Engineering Properties of AC 60/70 Asphalt Cement Mixed with Natural and Crumb Rubbers

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Abstract

This research is to study the properties of AC 60/70 asphalt cement mixed with natural and/or crumb rubbers. The AC 60/70 asphalt cement was replaced by natural rubber at 5%, crumb rubbers at 11%, and mixed with natural rubber and crumb rubbers at 8%. The suitable scale of dry crumb rubber was sizing from 0.25 mm down and the testing of penetration, loss on heating, ductility, and stripping were measured. The result finds the higher viscosity homogenized of natural rubber led from ternary mixing material, better properties than binary mixing. The ternary mixing property values are more inclined toward single mixing natural rubber to 55.32 mm, 0.081 g, 29.62 cm, and 4.68 scores of penetration, loss on heating, ductility, and stripping tests, respectively. Ternary mixing natural and crumb rubbers should be subjected to more testing at other ratios to find out its suitable proportion for better properties of asphalt mixture.

Keywords : Asphalt cement, Natural rubber, Crumb rubbers, Properties, Ternary mixing

Introduction

Paved road must be well designed and have a perfect asphalt mixture that is suitable for the total mass. It will have better efficiency when receiving aggregates with similar properties. Thailand has quite hot weather. The road surface in the country is regularly damaged by the heating of weather. As a result, the road has less life span. In the past, Thailand widely used asphalt concrete AC 70/80 standards in the general road construction. Nowadays, it is changed to AC 60/70 because the weather was heated up. Mostly, the cold countries used softer AC compared to AC in Thailand standard. Because, the lower temperature will enhance stiffness preservation [1].

At present, the amount of rubber planted in Thailand is an abundant volume in the southern and other regions. These rubber problems are caused by the oversupply of agricultural products. The majority of people turn to other areas for agriculture due to lower incomes from the sale of rubber. The government is trying to encourage rubber farmers to get more profits, but they still face the problem of reduced profits and not being cost-effective from rubber trading. So far, many researchers tried to help them by using natural rubber mixed with asphalt. Suranaree University studied by using 5%, 8%, and 10% of rubber mixed with asphalts AC 60/70 [2]. The results were represented to the ability of total mass in each percent. Moreover, the .5 % rubber was tested in bituminous materials CRS-2 for Saybolt viscosity, penetration, and ductility property [3].

Many research applied natural rubber mixed asphalt concrete 60 -70 for the finding its right qualifications before building the road in Thailand. 5% of rubber was suitably mixed with asphalt AC 60/70 [4]. And, softening point, penetration index, torsional recovery, toughness, and tenacity testing were used in this research [5].

Including, Thailand has a lot of unused tire wheels, which contain carbon dioxide and cause air pollution. In Portugal, crumb rubber was mixed with asphalt by a dry and wet process. The outcome showed that dry process have helped to prevent the occurrence of fatigue and more saving cost than a wet method [6]. The results were still the same in the United States [7]. The suitable scale of dry crumb rubber was sizing from 0.25 mm down, or through the sieve number 60, it was the highest efficiency for bituminous testing [8]. The property of them may enhance the performance of asphalt even further with suitable mixing [9]. Also, the life span of the road has increased to 3 years and heat resistant up to 60°C when used 5% and 11% of mixed natural and crumb rubbers, respectively [10].

Research objective

This research is to study the properties of asphalt cement AC 60/70 mixed with natural rubber and waste tire rubber by the testing of penetration, loss on heating ductility and stripping properties.

Research methodology

Materials

1. Asphalt Cement AC 60/70

It is a grade currently used in Thailand with penetration of 6-7 mm at a temperature of 25°C. Bituminous has a semi-solid and liquid characteristic. It is sticky and changed to be liquid when is heated to around 140 - 150 Celsius. Asphalt concrete must be heated before using. When it is dried, it will be solid. Asphalt is a binder to bind various materials and water can not passed through. Therefore, it is used as an integral part of road work. AC 60/70 is shown in Figure 1. The chemical composition of Asphalt material AC 60/70 consists of; Wax, Oil, Resin, and Asphaltene content at 6.88%, 28.90%, 55.10%, and 16.41% respectively.

Figure 1 Asphalt cement AC 60/70

Asphalt Cement AC 60/70 can withstand a loss heating up to 0.8 percent from its total weights at 163 degrees Celsius (°C) for 5 hours. There is flash point at a temperature not lower than 232 degrees Celsius. The ductility value is not lower 50 centimeters at 25 degrees Celsius of temperature, and its penetration is in around 6-7 millimeter. Including, peeling value not more than 50 percent in incubated at 63°C for 4 days.

2. Natural rubber

Rubber is a white liquid with viscosity about 12-15 centipoise. At 60% concentration, it is rapidly increased when the rubber concentration has increasing as well. Latex earns a double content of concentrated rubber will increases viscosity by 10 times. They are shown in Figure 2. The composition of natural rubber is total solid content, dry rubber content, protein, resin, fly ash, sugar and water at 30%, 60%, 1.5%, 1.25%, 1%, 1 %, and the rest is water content.

Figure 2 Natural rubber

Natural rubber alkalinity value is not less than 0.6% from its total weight, melting point at 30 - 35.5 ℃, and density is 0.906 - 0.93 gram • centimeter-3 at 20℃. Including, it has a specific gravity of 0.934 at 20℃ and increases when the rubber is stretched or cooled.

3. Dry crumb rubbers

It has a natural rubber concentration of around 54 -64 %. Crumb rubber manufactured from a mixture of rubber, black soot, sulfur, ozone, oil, substances to prevent deterioration of rubber, antioxidant substances from reacting with oxygen anti-aging agent from reaction with ozone process assistants, stimulants, retardants, color accelerators, white fillers, silica, calcium carbonate, kaolin, softening substances, and substances that help the tire change its shape better as well as reducing brittle hardness and improving properties at low temperatures. These ingredients led the tire resistant to heat and impact force from flexibility as well, shown in Figure 3. The chemical composition of dry crumb rubbers consist of; Rubber, Carbon black, Textile, Oxidize zinc, Sulfur, and additives at 54%, 29%, 2%, 1%, 1% and 13% respectively.

Dry crumb rubbers has melting point around 600 ℃, and resistant to heat up to 350 degrees Celsius. Tensile strength value is not lower 18 MPa, and elongation at tear is not lower 565 percent. Including, its viscosity is around 48 of Mooney viscosity at 100 ℃.

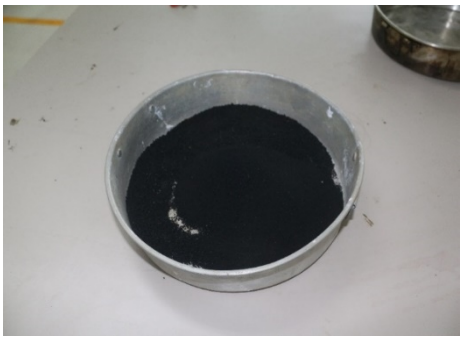

Figure 3 Dry crumb rubbers

Mix proportion

This research improves asphalt by mixing different amounts of natural rubber and crumb rubber. It divided into 4 cases are 0.0%, 5.0%, 8.0%, and 11.0% by weight of the mixture. They are showing more details in Table 1.

Table 1 Mixture proportion.

Mixture no.	AC 60/70 (%)	Natural rubber (%)	Crumb rubber (%)
1	100	0.0	0.0
2	95.0	5.0	0.0
3	89.0	0.0	11.0
4	92.0	2.5	5.5

Experiments

This research has 4 tests of asphalt concrete are showed in Figure 4(a) - 4(d), respectively. Penetration, ductility, stripping, and loss on heating of the recovered asphalt were compared with those of the original asphalt.

1. The penetration test according to DH-T 403 standard.

2. The ductility test according to DH-T 405 standard.

3. The stripping test according to DH-T 605 standard.

4. The loss on heating test according to DH-T 404 standard.

Figure 4 Testing apparatus

Results and discussions

After the 12 samples for each mixed already finished testing with 4 experiments. Their results for penetration test, ductility test, stripping test, and loss on heating test report and discuss to this part.

Penetration value

Natural and crumb rubber mixed with AC 60/70 have the average of penetration value between 54.33 - 56.97 mm The ternary mixed between natural and crumb rubber with bituminous is 55.32 mm Including, pure asphalt concrete AC 60/70 obtains the value at 66.70 mm compared with the standard value as 60 - 70 mm of a penetration test. They are as shown in Figure 5.

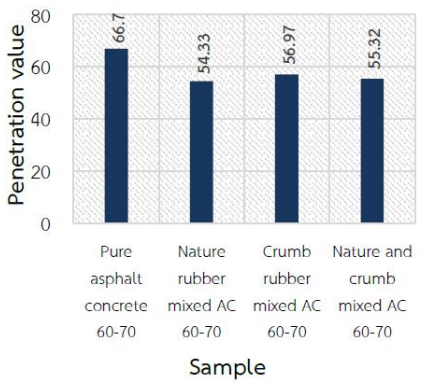

Figure 5 The penetration results

Natural rubber mixed with AC 60/70 has the best penetration property with 122.38% [5]. It helped asphalt material to be hard and greatly resistant to heat [4] because, natural rubber has the solid content up to 30 percent and 1.5 of resin also helps it to be homogeneous with asphalt material as well. Crumb rubber mixed with AC 60/70 has 118. 62%, it is dry scrap that may not spread throughout the asphalt [6]. Because the carbon black and additives help crumb rubber have high melting point. The ternary mixed between natural and crumb rubber with bituminous has penetration property better single crumb rubber and lower than single natural rubber. It halved the proportion of scrap rubber is more than the ratio of natural rubber. Therefore, the ternary material mixing property is more nearby single natural rubber mixing than crumb rubber. All samples are in the great properties when is setting 100% to penetration 70 mm, shown in Figure 6.

Ductility value

It has only pure asphalt cement AC 60/70 met the standard of ductility test to 142.33 cm Natural and crumb rubber mixed with AC 60/70 are received ductility values less than 50 cm 33.46 and 19.66 cm Including, ternary materials mixing between natural and crumb rubbers obtained to 29.62 cm They are shown in Figure 7.

The AC 60/70 has the best ductility value which it is in standards. Natural and crumb rubber mixed with AC 60/70 have 66.92% and 39.32% of ductility. They are not required to the standard that focused on 50 cm of ductility is 100%, shown in Figure 6.

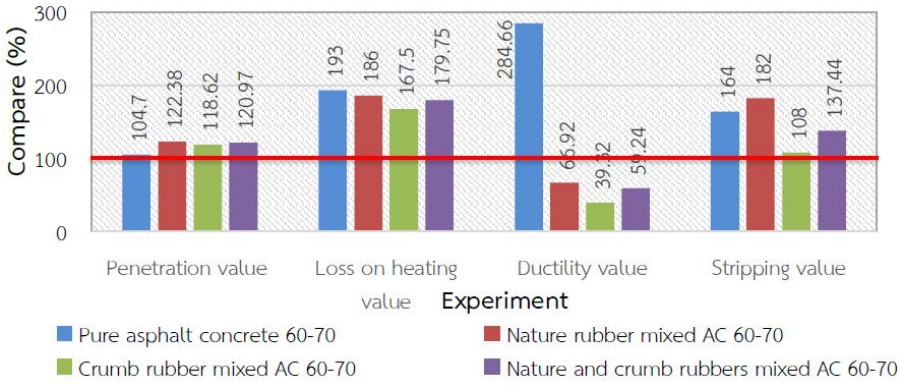

Figure 6 Summarized to each testing by quality % value of 3 samples

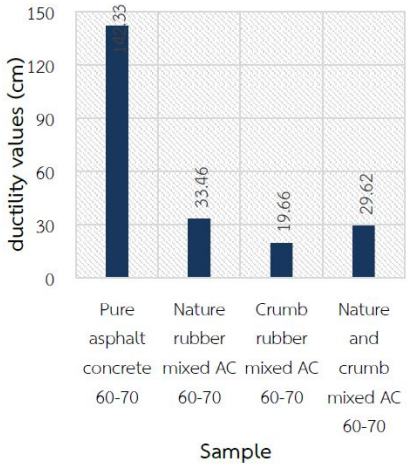

Figure 7 The ductility test results

The natural rubber property led asphalt has more stiffness from solid content that is supported reacting by the resin, and result in it is quickly recovery by viscosity [2].

Therefore, the distribution of them may not be throughout the coarse aggregate. This situation must be used more material to cover all these coarse aggregate [3]. But, the natural latex has better ductility than crumb rubber because it is greater homogenization of material which, the carbon black and additives are still making crumb rubber have the high melting point. Resulting, the ternary materials mixing of natural and crumb rubbers there is 29.62% of ductility property inclined toward binary mixed with natural rubber and AC 60/70. The amount of rubber scraps has reduced, the material to have more elongation [9].

Striping value

The stripping result for all mixing conforming to the standard, not over 12.5 of stripping score. Natural and crumb rubber mixed with AC 60/70, and pure asphalt cement AC 60/70 have the values at 2.25, 11.5, and 4.5, respectively.

Including, ternary mixed with natural and crumb rubbers is 4.68. The results are as shown in Figure 8.

When compared with the standard value as 100% (striping value is 12.5 score) as shown in Figure 6. Natural rubber helps the asphalt to be more stiff and resistant to heat will not peel off when exposed to heat [3] because, solid content and resin help it has more viscosity. Crumb rubber is not spread throughout the asphalt, and it may be less effective when it is forced to become a liquid and returned to a solid again by the heating [8]. Because, they have almost 50% of other substances mixed include Carbon black, Textile, Oxidize zinc, Sulfur and additives, and causing them to be received fatigue from these changes [7].

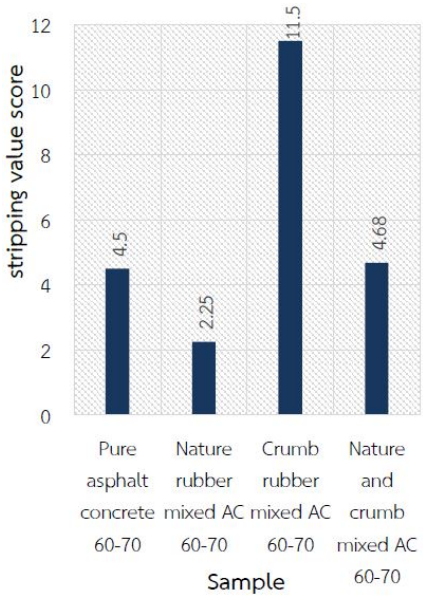

Figure 8 The stripping tests results

Therefore, natural rubber has better striping value than crumb rubber. Resulting, the stripping property of ternary mixing is inclined toward single mixing natural rubber with AC 60/70. It is harder and striker by less crumb rubber material ratio.

Loss on heating value

Single natural and crumb rubbers mixed with AC 60/70, ternary mixing, and asphalt cement AC 60/70 have a loss on heat values at 0.056, 0.130, 0.081 and 0.028 g, respectively. Compared with the standard value are not over 0.4 g of heat loss, as shown in Figure 9.

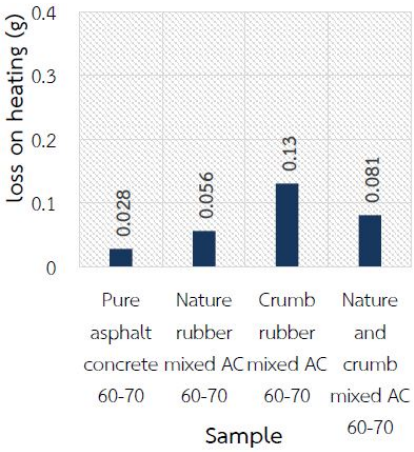

Figure 9 The loss on heating result

In the part of loss bituminous value on heating is determining the acceptable loss at 0.4 is 100%, shown in Figure 6. The binary mixing natural rubber is better homogenization of materials led it has lost less crumb rubber mixed with AC 60/70. This situation resulted in asphalt has a gap in adhesion from the high melting point of Carbon black and Additives in tire. The viscosity is from interaction between solids content and resins in natural rubber spread all the asphalt, helped to protect loss on heating [10]. The ternary materials mixing between natural and crumb rubbers with AC 60/70 are loss on heating greater single crumb rubber. Because the proportion of viscosity distribution is higher by natural rubber. Thus, ternary materials mixing are inclined toward single natural rubber mixing due to the spread of viscosity ratio amount. However, pure asphalt cement AC 60/70 has more intensity than natural rubber resulted in loss on heating value is the best [4].

Conclusions

1. Pure asphalt concrete 60/70 provides the greatest property on loss on heating and ductility of bituminous at 0.028 g and 142.33 cm

2. Natural rubber mixed with AC 60/70 has the most quality in penetration and stripping values as 54.33 mm and 2.25 score of peeling off. Crumb rubber mixed with AC 60/70 is number 2 in quality of penetration at 56.97 mm, but another testing is the lowest efficiency.

3. The ternary material mixing AC 60/70 has the properties test values are in the middle range between single material mixing natural and crumb rubbers to 55.32 mm, 0.081 g, and 29.62 cm, and 4.68 scores respectively.

4. The rubber is caused asphalt concrete 60/70 there is more viscosity. This property led to bituminous material has harder and better heat resistance. In the term of engineering property between the use of single and ternary mixing natural crumb rubbers are not much different.

5. Ternary mixing natural and crumb rubbers should be more testing in various ratios. To find out its suitable proportion led asphalt mixture has better properties.

Acknowledgments

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