The Use of Crumb Rubber as Modified Bitumen for Crack Filling at Deteriorated Pavement

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Abstract. Crumb rubber is tire retreading waste which is classified as a hazardous material because it can pollute the environment. In an effort to create an environment free of pollution, one of the efforts is to reuse it as building material. In this research, crumb rubber will be used to modify the 60/70 penetration bitumen to have a better performance as crack filler on roads that are damaged in the form of cracks. As crack filler the material must have resistance to softening at high pavement temperatures during the day. In this study, crack filler was examined in the form of penetrating asphalt with the addition of additives, namely Crumb Rubber. The result parameters are based on ASTM D5078 standards and testing procedures based on ASTM D5329, where tests include softening point, cone penetration, resilience and asphalt compatibility testing. The results show that the addition of 27% CR to 60/70 penetration asphalt can increase the hardness of the asphalt, the softening point value, the resilience or recovery value which means reduced vulnerability to temperature.

1. Introduction
Crack filling on the surface of asphalt pavement has long been used as a way of road maintenance. Crack filling is carried out in order to reduce water infiltration, prevent pumping and avoid premature pavement damage or delay the need for road rehabilitation. A good crack filling job can provide many benefits such as improved pavement conditions, increased safety for road users, longer service life, reduced need for road maintenance or rehabilitation and ultimately will reduce the life cycle cost of the road. According to George J. Chong [1] in general, there are two kinds of ways to overcome cracks on flexible pavement surfaces, namely by covering the pavement surface with a mixture of emulsion asphalt and sand or gravel, and the second method is by the rout and seal method, namely scraping and cleaning the crack cracks then filling the crack cracks with filler material. In its development, crack filling using the first method, namely by covering the pavement surface with emulsion asphalt and sand / gravel proved to be ineffective, but also can cause unwanted side effects. On the other hand, the rout and seal method showed better results and was effective in handling road surface cracks.

A comprehensive study on the feasibility of the method of filling the crack (rout and seal) surface of flexible pavements conducted by The Ministry of Transportation of Ontario (Canada) in 1986 showed the results that the application of crack handling by the rout and seal method was quite effective in delaying and even stopping pavement damage. This is more severe. In addition, this
method is also significant in achieving cost effectiveness in road maintenance, with optimal starting times of 3 - 5 years for initial treatment, and 8 - 9 years for follow-up care [1]. Crack sealing of roads has been shown to provide benefits in the form of improved pavement performance as well as extended service life which also translates to cost savings. The maximum road performance improvement can be achieved when crack filling is carried out on road conditions with a PCR (Pavement Condition Rating) value of 66 - 80. Meanwhile, the cost-effectiveness is achieved when crack filling is carried out on road conditions with a PCR value of 66 - 70 [2]. Crumb Rubber comes from the waste of rubber products in the form of used tires which are crushed by chopping, milling or grinding, then sorted based on grain size. Crumb Rubber is generally used for product mixes such as rubber carpets, rubber compounds, and rubber shoe soles, mixtures in building construction, asphalt mixtures, floor coatings and others. Crumb Rubber is an environmentally friendly product because it is one of the uses of waste, and its nature does not decompose in soil or dissolve in ground water. In addition to reducing the amount of rubber waste that is wasted into the environment, the reuse of rubber product waste can reduce the price of rubber as an important component in determining the price of the finished product. The use of rubber aims to provide certain desired properties, one of which is its use as an additive to asphalt in order to have better characteristics (resilience) [3]. Crumb Rubber is relatively easy to find in the market and is available in various grain sizes. The size of the Crumb Rubber in the asphalt mixture also greatly affects its fracture resistance. The fracture resistance of the asphalt mixture with a Crumb Rubber size of 30-80 mesh increased significantly [4]. This is a consideration in this study using a Crumb Rubber size of 50 mesh (grain diameter +/- 0.3mm) as an additive to asphalt penetration 60/70 as crack filler with several variations in the addition of Crumb Rubber content.

2. Experimental
In this study, the effect of adding additives in the form of tire powder to penetration asphalt will be examined in terms of the parameters of softening point, consistency (cone penetration value) and resilience / recovery. In addition, it will also be investigated whether the addition of the additive at a certain level can meet the requirements as a crack filler material as required in ASTM D5078 [5]. The first thing to do is to assess the properties of the base material used, namely penetrating asphalt, whether it meets the requirements so that it can be classified as 60/70 penetration asphalt. Then the data analysis of the test results of the crack filler material is then carried out, to look for trends / trends that occur related to the addition of additive content in penetration asphalt for crumb rubber crack fillers, as well as an assessment of each test object whether it meets the specifications required in ASTM D5078.

2.1 Primary Data
Primary data is data that is collected directly through a series of experimental activities which are carried out independently by referring to existing manual instructions, for example by conducting direct research or testing. The primary data collection aims to determine whether the specimen meets the requirements as stated in ASTM D5079 [6] as a crack filler. Primary data in this study include:

- Asphalt penetration examination, to determine the real consistency of penetrating asphalt used in the study (ASTM D5 testing procedure) [7]
- Softening point / softening point of asphalt (ASTM D36 testing procedure) [8]
- Cone penetration / penetration with cones (ASTM D5329 testing procedure) [9]
- Resilience / resilience / restoration of asphalt with ball penetration (ASTM D5329 testing procedure)

2.2 Secondary Data
Secondary data is data obtained indirectly, obtained from previous research using the same material / type as this research or based on product specifications from the material manufacturer. This study
uses secondary data, namely the specification data of concentrated natural latex products, used Crumb Rubber and cellulose fibres used in the study.

3. Results and Discussion

The results of the research and discussion consisted of the crumb rubber property obtained from secondary data and the result of 60/70 penetration asphalt testing. The test results show that the Crumb Rubber content of 27% meets all the requirements of ASTM D5078, namely the softening point value > 65.5°C, the cone penetration value < 70 dmm and the recovery value > 30%. In this study also analyzed the test data to determine the effect of adding Crumb Rubber additives to 60/70 penetration asphalt as crack filler on the softening point, cone penetration and recovery values.

3.1 The properties of Asphalt penetration 60/70

The basic material used in this research is 60-70 penetration bitumen in a 20 kg container / drum which is obtained from the Civil Engineering Transportation Laboratory. The results of the 60/70 penetration asphalt test including the softening point and needle penetration tests can be shown in Table 1.

| No. | Properties           | Conditions by Binamarga Specification | Results | Specification |
|-----|----------------------|----------------------------------------|---------|---------------|
| 1.  | Softening Point (°C) | ≥ 48                                   | 48.6    | ok            |
| 2.  | Penetration 100gr, 25°C, 5 second (0,1mm) | 60 - 70                                | 62.8    | ok            |

The Crumb Rubber produced by the factory with a mesh size specification of 50 with a specific gravity of 1.1 gr / cc.

3.2. The properties of Asphalt penetration 60/70 mixed with Crumb Rubber

Testing was initially carried out with test objects with 50 mesh Crumb Rubber content, namely 3%, 5%, 7% and 9%, but because the results did not meet the requirements of ASTM D5078, additional testing was necessary until the results met ASTM D5078 requirements, namely the Crumb Rubber content. 18%, 21%, 24%, 27%. The test results of Softening Point, Cone Penetration and Ball Penetration / Recovery of crack fillers in the form of 60/70 penetration asphalt with added Crumb Rubber are shown in Table 2.

| Crumb Rubber Content (%) | Softening Point (°C) | Cone Penetration (0.1mm) | Ball Penetration (%) |
|--------------------------|----------------------|--------------------------|----------------------|
| 3                        | 4910                 | 49.70                    | 2.30                 |
| 5                        | 50.23                | 48.20                    | 4.70                 |
| 7                        | 51.50                | 46.70                    | 7.30                 |
| 9                        | 52.30                | 45.30                    | 10.00                |
| 18                       | 58.43                | 40.80                    | 21.00                |
| 21                       | 60.85                | 39.70                    | 28.80                |
| 24                       | 63.68                | 38.30                    | 29.80                |
| 27                       | 67.48                | 37.20                    | 34.00                |

- The softening point requirement according to ASTM D5078 is more than 65.5°C, only at a Crumb Rubber content of 27% the softening point value meets the requirements.
- the requirement for the Cone Penetration value based on ASTM D5078 is less than 70 (0.1mm). At all levels of Crumb Rubbers tested, the Cone Penetration value met the requirements.
• Requirements for the recovery value based on ASTM D5078 are more than 30%. Only at cellulose fiber content of 27% the recovery value met the requirements.

3.3. The influence of Crumb Rubber Content on the Softening Point
From the data, the test results show that only the Crumb Rubber content of 27% meets the minimum requirements of softening point (65.5°C) as crack filler. It can be concluded that the addition of Crumb Rubber content to the 60/70 penetration asphalt can increase the softening point value of the mixture. In other words, the addition of Crumb Rubber content can reduce the susceptibility of penetration of asphalt to temperature increases, thereby reducing the occurrence of softening of the material when applied in the field. With the help of the Microsoft Excel program, regression analysis (polynomial order 2) can be carried out to predict the tendency of the soft point value to increase, so that the formula \( y = 0.015x^2 + 0.279x + 48.42 \) with a value of \( R^2 = 0.998 \) is obtained. The value of \( R^2 \) which is close to the value of 1 indicates that the Crumb Rubber content ("x" as the independent variable) affects the softening point value of the crack filler ("y" as the dependent variable), where the addition of Crumb Rubber content can increase the softening point value of the penetration asphalt 60/70 which is used as a crack filler.

3.4 The influence of Crumb Rubber Content on the Cone Penetration
From the test data, all variations of the Crumb Rubber content meet the requirements for the cone penetration value (<70 dmm) as a crack filler, it can also be concluded that the addition of Crumb Rubber content on the 60/70 penetration asphalt can reduce the value of cone penetration. This shows that the addition of Crumb Rubber can increase the hardness of penetration asphalt. With the help of the Microsoft Excel program, a regression analysis (polynomial order 2) can be carried out to predict the tendency of the increase in the value of cone penetration, so that the formula \( y = 0.008x^2 - 0.757x + 51.70 \) with a value of \( R^2 = 0.999 \) is obtained. The value of \( R^2 \) which is close to the value of 1 shows that the Crumb Rubber content ("x" as the independent variable) significantly affects the cone penetration value of the crack filler ("y" as the dependent variable) significantly, in this case the addition of Crumb Rubber content can reduce the cone penetration value. 60/70 penetration bitumen used as crack filler.

3.5 The influence of Crumb Rubber Content on the resilience/ recovery value
From the test data shows that only the addition of Crumb Rubber content as much as 27% meets the requirements of the recovery value (> 30%) as a crack filler, it can be concluded that the addition of Crumb Rubber content to the 60/70 penetration asphalt can increase the recovery value, or in other words, the addition of Crumb Rubber can increase the ability of crack fillers to withstand the entry of incompressible material on its surface. With the help of the Microsoft Excel program, a regression analysis (polynomial order 2) can be carried out to predict the tendency of the increase in the recovery value, so we get the formula \( y = 0.007x^2 + 1.088x - 0.814 \) with a value of \( R^2 = 0.999 \). The value of \( R^2 \) which is close to the value of 1 indicates that the Crumb Rubber content ("x" as the independent variable) significantly affects the recovery value of the crack filler ("y" as the dependent variable), in this case the addition of Crumb Rubber content can increase the recovery value of the 60/70 penetration asphalt used as crack filler.

4. Conclusion
Based on the results of testing and data analysis that have been carried out in this study, it can be concluded that the addition of Crumb Rubber to the 60/70 penetration asphalt as a crack filler can increase the softening point value, which means reduced susceptibility to temperature increases. The addition of Crumb Rubber to the 60/70 penetration asphalt as a crack filler can reduce the cone penetration value, so it can be said that the hardness of the asphalt increases. The addition of Crumb Rubber to 60/70 penetration asphalt as a crack filler can increase the resilience or recovery value, which means that there is an increase in the ability of the crack filler to resist the entry of other
materials on its surface and also its ability to return to its original shape. The requirements for 60/70 penetration asphalt as a crack filler in terms of the softening point value, cone penetration, resilience and conformity with asphalt according to ASTM D5078 can be fulfilled by adding 27% Crumb Rubber additive.

References
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