphalt binding material is more resistant to impact or abrasion compared to Pen 60/70 asphalt bonding material, this is due to rubber asphalt which has strength and elasticity which can reduce impact on impact.

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