The Use of Stress Absorbed Membrane Interlayer (SAMI) to Reduce Reflection Crack on Road Pavement

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Abstract: Reflection crack is one of main problems on road pavement in Indonesia. Reflection crack is a crack will reflect through an overlay placed on top of it. One of methods used in improvement of reflection crack resistance is Stress Absorbed Interlayer (SAMI). The purpose of this study is to evaluate the SAMI layer with different conditions. The SAMI layer systems used in this research were one layer and two layer systems. The samples of 30 cm x 30cm x 5 cm size were prepared using Whell Tracking Compacter. The SAMI had a significant effect on fatigue crack performance, which bituminous mix using SAMI exhibited better in reducing reflection crack compared to conventional bituminous mix. The use of the SAMI with one layer system and modified bitumen with 2% SBS showed the best performance in term of the fatigue crack.

***Key Words**: Reflection Crack, Stress Absorbed Interlayer (SAMI), Bituminous Mix*

1. INTRODUCTION

Crack is one of the main problems of road pavement in Indonesia. Crack which is incorrectly handled will cause a more serious damage and it leads to the traffic transportation disturbance. Resurfacing on the road pavement which has already had cracks will cause reflection cracks, while the removal of cracks area will spend relatively high cost. One of the cheap technologies and can be used to avoid reflection cracks is by installing reflection crack retaining layer before the road pavement is resurfaced.

Reflection crack is a crack on asphalt layer of new asphalt which is considered as the reflection of the crack under it. This crack will quickly emerge onto the surface layer if there is no other layer which will be able to retain the development of this crack, so this layer will fail prematurely. A special layer which has function to impede the development of the crack onto the surface may be able to handle this problem.

The level of reflection crack development is believed to depend on the level of load concentration (tension) which comes into that crack. The development of reflection crack is also influenced significantly by interface characteristic between existing asphalt layer and its overlay layer. On that account, the supplying of special layer which is aimed for absorbing the tension of the interface among asphalt layers is believed to be able to block the development of reflection crack

SAMI is a layer made from asphalt and aggregate (chip), which one of its functions is believed to be able to reduce the development of reflection crack. But, the effectivity of SAMI still depends on the type of asphalt and aggregatee being used.

The objective this study was to develop effective and efficient reflection crack retaining layer, that is by using Stress Absorbed Inter Layer (SAMI).

2. LITERATURE REVIEW

2.1 Reflection Crack

Reflection crack is a crack on overlay layer which is resulted by a reflection from a crack happening on the layer under it. In a not very long time, the crack on the existing layer will be reflected to overlay layer. The reflection of crack from existing layer to the overlay layer is caused by both the environment and the traffic. Besides the influences come from both the environment and the traffic, the speed of the reflection crack development is also influenced by the point of the flexibility before the overlay and intensity get their crack on its existing. Reflection crack has posibility to develop into the damage of ravelling or spalling in overlay layer. Besides that, the water can penetrate into this crack and cause the releasing of the old and new layer bonding. On that account, reflection crack can cause a quick detereoration of road pavement and at the end will cause the decrease of layer's service age which resulting the increase of maintenance cost. According Morosiuk et al (1992), giving 4 cm overlay layer to repair the existing road which has already had a crack is not effective for either all intensity or crack level.

2.2 The Mechanism of Reflection Crack

According to George (1982), basic mechanism which assumed as a cause of reflection crack emergence is a vertical and horizontal movement at the layer which is resurfaced. On an existing layer which has crack, the vertical movement which happens as the result of traffic load will cause the differential movement on that layer. Because of this differential movement, the crack on existing layer develop into overlay layer which exists on it. Whereas the dimension changing happening at the layer which has bonding material, especially the surface layer as contraction happens and or expansion as the result of temperature and humidity changing, will cause the happening of horizontal movement at that layer which has bonding material. The horizontal movement at the layer having bonding material that has a crack will cause the happening of high tension around the cracking area. On that account, this horizontal movement can cause the development of existing layer crack that has bonding material toward overlay layer on it.

Based on the description above, it can be concluded that if the overlay is applied on existing layer that has bonding material and crack on it, as shown on Figure 1, the vertical and horizontal crack movement on that existing layer will be reflected to the overlay layer on it.

Figure 1 Reflection crack propagation on road pavement

2.3 The Mode of Reflection Crack

As previously study stated that reflection crack will develop toward overlay layer if that layer is put directly on the older layer which had already had crack on it. Although both of them can cause a crack on overlay layer, the development mode of reflection crack at flexible pavement (overlay on asphalt layer) is different from what happening at composite layer (overlay on rigid permanent). In flexible pavement, the vertical movement which happening as the result of traffic load will cause differential movement on asphalt layer in the condiiton that layer is spread on existing cracked. As the result of this diffrential movement, the crack on existing layer will develop toward overlay layer on it. The mode of reflection crack development of this flexible pavement as ilustrated in Figure 2.

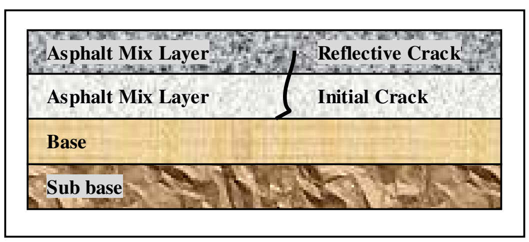


Figure 2 The mode of reflection crack development on road pavement

The study which was conducted by Nunn (1989) concluded that reflection crack which happened on asphalt layer that was spread on rigid pavement (composit pavement) started from its upper edge asphalt layer to its down section. According to him, because of the influence of environment, the topmost edge of asphalt layer has more aging experience than other sections of that layer. On that account, because of the temperature, attractive tension that happens will cause the crack at this topmost edge. Nesmas et al (2204) said that in composite pavement, environment factor (asphalt aging) gives more influence in reflection crack development than traffic, as shown in Figure 3. According to him, because of the temperature, maximum atractive tension at rigid pavement happens at the crack containing on that rigid pavement. On that account, if it is overlaid, reflection crack that happens at asphalt layer in this pavement will happen in the area and follow the crack pattern at its rigid pavement, but this crack started from its asphlat upper edge layer toward its down section. The mode of reflection crack development at this composite pavement is as illustrated in Figure 4

Figure 3 The reflection crack on the road that has never been passed by vehicles traffic for 12 years

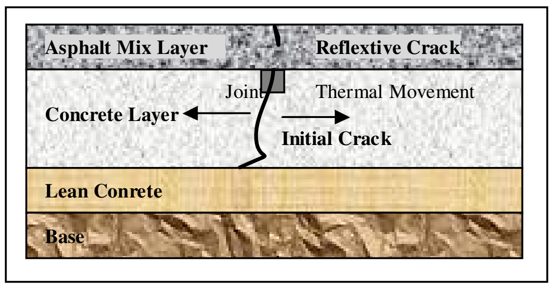


Figure 4 The mode of reflection crack development on rigid pavement

2.3 The Method to Minimize Reflection Crack.

From several studies that have been conducted by some researchers, reflection crack can be minimized by applying some ways, some of them are:

1. By giving thick overlay layer (>50mm)
2. Changing the viscocity of used asphalt
3. By using additive in the asphalt
4. Giving maintenance in existing road pavement (seal coat, crack filling, pavement breaking, and others) before overlaying.
5. Giving the inter layer which can reduce the cracks (*stress-relieving interlayer*), such as: asphalt rubber, membranes, geosyntetics, low viscosity asphalt concrete, open greaded asphalt and agregate

3. LABORATORY TEST AND SAMPLE PREPARATION

Four types asphalts were used in this study, i.e penetrating asphalt 60 (code P60) and polymer asphalt SBS that contained variety polymer (three varieties), i.e Pen asphalt 60 + 2% SBS + 0,5 % Stabilizer (code E-55), Pen Asphalt 60 + 4% SBS + 1,0% Stabilizer (code E-70). The asphalts characteristics that used in this study as shown in Table 1 and Table 2.

Table 1 Properties of asphalt pen 60

Tests	Results	
	Results	**Specification**
Penetration,1 mm	64	60 - 79
Softening Point, ^{o} C	49	48 - 58
Flash Point ^{o} C	300	Min. 200
Viscosity on 135^{o}C, cCt	335	-
Ductility, 25^o C 5 cm/mny, cm	> 140	Min. 100
Density	1,0389	Min. 1,000
Solubility in C^2HCl_3, %	99,89	Min. 99
Weight Loss (TFOT), %	0,624	Maks. 0,8
Penetration after TFOT, %	85,9	Min. 54
Softening Point after TFOT, ^{o} C	51,6	-
Ductility after TFOT, cm	> 140	Min. 50
Temperature of Mixing, ^{o}C	157	-
Temperature of Compaction, ^{o}C	144	-

Table 2 Properties of modified polymer bitumen

Test	Results			
	Results			**Specification**
	E-55	E-60	E-70	
Penetration,1 mm	50	52	64	50 – 75
Softening Point, ^{o} C	58,7	66,7	66,4	Min. 54
Flash Point ^{o} C	316	310	308	Min. 232
Ductility, 25^o C 5 cm/mny, cm	>140	>140	>140	-
Viscosity on 135^{o}C, cCt	695	885	940	Maks. 2000
Density	1,036	1,036	1,034	-
Solubility in C^2HCl_3, %	99,66	99,62	99,75	Min. 99
Weight Loss (TFOT), %	0,020	0,002	0,020	Maks. 1,0
Penetration after TFOT, %	16	12	9	Maks. 40
Softening Point after TFOT, ^{o} C				-
– Increasing SP after TFOT	3	-	-	Maks. 6,5
– Decreasing SP afterTFOT	-	0,9	4,7	Maks. 2
Ductility after TFOT, cm	>140	131,5	>140	-
Elastic recovery on 25 ^{o}C	65	77,5	85	Min. 45
Temperature of Mixing, ^{o}C	170	191	181	-
Temperature of Compaction, ^{o}C	154	177	168	-

Notes :
E-55 = Aspal pen 60 + 2% SBS + 0,5% Stabilizer
E-60 = Aspal pen 60 + 3% SBS + 0,75% Stabilizer
E-70 = Aspal pen 60 + 4% SBS + 1,0% Stabilizer

In this study, two types of SAMI were made, i.e SAMI with one layer and two layers cobblestone. For SAMI with one layer cobblestone (SAMI-1), the size of used aggregat is No. 8 (AASHTO M 78 – 64) with the using quantity as many as 4,3 – 4,5 kg/m2. Whereas SAMI with two layers cobblestone (SAMI-2), the used aggregat was No. 8 and No. 4 with the using quantity of each is 4,3 – 4,5 kg/m2 and 5,3 – 5,5 kg/m2. In building the SAMI, the asphalt that was heated based on its mixing temperature poured in hot condition onto asphalt layer which had already had a crack (being simulated by cutting up the asphalt layer) by applying variety pouring quantities, i.e 1,0 ; 1,3, 1,6 and 1,9 ltr/ m2.

The testing sample was made by using 30 cm x 30 cm x 5 cm mould and compressed by using Whell Tracking Compacter. For the solid testing, a cutting up was made in oder to simulate an early crack at existing layer. Then, on this testing sample was poured the asphalt that had been heated based on its mixing temprature. It was poured in hot condition into asphalt layer that had already had a crack (being simulated by cutting up the asphalt layer) by applying variety pouring quantities, i.e 1,0 ; 1,3, 1,6 and 1,9 ltr/ m2 for each used asphalt.

Then onto this asphalt was poured chip with certain quantity depended on the types of the sami that made (SAMI-1 and SAMI-2). Every cobblestone layer was compressed by applying 4 line compression Whell Tracking. After that, on this SAMI was given asphalt mixing layer (simulating the overlay layer) and compressed by using the same previous way. Then, this testing sample was cut into pieces in order to get testing object to handle the test of four point flexibility with the size of 30 cm x 5 cm x 10 cm and the test of displacement with the size of 30 cm x 5 cm x 10 cm. The typical of testing object that uses SAMI to do a flexibility and displacement test as shown in Figure 5.

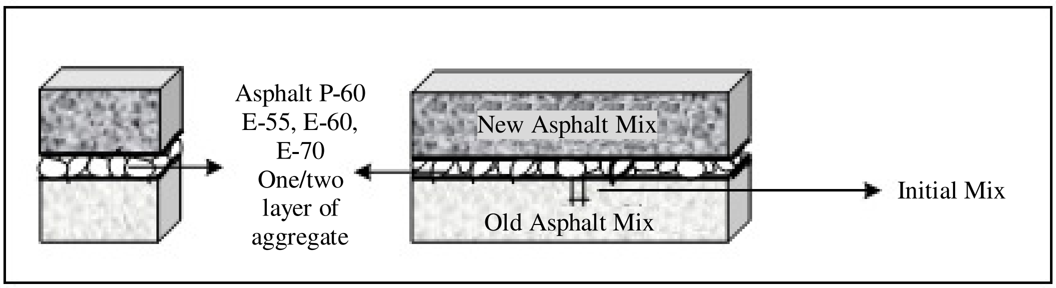
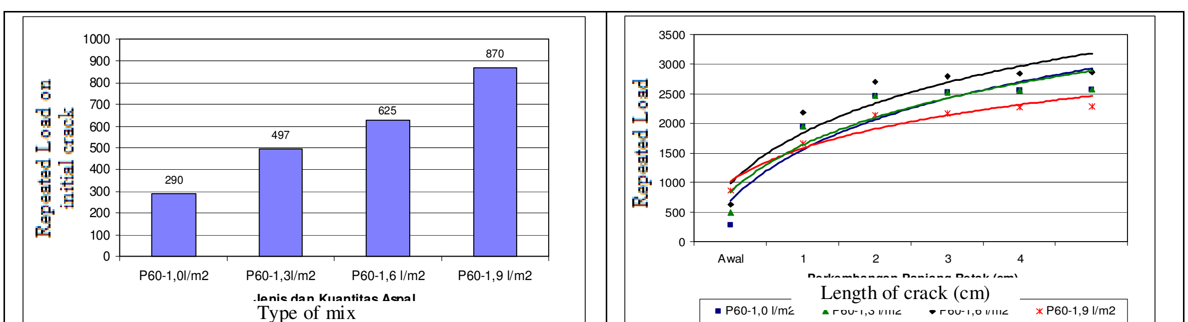


Figure 5 Typical of sample with SAMI on shear resistance test

4. TESTING RESULT AND ANALYSIS

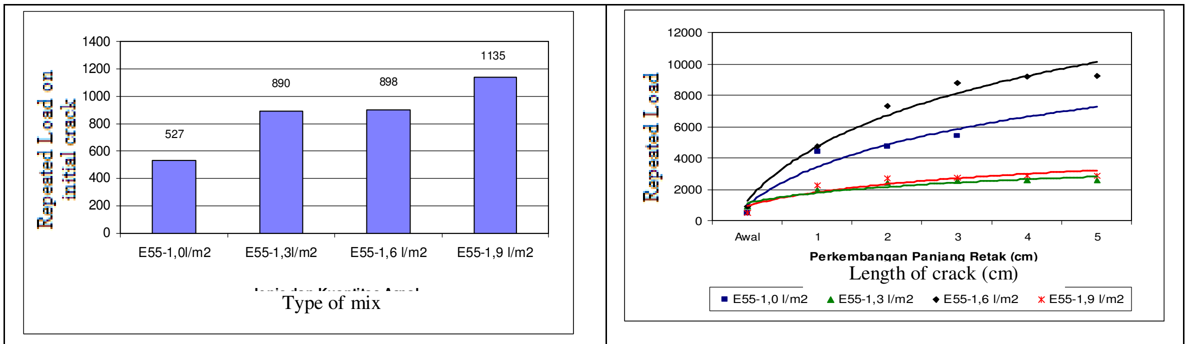
The result of layer testing that uses SAMI as interlayer, as shown in Figure 6 – Figure 10 for SAMI-1 and Figure 11 – Figure 15 for SAMI-2.



a. Initial Crack

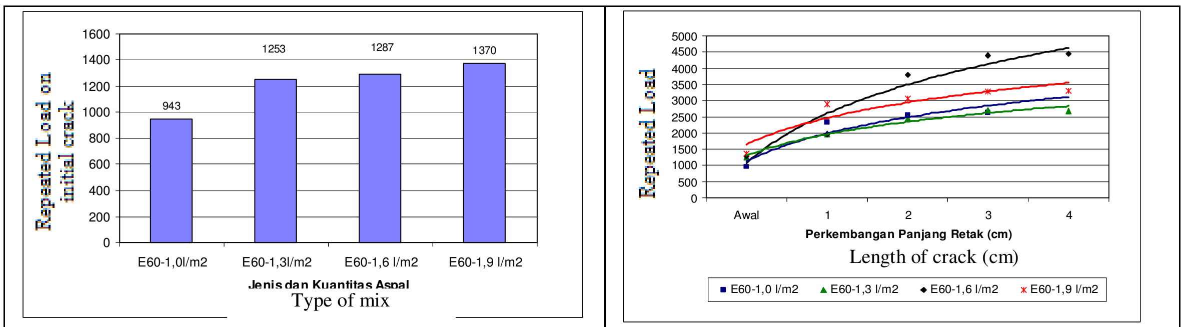
b. Crack Propagation

Figure 6. The effect of SAMI-1 for asphalt pen-60 on initial crack and crack propagation development



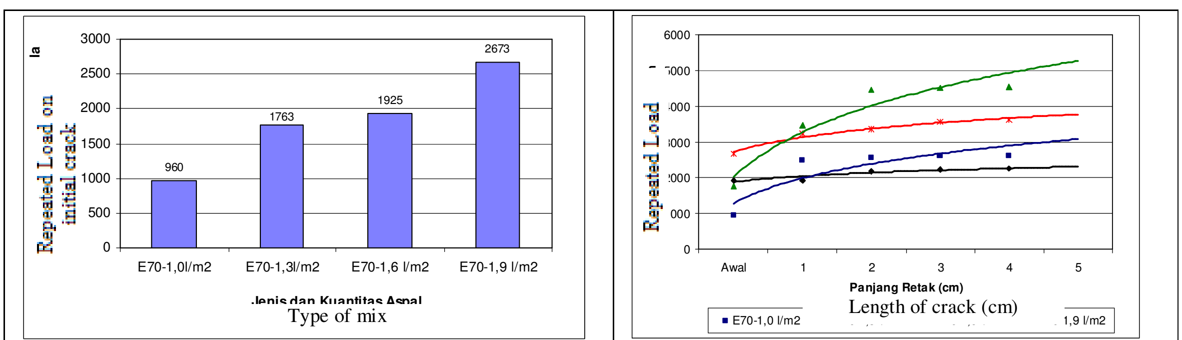
a. Initial Crack b. Crack Propagation

Figure 7. The effect of SAMI-1 for asphalt E-55 on initial crack and crack propagation development



a. Initial Crack b. Crack Propagation

Figure 8 The effect of SAMI-1 for asphalt E-60 on initial crack and crack propagation development



a. Initial Crack b. Crack Propagation

Figure 9 The effect of SAMI-1 for asphalt E-70 on initial crack and crack propagation development

It can be seen in Figure 6.a; 7a; 8a and Figure 9a that the influence of asphalt quantity which was used in SAMI-1 to retain the reflection crack untill that crack emerged on its upper layer.These figures show that the more the quantity of asphalt was given, the more the number of repeating which held out by overlay layer before reflection crack happened at that overlay crack.

This case showed that SAMI-1's asphalt had function not only as a binder which tied and united the used chip but also as a layer that could absord tension so that the tension that happened at layer interface became lower.

The influence of asphalt quantity that was used in the building of SAMI-1 also gave influence to the reflection crack development velocity that was happening. Figure 6.b; 7.b; 8.b; and Figure 9.b shows the influence of that asphalt quantity. It can be known from Figure 6.b; 7.b; 8.b and 9.b that for P-60, E-55 and E-60 asphalts, the quantity of asphalt in SAMI-1 gave tenacity to the rate of reflection crack development with the highest of 1,31/m^2.

The excessively use of asphalt in SAMI could also give negative influence for displacement resistance at layer interface, as shown in Figure 10. In this picture, it can be seen clearly that there was an asphalt using optimum rate in SAMI-1, where the rate of displacement resistance at interface is maximum.

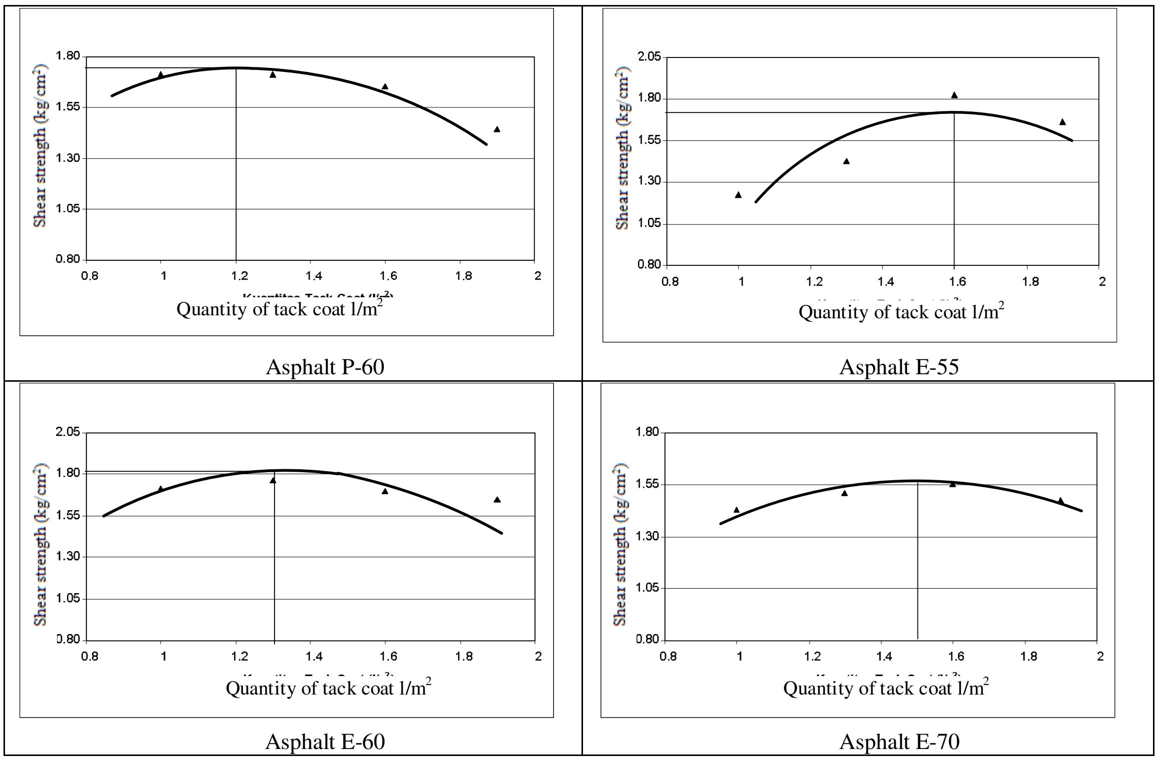


Figure 10 The effect of SAMI-1 for various asphalt types on shear resistance

For each types of used asphalts, i.e P-60, E-55, E-60 and E-70 the optimum rate of used asphalts for SAMI-1 was 1,2 l/m^2; 1,6 l/m^2; 1,3 l/m^2 and 1,5 l/m^2. Based on the above optimum rate, the work of SAMI-1 to retain each asphalt's type that was used as shown in Figure 11. It can be seen in this Figure that at each optimum degree, the number of the most repeating burden which could be handled by asphalt layer until the reflection crack happened at its interlayer was SAMI-1 that used E-70 asphalt.

If the capability of P-60 asphalt was considered as the guideline, so the capability to retain the number of load repeating untill the reflection crack was begun to happen at its upper layer for E-55, E-60 and E-70 asphalts for its each optimal condition was 2,3; 3,2 and 4,7 to the capabiltiy of P-60 asphalt.

From the view of crack development velocity (Figure 12), the capability of E-60, E-70 and P-60 that used in SAMI-1 to retain the reflection crack development rate at its optimum asphalt value was relatively similar. In this aasphalts's optimum value, E-55 asphalt retained the rate of reflection crack development the best of three other asphalt types (E-60, E-70 and P-60).

This is shown by the gradien of connection curve between the development of crack length and the number of load repeating, where E-55 has sharper curve gradien than those for E-60, E-70 and P-60.

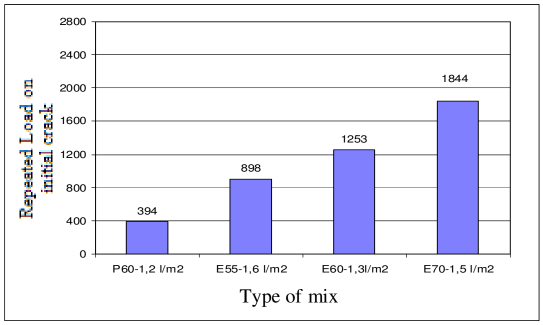


Figure 11 The effect of SAMI-1 on repeated load until occurring reflection crack for optimum asphalt quantity

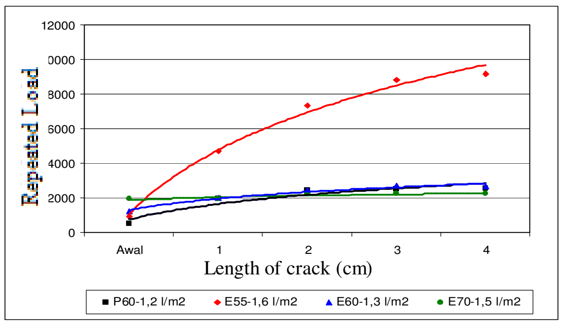
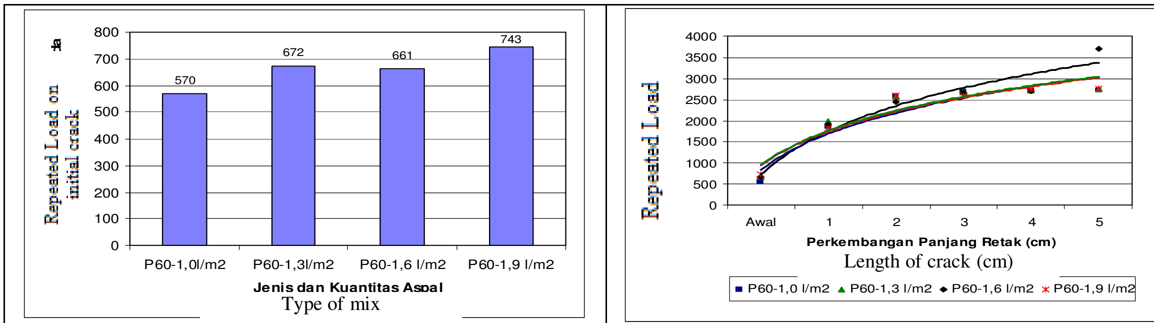


Figure 12 The effect of SAMI-1 on reflection crack propagation for optimum asphalt quantity

As in SAMI-1, the tendency of SAMI-2 to retain reflection crack until that crack emerged on the new layer (overlay) was significantly decided by the type and the quantity of used asphalt. It can be seen in Figure 13.a; 14.a; 15.a and Figure 16.a the influence of asphlat's quantity that was used in SAMI-2, the more the asphalt was given, the more the number of repeating that was retained by overlay layer before reflection cracks happened.

Positive influence from the quantity of used asphalt to the tenacity to retain early reflection crack that happened, was not in line with its capabiltiy to retain the rate of that crack development.

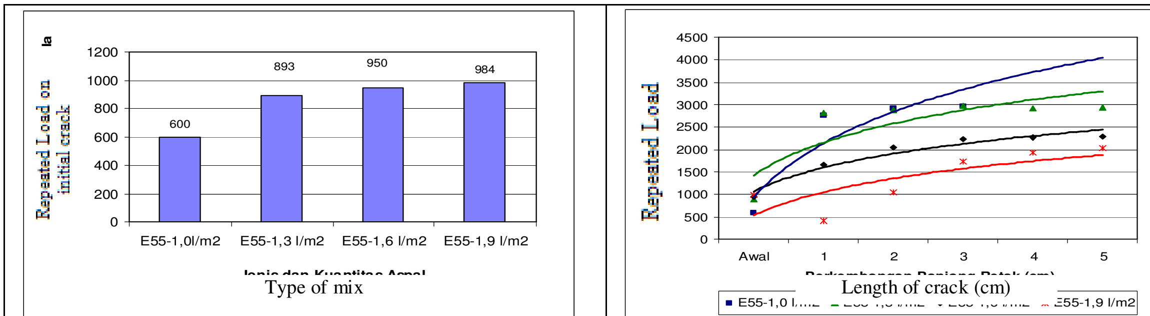
The more the asphalt used was not a certainty to give better tenacity to retain the rate of that crack development as shown in Figure 13.b; 14.b; 15.b and Gambar 16.b. This tendency was similar with SAMI-1 on the rate of reflection crack development. For P-60 asphalt (Figure 13.b), the tenacity of SAMI-2 to block the rate of resulted reflection crack development for asphalt's quantity as much as 1,6 l/m^2. However, in other quantities, the capabiltity of P-60 asphalt to retain the rate of reflection crack development was not too different from the capability in that 1,6 l/m^2 quantity. For E-55 and E-70 asphalt, the quantity of asphalt in SAMI-2 considered to be more able to block the rate of reflection crack development was similar with 1,0 l/m^2 (Figure 14.b and Figure 16.b)



a. Initial Crack

b. Crack Propagation

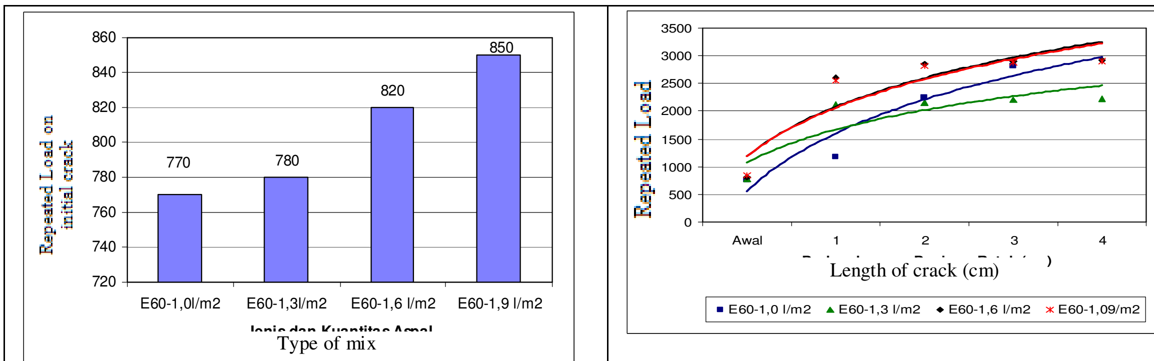
Figure 13 The effect of SAMI-2 for asphalt pen-60 on initial crack and crack propagation development



a. Initial Crack

b. Crack Propagation

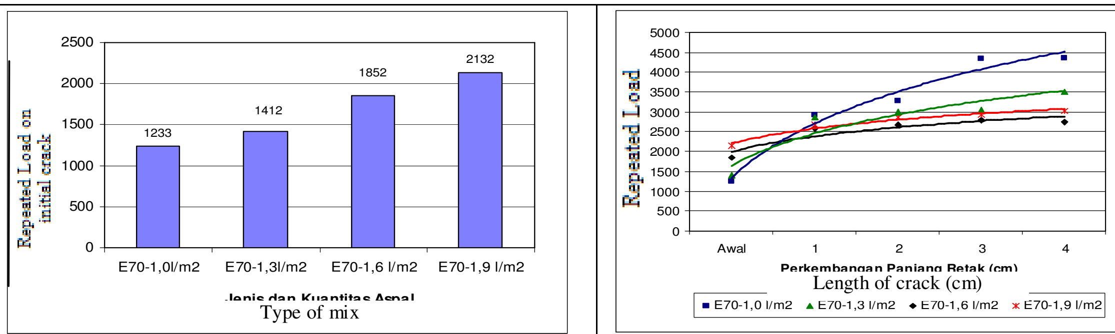
Figure 14 The effect of SAMI-2 for asphalt E-55 on initial crack and crack propagation



a. Initial Crack

b. Crack Propagation

Figure 15 The effect of SAMI-2 for asphalt E-60 on initial crack and crack propagation development



a. Initial Crack b. Crack Propagation

Figure 16 The effect of SAMI-2 for asphalt E-70 on initial crack and crack propagation development

Whereas for E-60 asphalt (Figure 15.b), the highest capability to retain the rate of reflection crack development was resulted in asphalt using quantity as much as 1,6 l/m^2 and 1,9 l/m^2.

From the point of displacement retaining, the performance of SAMI-2 on displacement retaining had the similar tendency as tack coat performance, i.e there was an optimum value that gave maximum displacement retaining value. For SAMI-2, for each types of asphalts that were used (P-60, E-55, E-60 and E-70), this optimum value was acquired each from Figure 17, i.e 1,5 l/m^2; 1,3 l/m^2; 1,4 l/m^2; and 1,4 l/m^2.

At this optimum value, the performance of SAMI-2 to retain the load repeating untill the happening of reflection crack for each used asphalt's type as shown in Figure.17. This figure shows that each optimum value, the most number of load repeating that can be handled by the asphalt layer until the moment of reflection crack happened on the overlay layer that used SAMI-2 as its interlayer was SAMI-2 that used E-70 asphalt. If the capability of P-60 was considered as the guideline, the capablitiy in retaining the number of load repeating until reflection crack started to happen in its upper layer for E-55, E-60 and E-70 asphalt for each optimum condition was 1,3; 1,2 and 2,4 to the capability of P-60 asphalt.

From the point of reflection crack development velocity (Figure 18), the capability of E-70, E-55 and P-60 asphalt in SAMI-2 to retain the rate of reflection crack development at the asphalt's optimum value was relatively similar. This is shown by the almost similarity of curve declivity gradient of the connection between crack length development and load repeating number. But, the quality of used asphalt in SAMI-2 E-70 (1,4 l/m^2) and SAMI-2 E-55 (1,3 l/m^2) is relatively less than SAMI-2 P-60 (1,5 l/m^2).

If the capabiltiy of SAMI-1 and SAMI-2 compared with asphalt layer that is made without using the SAMI (conventional layer), so the performance of SAMI-1 and SAMI-2 to retain load repeating until the happening of reflection crack and to reatin the velocity of reflection crack development for each type of used asphalt as shown in Figure 2o and Figure 21.

This Figure shows the leading of SAMI-1 and SAMI-2 over the conventional overlay (without using the SAMI). The leading ratio of SAMI-1 and SAMI-2 and the method choice priority and the type of asphalt that was used to retain the load repeating until the happening of reflection crack and to retain the velocity of reflection crack development which is resumed in Table 3.

This table shows that from the aspects of load repeating retaining until the happening of the reflection crack, SAMI-1 that used by using E-70 asphalt gave the best result. Whereas SAMI-1 that used P-60 asphalt was not recomeded to be used in this intention. From the aspect of retaining the rate of reflection crack development, SAMI-1 taht was made by using E-55 asphalt gave the best result. Whereas SAMI-1 that used P-60 and E-70 asphalt was not recomeded to be used in this intention.

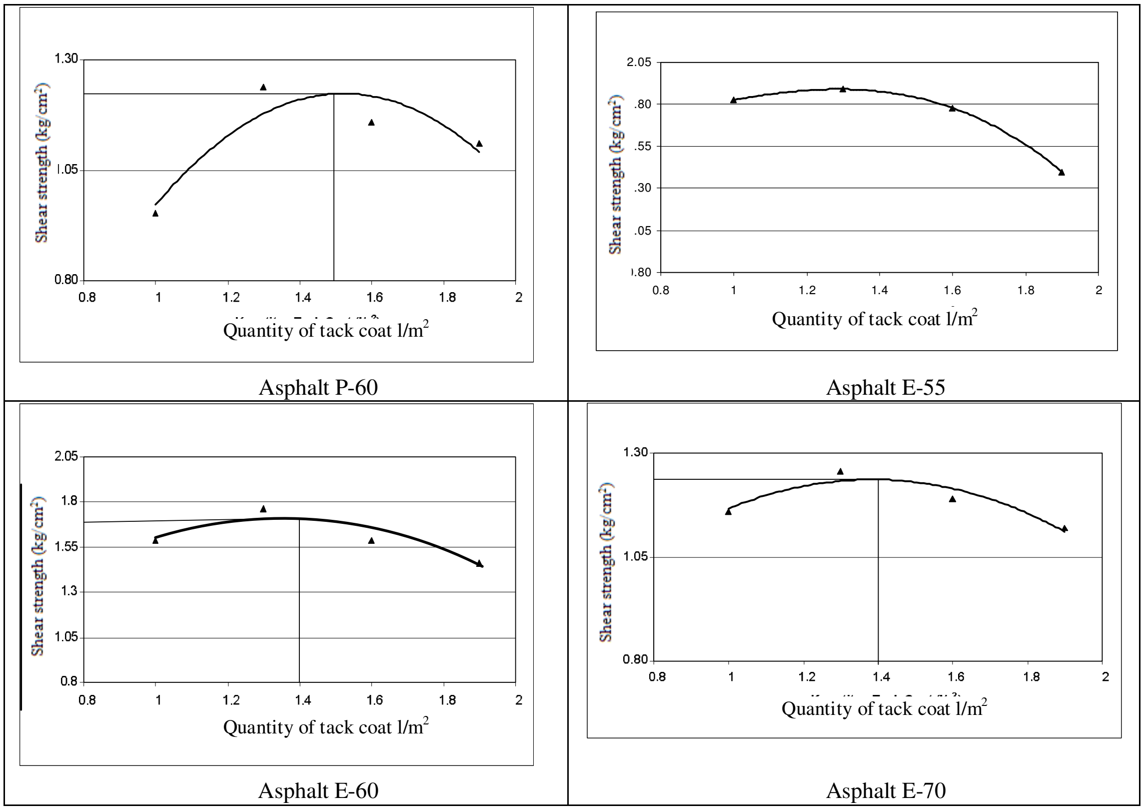


Figure 17 The effect of SAMI-2 for various asphalt types on shear resistance

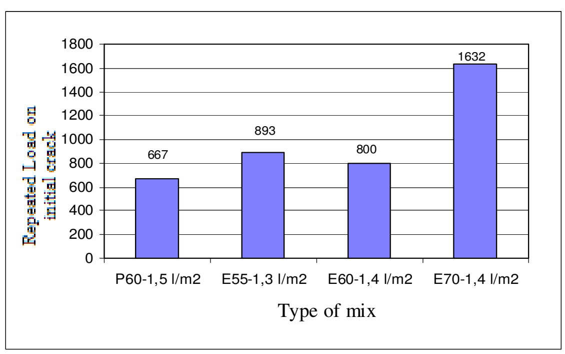


Figure 18 The effect of SAMI-2 on repeated load until occurring reflection crack for optimum Asphalt quantity

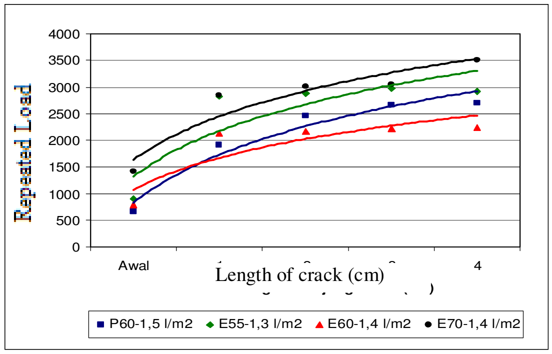


Figure 19 The effect of SAMI-2 on reflection crack propagation for optimum asphalt quantity

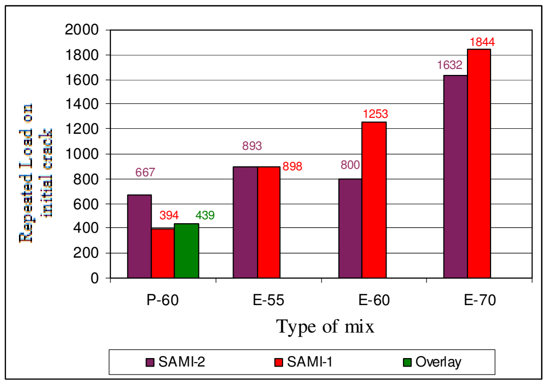


Figure 20 Repeated load until occurring reflection crack for SAMI-1 and SAMI-2 on optimum asphalt compared to conventional mix

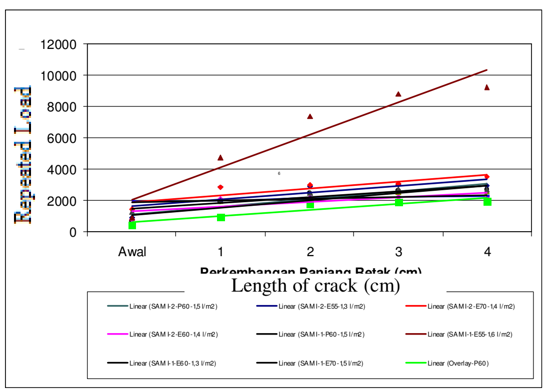


Figure 21 Reflection crack propagation for SAMI-1 and SAMI-2 on optimum asphalt compared to conventional mix

5. CONCLUSIONS

Several conclusions can be taken from this study, i.e:

1. The asphalt used in SAMI that is made by using single chip number 8 (SAMI-1), has function not only as a binder that binds and joins the used chip but also as an early crack tenacity layer if used with that chip (SAMI). The crack can happen on overlay layer as the result of crack reflection from existing layer.

2. The asphalt that is used in SAMI-1 also gives influence to the velocity of reflection crack development happens. For P-60, E-55 and E-60 asphalt, the asphlat quantity in SAMI-1 that gives tenacity to the rate of the highest reflection crack developemnt is 1,6 l/m^2. Whereas for E-70 asphalt is 1,3 l/m^2.
3. The excessive using of asphalt in SAMI also gives negative influence to displacement detention on interface layer.
4. Optimum value of asphalt using that gives displacement detention in SAMI-1, for the asphalt that is used, i.e P-60, E-55, E-60 and E-70 each is a 1,2 l/m^2; 1,6 l/m^2; 1,3 l/m^2 and 1,5 l/m^2.
5. At its optimum asphalt value, the capability of asphalt type E-55 (1,6 l/m^2), E-60 (1,3 l/m^2), and E-70 (1,5 l/m^2) in SAMI-1 that are used as interlayer to retain the number of load repeating until the reflection crack happens on its upper layer is 2,3; 3,2 and 4,7 to the capability of P-60 asphalt (1,2 l/m^2).
6. At its asphalt optimum value , the capability of E-60 (1,3 l/m^2), E-70 (1,5 l/m^2) and P-60 (1,2 l/m^2) asphalts in SAMI-1 that used as interlayer to retain the rate of reflection crack development is relatively similar. E-55 (1,6 l/m^2) asphalt retains the rate of reflection crack development the best of E-60 (1,3 l/m^2), E-70 (1,5 l/m^2) and P-60 (1,2 l/m^2) asphalts.
7. The optimum value of asphalt using that gives displacement detention in SAMI-2 for used asphalt, i.e P-60, E-55, E-60 and E-70 each is 1,5 l/m^2; 1,3 l/m^2; 1,4 l/m^2 dan 1,4 l/m^2.
8. At its optimum asphalt value, the capability of asphalts type E-55 (1,3 l/m^2), E-60 (1,4 l/m^2), and E-70 (1,4 l/m^2), in SAMI-2 that is used as interlayer to retain the number of load repeating until refletion crack starts to happen on upper layer each is 1,3; 1,2 and 2,47 to the capability of P-60 (1,5 l/m^2) asphalt,
9. In SAMI-1 and SAMI-2, the positive influence of interlayer from asphalt quantity used in that SAMI is used as interlayer to retain early reflection crack that happens, is not in line with its capability to block the rate of that crack development.
10. From the aspect of retaining the load repeating until refelection crack happens, SAMI-1 made from E-70 asphalt gives the best result. Whereas SAMI-1 used P-60 asphalt is not recomended to be used for this intention.
11. At optimum asphalt value, the capability of asphalt type E-70 (1,4 l/m^2), E-55 (1,3 l/m^2) and P-60 (1,5 l/m^2) in SAMI-2 that are used as interlayer to retain the rate of reflection crack development at its optimum asphalt value is relatively similar and more superior than in E-60 (1,4 l/m^2). But, the quantitiy of asphalt used by SAMI-2 E-70 (1,4 l/m^2) and SAMI-2 E-55 (1,3 l/m^2) is relatively less than in SAMI-2 P-60 (1,5 l/m^2).
12. From the aspect of retaining the rate of reflection crack development SAMI-1 made from E-55 asphalt gives the best result. Whereas SAMI-1 used E-60 and E-70 is not recomended to be used for this intention.

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