THE USE OF PLASTIC MINERAL WATER BOTTLES AND SCRAPPED TIRE RUBBER FOR IMPROVING THE PERFORMANCE OF MIXED ASPHALT CONCRETE

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ABSTRACT

Asphalt is the binder in asphalt-concrete mixture for road pavement. Given the asphalt is a visco-elastic material, so that its condition is strongly influenced by temperature and the existing traffic load, there is no doubt that during its service the asphalt-concrete pavement often suffers from various damage, such as being brittle, chipped (cracks), and bleeding.

There are a number of ways to improve the performance and durability of asphalt, one of them is using additive material to modify the physical properties of asphalt. Additive materials commonly used, such as arbocel, cellulose fibres or roadcel are all imported material. Their prices are very expensive, so overall they are not economical. Therefore, it is necessary to find a local material that could be used to replace them.

This research attempts to use vehicle scrapped tire rubber and plastic mineral water bottles instead of imported additive material, while both of them are environmental-concerned due to their disposal. The study was conducted on the type of Asphalt ConcreteWearing Course(AC-WC) using penetration bitumen 60/70.

The results indicate that the addition of scrappedtirerubber and disposible plastic mineral water bottleson the asphalt concrete mixtures leads to an increment in voids in mix (VIM), reduction in the value of flow, voids increment in mineral aggregate (VMA), stability-increment, and durability and flexibility increment of asphalt concrete mixtures.

Keywords: plastic mineral water bottles, scrapped tire rubber, asphalt concrete mixture, Asphalt Concrete Wearing Course (AC-WC).

1. INTRODUCTION

Asphalt is a common binder material usedinasphalt concrete mixture for road pavement. Because it is a *visco-elastic* material, its conditionis strongly influenced by the road temperature and traffic load. Hence, there are often various possible damages occur during its service-life, such as being brittle, chipped or cracks,and the bleeding of asphalt to the surface of the road.

Therefore, the additive material is needed to elongate the asphalt service-life and also to improve its service-ability. The additive material should be effective, practical and economical. Furthermore, it must also be easily obtained, able to resist degradation during mixing, capable to blend with asphalt, possesses the yielding resistance at higher temperature and economical.

In the last twenty years, researchers had developed many methods to improve the asphalt service-ability by modificating the asphalt itself for highway construction application. In Indonesia, there

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are many asphalt mixtures used for road pavement such as arbocel, cellulose, fibres, roadcel, etc. However, all of them can be categorized as imported material with expensive prices. The use of solid waste as a construction material can be very beneficial in terms of controlling the environmental issue caused by the waste disposal and also can provide more economic value for the solid waste itself by using it as the road pavement construction material.

The plastic addition in asphalt can provide better asphalt characteristic (Asrar 2007). The Marshall test result from asphalt-mixture containing plastic, reveals that mixing plastic content 3% into asphalt can improve its stability value, unit weight and Marshall quotient. The permanent deformation values of mixture decreases as themore plastic is added into asphalt. Furthermore this causes larger dynamic stability.

Mixing plastic content 0.5%, 1% and 1% of penetration bitumen 60/70 into asphalt can significantly improve the asphalt quality (Rezza and Aschuri 2009). The use of tire rubber in asphalt concrete mixture improves the resistance to permanent deformation caused by wheel trace (Kurniati 2004).

The use of additive material such as scrapped tire rubber into asphalt mixture can also result in higher durability value for higher temperature and traffic load, compared to the asphalt without using additive material. Additive material can be used as an indicator whether there are possible shear resistance decrease caused by the higher temperature. Hence, the damage can be prevented (Aprina and Silfani 2005).

The additive can be introduced into asphalt for various purposes. The rubber polymer in tire rubber has been used as an additive material to increase the bonding between asphalt and aggregates. It means that the environmental issue caused by the disposal of the wasted tire rubber can be solved by using it as an additive material. In relation to environmental issue, some countries has already used the recycled asphalt. The damaged asphalt road is fixed by using the recycled asphalt instead of using the new one (Ismunandar 2006).

Adding scrapped tire rubberup to 3% to the asphalt-concrete pavement can increase its performance, especially when the temperature is above 30 ^{0}C (Sugiyanto 2008). Replacement of a portion aggregate on the fraction number 50 with scrapped tire rubber can increase the water resistance of hot rolled asphalt. Hence, it can be used to reduce the road damage.

From previous research as mentioned above, it can be concluded that the addition of plastic and scrapped tire rubberinto asphalt can increase the asphalt quality and then, simultaneously improves the quality of asphalt-concrete mixture. Plastic waste, which is difficult to decompose or degraded by soil, has been able to be used as the asphalt filler that can minimize the road damage.

This research uses the local additive material i.e. scrapped tire rubber (STR) and plastic mineral water bottles (PMWB). These materials are solid waste materials that can caused environmental issue if they are not well-treated. Therefore, they should be used as an asphalt filler in asphalt concrete mixture to solve the environmental issue and provide economic value.

The purpose of this research is to analyze the properties of asphalt-concrete mixture in corporating scrapped tire rubber and plastic mineral water bottles as an asphalt filler. This research result is expected to obtain material that can be used as an economic alternative to imported additive material, easily obtained and also can be used to solve environmental problems and damage of road pavement.

2. EXPERIMENTAL DESIGN

2.1. Materials

Coarse aggregate, fine aggregate and fly ash were taken from Kuari Wai Sakula, Kecamatan Teluk Ambon, Ambon, Indonesia. Asphalt was obtained from the Laboratory for Testing Road and Bridge

Material at Dinas Bina Marga, South Sulawesi, Indonesia. Plastic mineral water bottle was taken from the landfill, while the scrapped tire rubber was obtained from Tire Retreading Plant in Makassar Industrial Area.

2.2. Asphalt Concrete Mixtures AC-WC Tests

The testing of AC-WC includes stability, flow, Marshall Quotion (MQ), Void in Mix (VIM), andVoid in Mineral Aggregate (VMA).

2.3. Marshall Test

For the Marshall test, there were initially performed to predict the optimum asphalt content.Then, the specimen was prepared based on the predicted optimum asphalt content. Three specimens with the asphalt content higher than its optimum value and two specimens with asphalt content lower than the optimum value were also made with having each different value 0.5%. Three specimens were made for each asphalt content. The standard size for specimen used in testing was 63.5 mm (2.5 in). The adjustment for each the mixing temperature and compaction process were performed when the asphalt viscosity value reached about 170 ± 20 centistokes and 280 ± 30 centistokes, respectively.

Compaction process was performed by applying 2 x 75 blows using Marshall compacting hammer. Then the specimen was kept in room temperature for 24 hours. Finally, the specimen was measured and weighed in air and water. The specimen was also measured in saturated surface dry condition. Then, they were allowed to cure at temperature 60^0 C for 30 minutes and ready to test.

The testing parameters were stability value, flow value, MQ, VIM and VMA. Next, the charts, to illustrate the correlation between asphalt content and each parameter, were made. The optimum asphalt content (i.e. the asphalt content that reaches all design criteriafor AC-WC) could be determined from the charts. In this research, the optimum asphalt content was then called the Optimum Asphalt Content (OAC).

2.4. Marshall ImmersionTest

There were six specimens made for each mixture, the first three specimens wereimmersed in water at 60^0 C for 24 hours(immersed condition) and then the Marshall Test was performed to obtain its stability value. For the next three specimens,SNI 06-2489-1991 was used as the standard method for Marshall Test. Ratio between the immersion stability value and the standard stability value providesIndex of Retained Strength (IRS) stated in percentage value.

2.5. Cantabro Loss Test

Cantabro Loss Test was performed to analyze durability and flexibility of asphalt mixture. The bricket samples were made, then they were tested with Los Angeles Test machine for 300 circling without using ball bearing. The bricket weight was measured before it was tested in Los Angeles Test machine, then it was measured again after the Los Angeles Test. Different percentage value of the bricket weight provides durability value (Cantabro Loss).

Three bricket samples were used in Cantabro LossTest for each additive content (0%, 2%, 4%, 6%, 8% and 10%) and the other three samples were also tested without using additive.

3. RESULTS AND DISCUSSION

3.1. Mixture Composition

The asphalt contentused in AC-WC mixture was the Optimum Asphalt Content (OAC) which has reached all design criteria according to the standard Marshall parameter 6.5% (Figure 1).

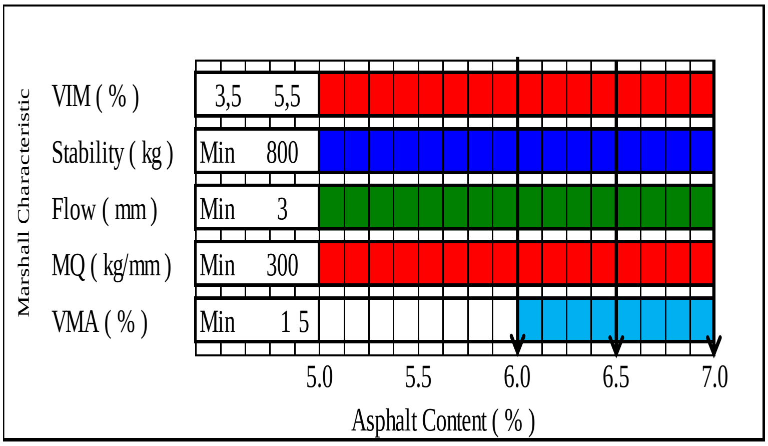

Figure 1: OAC analysis diagram of asphalt conceret mixtures AC-WC

3.2. Marshall Test Result

Marshall Test result that illustrates the value of VIM, stability, flow, MQ and VMA for plastic mineral water bottles and scrapped tire rubber, is shown in Figure 2 and Figure 3, respectively.

The VIM result shows that increasing the additive content in AC-WC mixture can provide the more and larger pore in asphalt because plastic and scrapped tire rubber themselves cannot cure faster and both of them do not have thermoplastic characteristic. Hence, there will be created the larger pore and the pore itself will not be easily filled by the mixture. Compared between both plastic and scrapped tire rubber, plastic waste cures faster than scrapped tire rubber when each of them is mixed in asphalt. Hence, the characteristic of plastic is not as well as the scrapped tire rubber to fill the pore between aggregates. The VIM value which is not filled by asphalt, will be higher as the more addition of additive material.

Stability test indicates that more additive used can provide the higher stability value. The stability value for asphalt added with plastic is higher than asphalt added with scrapped tire rubber.This is caused by the ductile characteristic of plastic that is higher than the scrapped tire rubber especially when the hardening process occurs after the additive is mixed with asphalt. This ductility can improve the interlocking between aggregates,therefore, the stability value will increase.

The flow value using plastic as additive material is higher than scrapped tire rubber because the elasticity of scrapped tire rubber itself. The flow value will decrease as the more additive content is used. Both plastic and scrapped tire rubber do not have the same flexibility with asphalt.

The MQ test results that the MQ value will be higher as the stability value is higher, in spite of that, the flow value will be smaller. The mixture using plastic as the additive provide the higher stability value but the flow value itself become smaller.

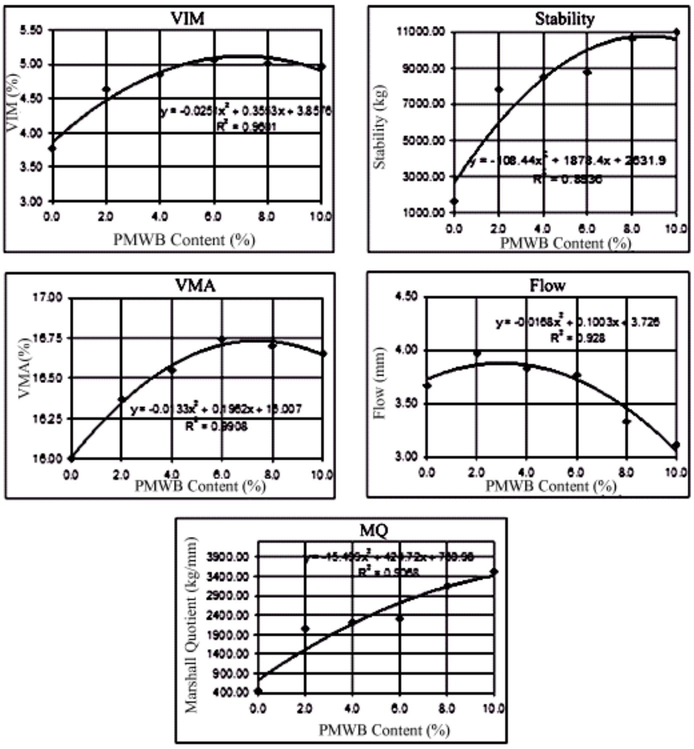

Figure 2: The Characteristic chart of Marshall AC – WC mixture using plastic

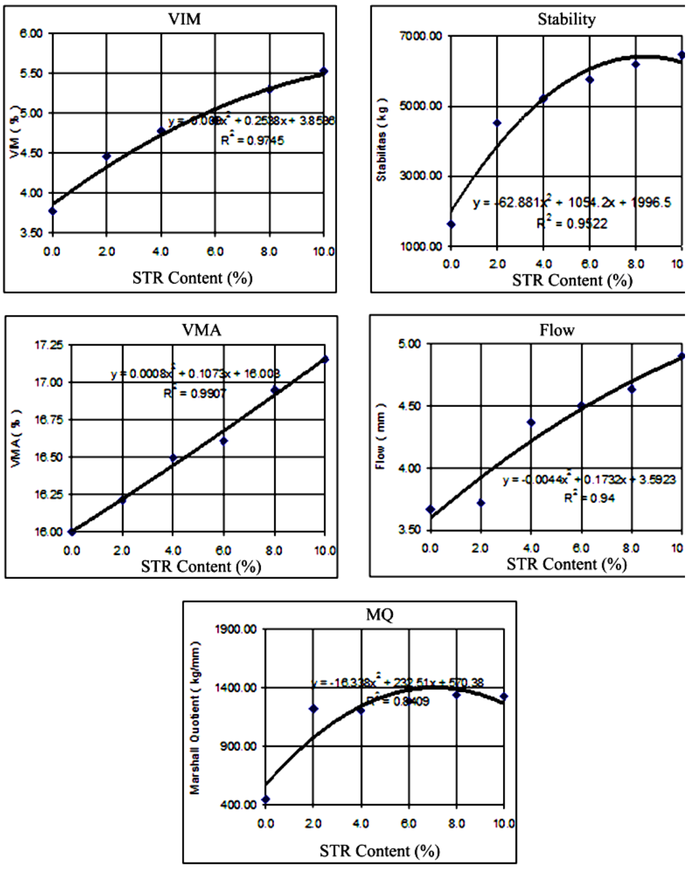

Figure 3: The characteristic chart of Marshall AC – WC mixture using scrapped tire rubber

The higher VMA value indicates that using additive can cause the larger aggregate pore, because the yielding additive material can not fill the aggregate pore as well as asphalt. This is caused by the characteristic of additive material that can not be easily hardening. Comparing between both plastic and scrapped tire rubber, scrapped tire rubber is still better than plastic to fill the aggregate pore, because the scrapped tire rubber can be easily blended with asphalt when it is mixed with the hot rolled asphalt. The aggregate pore will be larger as the more additive is used, because both the additive materials used can be easily hardening than the asphalt itself.

3.3. Determining the Optimum Additive Mineral Content (OAMC)

It is recommended that the optimum additive material should be around 2-5% (shown at Figure 4). This value is determined according to the standard specified by Indonesian Public Works Department having fulfilled all the standard specification for additive material in AC-WC asphalt.

After determining the aggregate composition and total weight of scrapped tire rubber and plastic mineral water bottles as the asphalt replacement,then the total composition mixture used in this research will be determined, can be shown at Table 1.

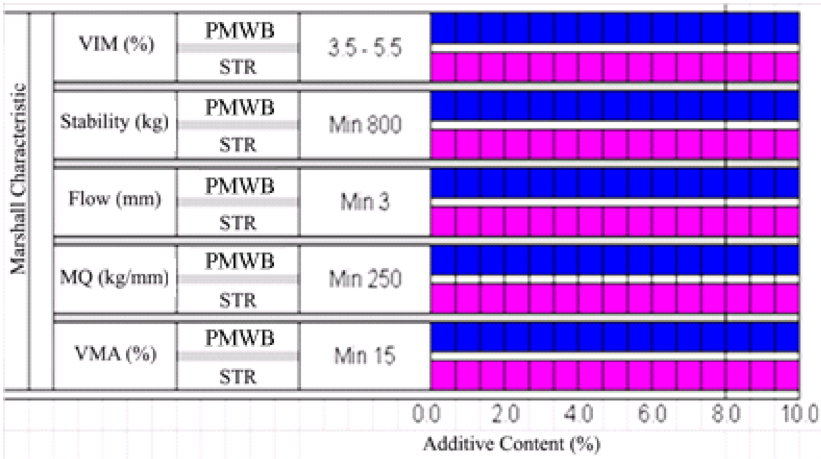

Figure 4: The chart for determining the optimum additive mineral content

Table 1: Composition mixtures

Asphalt Content	0 %	2 %	4 %	6 %	8 %	10 %
Weight of Aggregate (gr)	1200	1200	1200	1200	1200	1200
Weight of Asphalt (gr)	83,42	81.75	80.08	78.41	76.75	75.09
Weight of STR / PMWB (gr)	0	1.67	3.34	5.01	6.67	8.33
Total Weight of Asphalt + (STR/ PMWB) (gr)	83,42	83,42	83,42	83,42	83,42	83,42
Weight of Mixtures (gr)	1283.42	1283.42	1283.42	1283.42	1283.42	1283.42

Note: ***6.5 % (Total Weight of Asphalt + (STR/ PPW)***

3.4. Marshall Immersion Test

The Index of Retained Strength (IRS) obtained from Marshall Immersion Test is 97.24% for AC-WC without additive, 94.99% for AC-WC using plastic as additive, and 95.06% for AC-WC using scrapped tire rubber as additive. This IRS value has fulfilled all the standard criteria specified by Bina Marga (≥ 75%).

This test provides that the road pavement using both scrapped tire rubber and plastic mineral water bottles as the asphalt replacement with additive content 10% in AC-WC mixture can provide the resistance of temperature and the water-immersed condition, although its value is still lower than IRS of AC-WC without using additive because the asphalt itself contains grease that has better cohesion and adhesion.

3.5. Cantabro Loss Test

Cantabro Loss Test is conducted to determine the durability and flexibility value of asphalt mixture. This test is performed for each additive material.Cantabro Loss Test result is shown at Figure 5.

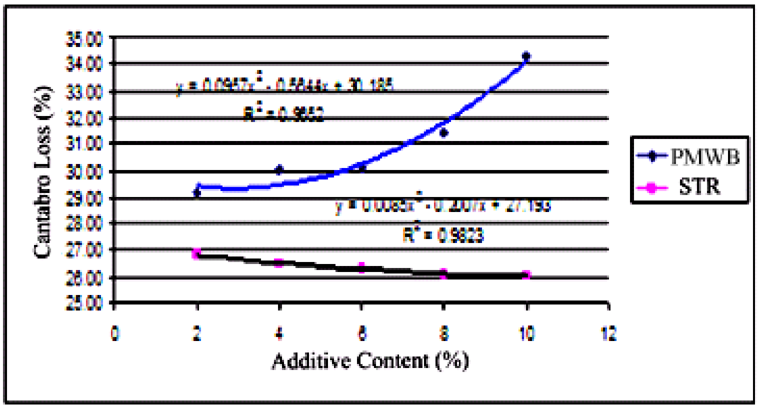

Figure 5: The chart of durability value (Cantabro Loss)

For mixture using plastic, the result indicates that the road pavementtends to not having the capability to stay with its original shape (durable) and simultaneously begins to crack. For mixture using scrapped tire rubber, the result indicates that the road pavement tends to have been able to stay with its original shape and simultaneously harder. This is caused by the ductility of plastic that is higher than scrapped tire rubber in asphalt.

Both durability and flexibility value of the mixture using plastic are higher than the mixture using scrapped tire rubber and also still higher than the mixture without using additive. Plastic is more ductile than both asphalt and scrapped tire rubber hence the mixture can not be easily damaged when it is tested in Los Angeles Test machine (Cantabro Loss Test machine).

4. CONCLUSION

There are some conclusions that can be gathered from the data analysis i.e.:

1. The result indicates that using plastic mineral water bottles and scrapped tire rubber content about 2-10% in AC-WC asphalt mixture can provide the higher porosity in mixture (Void in Mix (VIM)). In spite of that, it can also decrease the flow value, produce the larger aggregate pore that can not be filled by the asphalt(Void in Mix/VMA), and increase the stability value of mixture.

2. The Index of Retained Strength (IRS) indicates that the mixture without additive can provide the higher stability and Marshall Immersion Test value than the mixture using either plastic or scrapped tire rubber as an additive, even though the three specimens indicates that all of them can be more durable to the changing temperature, climate, or even with the immersion condition in water.

3. Both durability and flexibility values for mixture using plastic as an additive are higher than the mixture using scrapped tire rubber. Plastic is more ductile than asphalt and scrapped tire rubber, hence, it can not be easily damaged when it is tested in Los Angeles Test machine (Cantabro Loss Test machine).

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