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THE INFLUENCE OF FIBER ON THE CHANGES OF MICRO STRUCTURE OF POROUS CONCRETE ASPHALT MIXTURE

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***Abstract*—The use of additional material such as fibers in concrete asphalt mixture may affect the micro structure of the mixture. The micro-structural change is identifiable by the existence of various sub-atomic particles. In general, the study aims to investigate the effect of fibers addition on the micro-structural atomic changes in porous concrete asphalt mixture with asphalt material of oil-based (penetration of 60/70) and of polymer asphalt stabilised with *polypropylene*. The study was carried out by performing a test on samples by means of XRD (*X-ray diffraction*) and SEM (*scanning electron microscope*). The study shows that the petroleum-based asphalt pen 60/70 has compound elements of Carbon (C_{70}), Cyclo-octasulphur monoxide (S_8O) and Cristobalite beta (S_iO_2), while the petroleum-based asphalt pen 60/70 enhanced with polypropylene fibers has compound elements of Carbon (C_{70}), Cyclo-tris(suphur VI)oxide with chemical formula of SO_3, Cristobalite beta (SiO_2), and Carpathite compound $C_{24}H_{12}$. The polymer asphalt added with polypropylene fibers has compound elements of Octacarbon (C_8), S_iO_2, Sulphur trioxide SO_3 and D-Tartaric acid hydrateC_4 H_6O_6. SEM test result of porous concrete asphalt indicates that the existence of pores functioning to drain water through the concrete mixture. The study concludes that there is a difference of compound elements in the petroleum-based asphalt pen. 60/70 added with fibers i.e. Carpathite $C_{24}H_{12}$ while in polymer asphalt added with fibers, there are compounds of D-tartaric acid hydrate C_4 H_6 O_6 with different compositions. Porous petroleum-based concrete asphalt mixture and polymer asphalt added with fibers have a better distribution and bonds among pores.**

***Keywords*— porous concrete asphalt, fiber, micro-structure**

I. Introduction

Pavement construction of porous asphalt concrete mixture is one of the alternatives of flexible pavement in order to provide flexibility for water to penetrate into the surface layer of the road. Open gradation provides tolerance in each size and amount of stone so as to result in pores and better flexibility of asphalt concrete (Suhartono, 2010). *National Asphalt Pavement Association (NAPA)* in 2003 had promoted *Open Graded Friction Course (OGFC)* as a new generation of flexible pavement.

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The problem with porous concrete asphalt pavement mixture of open gradation lies in the structural value of the pavement, for instance, low stability value when compared with pavement of close gradation. An effort to increase pavement strength of porous concrete asphalt mixture is mandatory and one of them is fiber stabilisation in the mixture of porous concrete asphalt. The type and size of fiber have to be modifiable to improve the stability of the mixture. The fiber material for the road pavement is thought by several researchers to be capable of improving the pavement performance. Jiang *et. al* conducted a study in 1993 insisted that *polypropylene* fiber was capable of reducing reflection cracking in asphalt pavement that the type of such fiber can be used in porous concrete asphalt mixture. Fiber addition in the asphalt material will influence the performance of micro-structure of the mixture as marked by the existence of element differences in the atomic elements.

II. The Objectives of The Study

The study is devoted to investigating the effect of fiber addition on the changes of atomic micro-structure of porous concrete asphalt mixture with petroleum-based asphalt (penetration 60/70) and polymer asphalt stabilised with *polypropylene fiber*.

III. Literature Review

A. *Micro-structural Test of Porous Asphalt Mixture*

1) *Scanning Electrone Microscope (SEM)*

To describe the porous concrete asphalt mixture in its micro-form, *scanning electron microscope* (SEM) needs to be performed. SEM is an electron gun producing electron beam at a fastened voltage between 2 to 30 kV. Such electron beams are passed through several electromagnetic lenses to produce images with a size of <~10nm on the sample shown in the form of photographical film or inserted into screen tube (Trewin, 1988). SEM fits for the situation in which coarse surface observation is needed with enlargements of 20 to 500,000 times. Before passing through the last electromagnetic lense, *scanning raster* deflects the electron beam to scan the sample surface. This scan result is synchronised with cathode ray tube and the sample image will appear on the scanned area. The contrast rate appearing on the cathode ray tube is visible due to the various reflection results of the sample. When the electron beam hit the surface of the sample, a number of electrons were reflected as *backscattered* *electrons* (BSE) and the rest released lower energy *secondary electron* (SE) (Nuha, D.N, 2008).

2) *X-Ray Diffraction*

Spectroscopy of X-ray (*X-ray diffraction/XRD*) is one method to characterise the materials to be used e.g. to identify the crystalline phase in material by determining the parameter of lattice structure and to obtain the particle size. The main components of XRD are cathode tube (a means to produce X-ray), sample holder, and detector. XRD provides data on diffraction and on quantification of diffraction intensity of the material angle. The data obtained through XRD are the intensity of X-ray diffraction and angles of 2ϴ. Every pattern that appears on the XRD pattern represents one crystal field having a certain orientation (Faansir, et.al., 2013). The measurement result using *X-ray Diffraction Instrument* are diffractogram graphs. They are the output in the form of graphs *diffraction angle* on X axis versus intensity on Y axis is a transitional angle between incoming rays and the reflecting ones. Meanwhile, the intensity is the total of X-rays diffracted by the crystal gratings. These crystal gratings would depend on the crystal it self. The gratings are formed by the crystal forming atoms. If no atom composes a crystal area, the incoming X-ray can not be diffracted or in other words there is no grating. From the diffraction pattern of crystal compaction analysed by XRD, several other types of information will be obtained such as used X-ray wavelength (λ), refraction order/intensity strength (n), and the angle between incoming rays and normal field (ϴ) , (XRD online, 2011).

IV. The Study Result

A. *Micro structure analysis with XRD*

To clearly identify the elements or atomic compounds of the asphalt used in the study, XRD test is performed.

1) *Micro Test Result of Petroleum-based Asphalt pen. 60/70*

Atomic particle composer of petroleum asphalt in general can be seen in Figure 1.

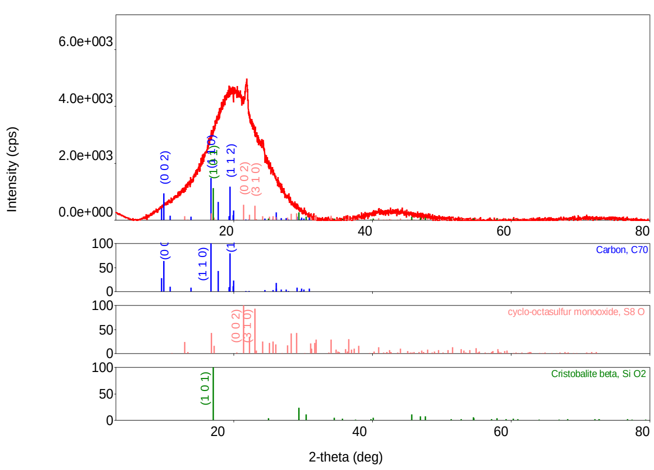


Figure 1. Atomic Composing Element Intensity of Petroleum-based Asphalt (Petroleum-based)

Figure 1 shows the compound elements which compose the petroleum-based asphalt: Carbon (C_{70}), Cyclo-octasulphur monoxide (S_8O), Cristobelite beta (S_iO_2) or expressed in compound formula C_{70} + S_8O + S_iO_2. The composition of petroleum-based asphalt in quantity can be seen in Table 1 with C = 66%, Cyclooctasulphur monoxide = 23-24%, and Cristobalite beta = 10 – 11%.

Table 1. The Composition of Petroleum-based Asphalt Elements

Phase name	Content(%)
Carbon	66(112)
cyclo- ctasulfurmonooxide	24(19)
Cristobalite beta	11(10)

2) *Micro Test Result of Petroleum-based asphalt + Polypropylene Fiber*

Composing atoms of petroleum-based asphalt added with 1% *polypropylene fiber* can be seen in Figure 2.

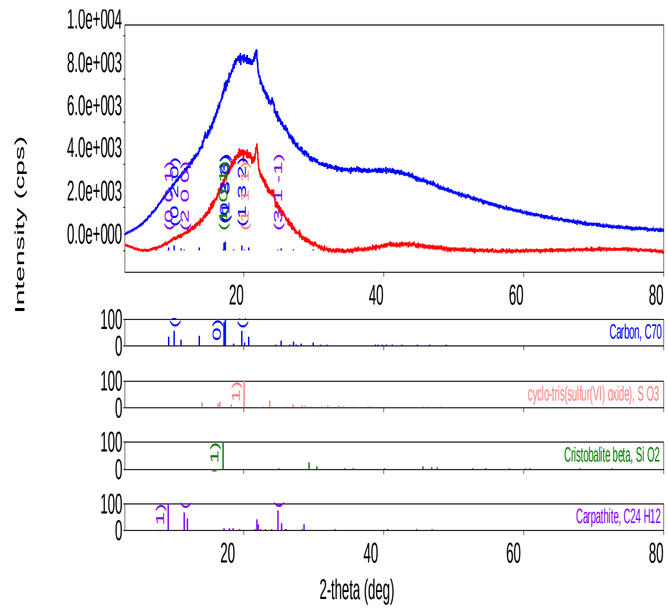


Figure 2. The Intensity of Atomic Composing Element of Petroleum-based Asphalt + Fiber

Figure 2 shows the intensity of the elements of petroleum-based asphalt + fiber. It indicates compound elements which are different with those of petroleum based asphalt without fiber. The elements identified in this kind of asphalt are Carbon (C_{70}), Cyclo-trissulphur (VI) oxide (SO_3), Cristobalite beta (S_iO_2) and Carpathite compound ($C_{24}H_{12}$). The compositions of the elements that compose the petroleum-based asphalt with added fiber are C_{70} = 92%, SO_3 = 2.12%, S_iO_2 =1.07% and $C_{24}H_{12}$ = 5.2% as seen in the following table:

Table 2. The Composition of the Elements of Petroleum-based Asphalt + Fiber

Phase name	Content(%)
Carbon	92(15)
Cyclo-tris(sulfur (VI) oxide)	2.12(17)
Cristobalite beta	1.07(8)
Carpathite	5.2(4)

3) *Micro Test Result of Polymer Asphalt (PA)*

Atomic elements or the compound of the polymer asphalt composer in general can be seen in Figure 3.

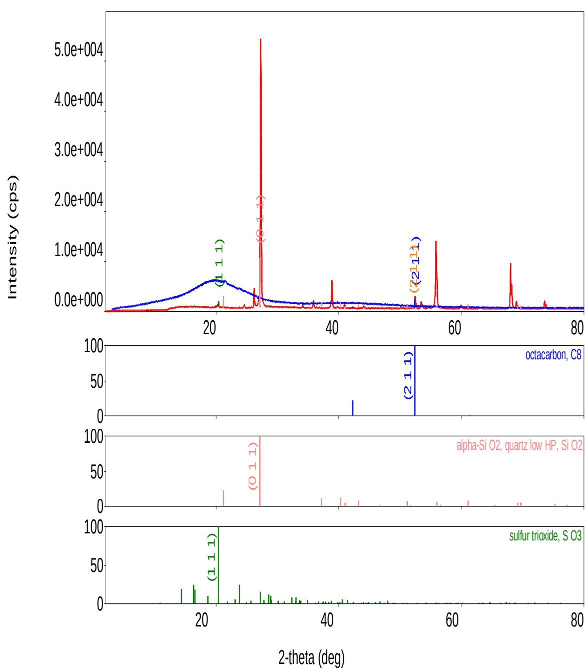


Figure 3. The Intensity of Atomic Element Composer Polymer Asphalt (PA)

Figure 3 shows the result of XRD test on the polymer asphalt (PA) sample. It reveals the elements of Octacarbon (C_8), alpha- S_iO_2, Sulphur trioxide SO_3 in that type of asphalt. The molecular formula of the compound is $\mathbf{C_8 + SO_3 + S_iO_2}$. The element composition of polymer asphalt in quantity can be seen in Table 3 with Octacarbon (C_8) = 26.70%, alpha-S_iO_2 = 36%, and Sulphur trioxide SO_3 = 37%.

Table 3. Element Composition of Polymer Asphalt

Phase name	Content(%)
octacarbon	26.7(3)
alpha-Si O2, quartz low HP	36.0(14)
sulfur trioxide	37(3)

4) *Micro Test Result of Polymer Asphalt (PA) + Fiber*

The atoms that compose the polymer asphalt added with *polypropylene* fibers can be seen in Figure 4. XRD test on the sample of polymer asphalt with fiber reveals the elements existing in the mixture: Octacarbon (C_8), S_iO_2, Sulphur trioxide SO_3 and Tartaric acid hydrate $C_4 H_6 O_6$.

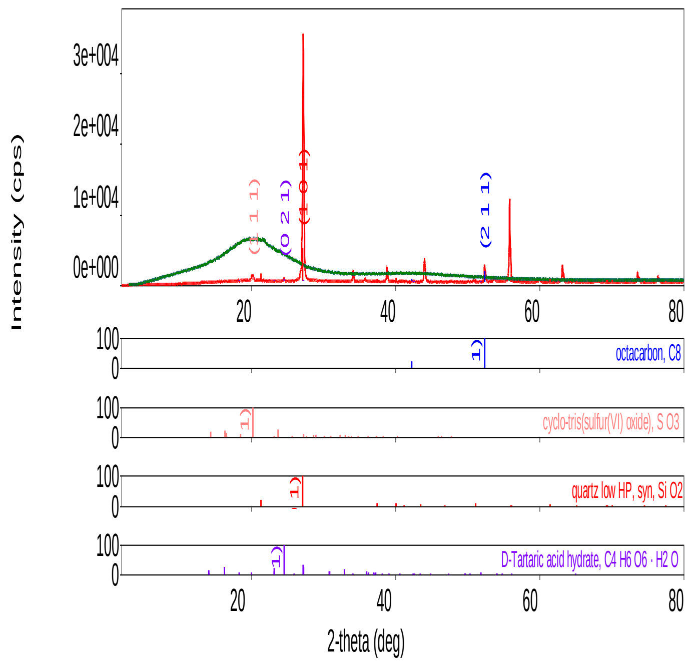


Figure 4. The Intensity of Atomic Elements of Polymer Asphalt + Fibers

Quantitatively, the element composition of polymer asphalt with added fiber can be seen in Table 4: Octacarbon (C_8) = 35%, alpha-S_iO_2 = 58%, Sulphur trioxide SO_3 = 3%, and Tartaric acid hydrate $C_4 H_6 O_6$ = 4%.

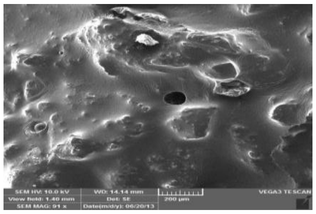
Table 4. The Composition of Polymer Asphalt with Fiber

Phase name	Content(%)
octacarbon	35(8)
cyclo-tris(sulfur(VI) oxide)	3(5)
quartz low HP, syn	58(6)
D-Tartaric acid hydrate	4(3)

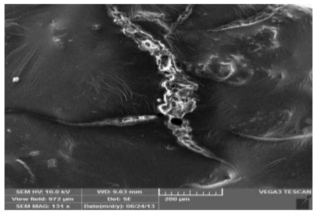
B. *Micro-structure Analysis with SEM Test*

Scanning Electron Microscopy (SEM) has a higher resolution than light. Light only reaches 200 nm while electron may reach 0.1 to 0.2 nm. The micro-structure of porous asphalt mixture can be seen through a testing device *Scanning Electron Microscope* (SEM) focussing on the sample of asphalt mixture on a surface area. From the observation made in the laboratory, several images connected to mixture pores were taken as seen in Figure 5:

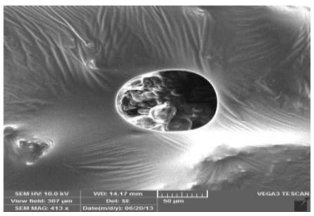
1) *The Comparison of SEM Pictures of Porous Concrete Asphalt between Petroleum-based Asphalt and Petroleum-based Asphalt + Fiber*



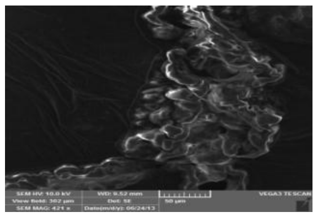
Petroleum Asphalt1



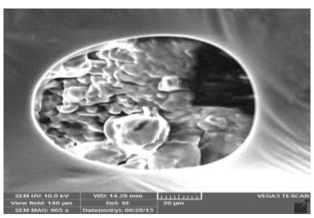
Petroleum Asphalt + Fiber 1



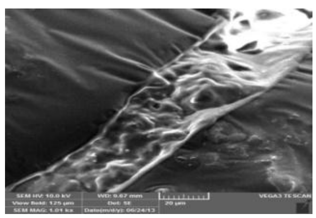
Petroleum Asphalt 2



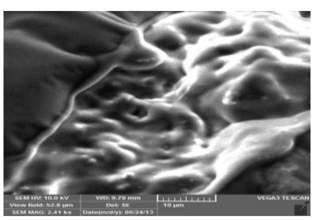
Petroleum Asphalt + Fiber 2



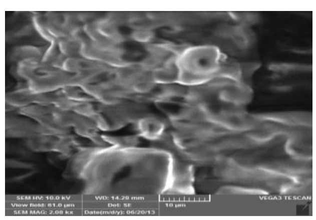
Petroleum Asphalt 3



Petroleum Asphalt + Fiber 3



Petroleum Asphalt 4



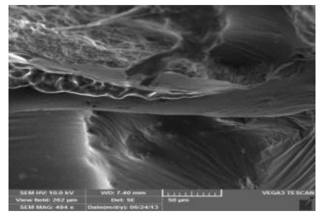
Petroleum Asphalt + Fiber 4

Figure 5. SEM Test Result of Porous Concrete Asphalt Mixtures of Petroleum-based Asphalt (1 to 4) and Petroleum-based Asphalt with Fiber (1 to 4).

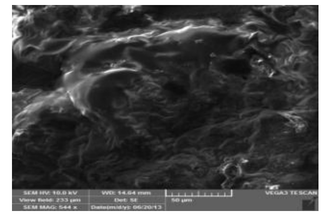
In Figure 5, the enlargement with a scale of 200 um of petroleum-based asphalt and petroleum-based asphalt with fiber clearly shows pores on both mixtures from the surface. The pictures of petroleum-based 1 and 2 show asphalt covering the whole surface with pores formed without link to other pores in the surface of the mixture while the pictures of petroleum asphalt with fiber 1 and 2 the pores formed in the mixture have links with other pores indicating that the fibers added to the mixture provide better ties among pores. When enlargement on scales of 10 um were made on both petroleum-based mixture and petroleum-based with fiber mixture, a lot of pores are visible in micro on the mixture implying that there are many pores that would allow water to pass through the mixture in the surface.

2) *The Comparison of SEM Images of Porous Asphalt between Polymer Asphalt (PA) and Polymer Asphalt with Fiber (PAF)*

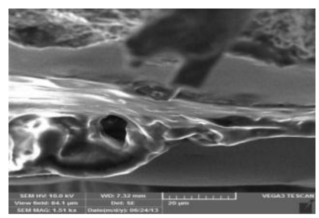
The micro-structure in porous asphalt mixture using pure polymer asphalt and polymer asphalt with fiber can be seen in Figure 6.



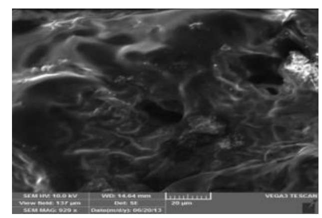
Polymer Asphalt
(PA – 1)



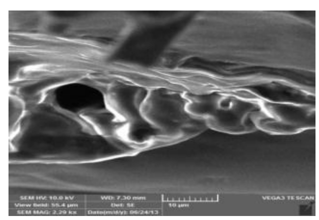
Polymer Asphalt with Fiber
(PAF – 1)



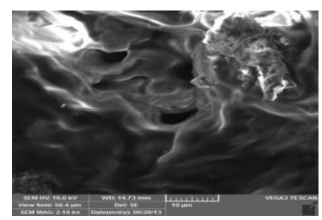
Polymer Asphalt
(PA – 2)



Polymer Asphalt with Fiber
(PAF – 2)



Polymer Asphalt
(PA – 3)



Polymer Asphalt with Fiber
(PAF – 3)

Figure 6. SEM Test Result of Porous Concrete Asphalt Mixture of Polymer Asphalt (PA 1 to 3) and Polymer Asphalt with Fiber (PAF 1 to 3)

Figure 6 shows the formation of air cavities or pores in the polymer asphalt (PA) and polymer asphalt with fiber mixtures. On 20 um enlargement, PA 2 and PAF 2 figures display several pores connected to each other. On the mixtures of PA-3 and PAF-3 are visible the pore ties evenly distributed in the mixture but PAF-3 have more pores and ties that they will be more effective in allowing water to pass through the mixture.

V. Conclusions

Based on the result of the study, it can be concluded that:

1. *Polypropylene* fiber provides changes to the micro-structure of the petroleum-based asphalt pen. 60/70, polymer asphalt, and porous concrete asphalt mixture.
2. There are differences in compound elements of petroleum-based asphalt pen. 60/70 added with fiber which is Carpatithe $C_{24}H_{12}$ while in Polymer Asphalt added with fiber there is D-Tartaric acid hydrate $C_4H_6O_6$ with different compositions.
3. Based on the observation by means of SEM test, it can be stated that the porous concrete asphalt mixture with open gradation based on its micro-structure has pores or air cavities in it.
4. Porous concrete asphalt mixture of petroleum-based asphalt and polymer asphalt added both with fiber have better distribution of and link among pores.

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