Mechanical properties of asphalt mixed with EM

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1. Introduction

This study focused on the antioxidant effect of Effective Microorganisms (EM) on organic asphalt Two types of bitumen materials (asphalt emulsion and asphalt) mixed with 4 different types of EM (5% by weight) were studied, and the mechanical properties, particularly degradation characteristics at high temperature were examined. The breaking points which are directly related to the mechanical properties of asphalt pavement were examined through the Fraass breaking point, Moriyoshi breaking point and flexural bending test to assess the stress and strain at breaking point of asphalt. The experiments studying the degradation characteristics were performed through the comparison of the stress and strain at break point. The asphalt is considered chemically stable when the degradation characteristics change little with the break points. Also the asphalt is considered more stable when it has a higher stress and higher strain at breaking point at the same temperature. In general, the breaking point of asphalt is 26 ℃ lower than that of asphalt mixture (pavement). For pavement at temperatures lower than breaking point (asphalt breaking point 26 ℃), cracks may occur, while flow is dominant at a higher temperature. It has been determined that when the breaking point of the mixture changes by 2-3 ℃, cracks or rutting may occur.

2. Materials used

The following two types of asphalt was used.

1. Straight asphalt
   Penetration 80/100 grade, manufactured by Showa Shell Petroleum
2. Asphalt emulsion
   PK, Toa Douro Corporation

Straight asphalt is a representative asphalt used in Japan as a binder material for conventional heated asphalt pavement. On the other hand, asphalt emulsion is used in dust-proof processing and as a penetration to the internal of the granular base course layer. The former is used at high temperature, at which its anti-oxidant effects are high, whereas the latter's anti-oxidant effects are significant at room temperature.

The types of EM added to asphalt and asphalt emulsion are listed below, the added amount being 5% by weight:

1. EM-1
2. EM-3
3. EM-X
4. EM ceramics

3. Equipment used

Equipment used for the experiments are as follow:

1) Fraass breaking point test

Fraass breaking point test is as follows:
The test sample was a special steel sheet measuring width 2 cm, length 4 cm, and thickness 0.1 mm was evenly coated with 0.4 g of asphalt, to a homogeneous thickness of 0.5 mm. The sample was set on the Fraass breaking point apparatus in a constant temperature methanol bath, and bent at a constant speed and its destructability was checked. If the sample did not break it was returned to its original length, and the methanol bath temperature was lowered by 1°C. This procedure was repeated until the sample failed, and the temperature at which this happened was termed its Fraass breaking point. The test was repeated 3 times and an average was calculated.

The normal accuracy of this test is ±3-4 ℃, for the machine carried out in this study the error is ±1℃, for all asphalt.

2) Moriyoshi breaking point test

Two special stainless steel plates of diameter 14 cm, height 1 cm and thickness 1 mm were prepared. For each plate 50 g of asphalt homogeneously coated to the same thickness. They were incubated in a room at 45°C for 30 min. Both plates were submerged in a methanol bath at a constant low temperature for 1 min. After they were removed from the bath, they were visually inspected for cracks on the surface. When no cracks occurred, the plates were re-incubated at 45°C for 30 min, and re submerged in the methanol bath at a temperature 1°C lower than previously. The procedure was repeated until cracks appear. Were the breaking points of both plates to differ by more than 2°C, the experiment will be disregarded and started over. The temperature at which the plates show failure is termed the Moriyoshi Breaking Point. The accuracy of this apparatus is ±1°C for all asphalts. In this experiment, a thin film may occur on the surface of the thin film-heated asphalt. It is possible to accurately assess the effects of this thin film. However, in the conventional test methods, the asphalt must be removed for testing unless it is heated and remixed, and such an evaluation of the thin film is impossible.

3) Oxidation test, carried out as below:

① Thin film heating test
In a special stainless steel plate of diameter 14 cm, height 1 cm and thickness 1 mm, 50 g of asphalt was added. The sample was placed in a heated room at 163°C for 5 hours, while kept in rotation horizontally. This is a common method to study the degradation characteristics of asphalt.
It is said that this degradation test reproduces the conditions asphalt is exposed to during mixing at high temperature.

② Ultraviolet degradation test
This test was originally developed in our laboratory. The sample for determining Fraass breaking point was prepared, and subjected to ultraviolet irradiation of 700 W/m^2 output for 48 hours. The Fraass breaking point (degradation characteristics) due to ultraviolet radiation was thus determined for the sample. A special feature of this experiment is the extreme thinness of the sample, at 0.5 mm, to ensure deterioration to the internal of the asphalt. In traditional methods using ultraviolet degradation, samples were subjected to varying wavelengths of the infra-red (IR) absorption spectrum, in an IR spectrometer. However, as the IR methods cannot be performed for mechanical tests, the UV degradation tests were performed instead.

4. Experimental results and discussion

1) Fraass breaking point

As shown in Table 1, Fraass breaking point (FBP) due to the addition of various EM bituminous material.

Table 1. Fraass breaking point of original asphalt (℃).

	Sample 1	Sample 2	Sample 3	Average
Straight asphalt	-14	-13	-13	-13
Straight asphalt +EM-1	-12	-12	-13	-12
Asphalt emulsion	-14	-13	-13	-13
Asphalt emulsion + EM-1	-11	-11	-12	-11

The Fraass breaking point of asphalt emulsion tends to be somewhat higher than that of heating asphalt. There was one sample (asphalt emulsion with no added EM) that achieved an extremely low -18^{o}C, although in overall it appears that there was no effect from the addition of EM. But even if the results are slightly higher, it is believed to be due to the anti-oxidation effects of asphalt emulsion than EM addition, in the case of Fraass breaking point.

Table 2. Heat deterioration (FBP) due to addition in EM in various bituminous material

	Original (A)	TFOT (B)	(B)-(A)	UV (C)	(C)-(A)	(C)-(B)
Straight asphalt	-13	-10	3	-10	3	0
+ EM-3	-11	-8	3	-8	3	0
+ EM-X	-10	-9	1	-11	-1	-2
+ EM ceramics	-11	-9	2	-9	2	0
Asphalt emulsion	-14	-12	2	-9	5	3
+ EM-3	-14	-11	3	4	18	15
+ EM-X	-14	-10	4	5	19	15
+ EM ceramics	-14	-9	5	-8	6	1

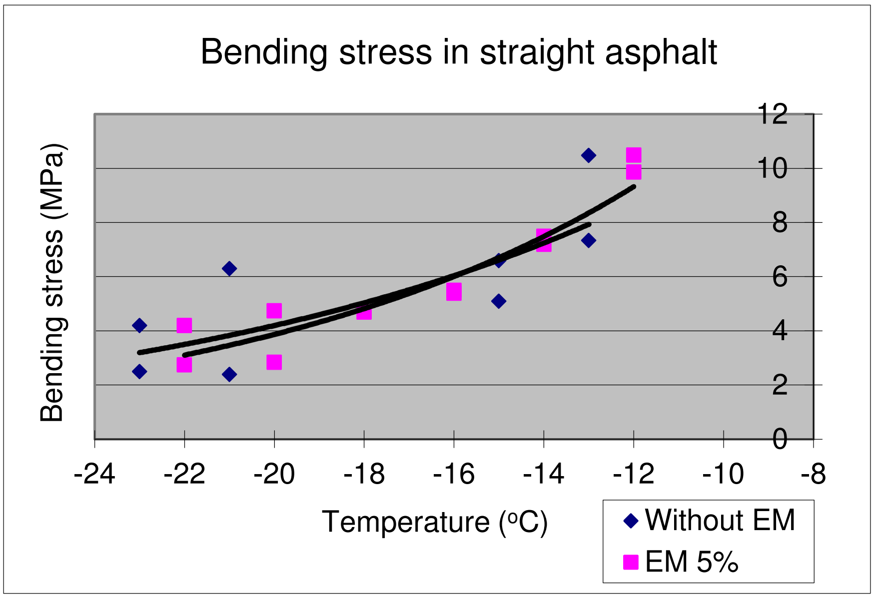
In Table 2, the addition of ceramics-type EM to straight asphalt significantly suppressed the rise of breaking points, due probably to the anti-oxidation action. It can be said that there is an effect when considering the fact that the occurrence of cracks on asphalt pavement was determined by a temperature difference of 2-3^{o}C, and that the rise of the breaking points caused asphalt to become hard and cracks to appear easily.

2) Bending test

Figure 1 shows the stress vs temperature curve of the asphalt and asphalt emulsion obtained from the bending test. Figure 2 shows the strain (at break) vs temperature curve of asphalt and asphalt emulsion. From the two curves, the breaking stress did not appear to be affected by the addition of EM-1 in asphalt, although the addition of EM-1 to asphalt emulsion shows a trend of increasing stress at low temperatures. On the other hand, the difference in breaking strain due to EM-1 addition was not apparent in both asphalt and asphalt emulsion. However, there is a tendency for the strain to drop slightly when EM-1 was added to asphalt at higher temperature. Taken together, although the stress was increased when EM-1 was added to asphalt emulsion, the breaking strain remained unchanged, indicating an increase in the modulus of elasticity and that the asphalt emulsion has become brittle slightly.

Compared to this, when EM-1 was added to asphalt, due to the slight decrease in the breaking strain at high temperature, the modulus of elasticity increased slightly. But since the change was not large, there appears to be no change in the asphalt's properties upon mixing (at 130°C).

Figure 1 Bending stress vs temperature curves for different asphalts mixed with EM.



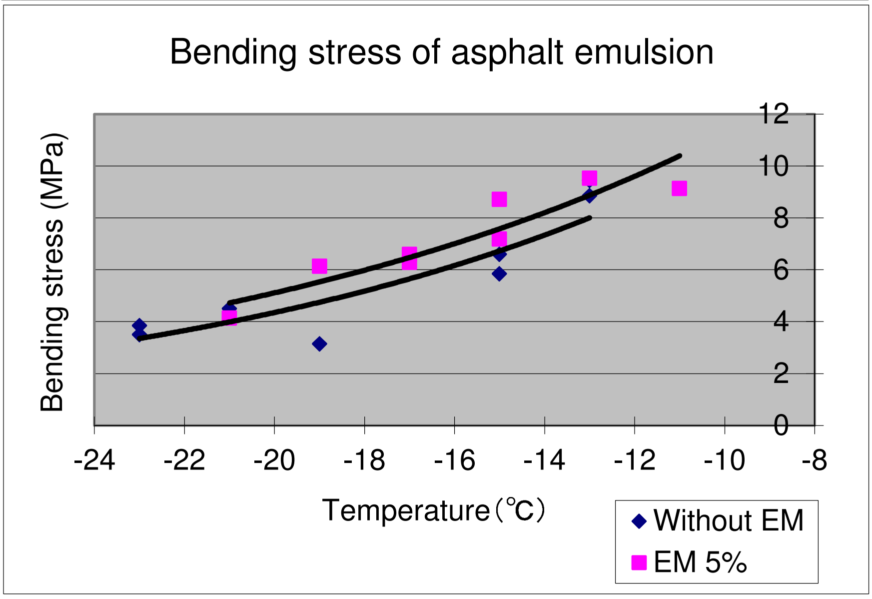
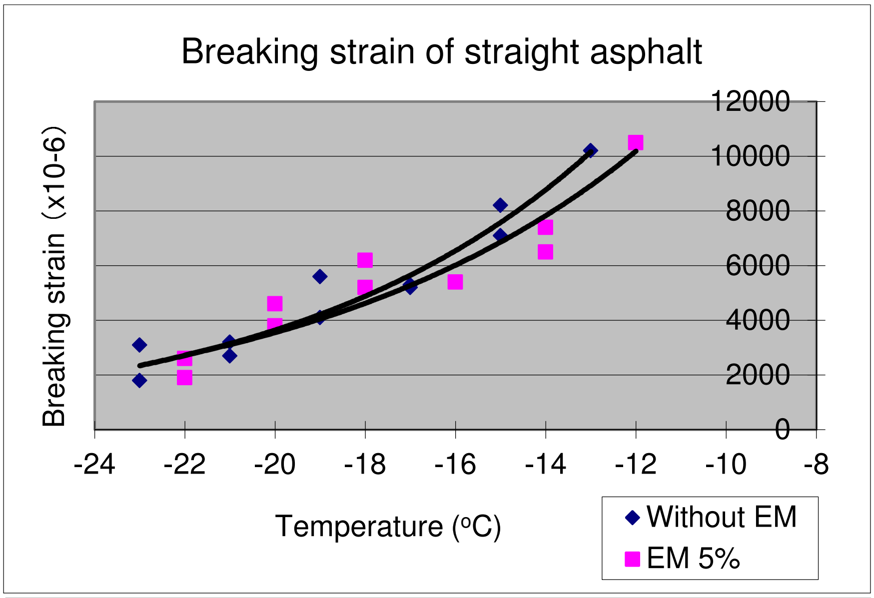
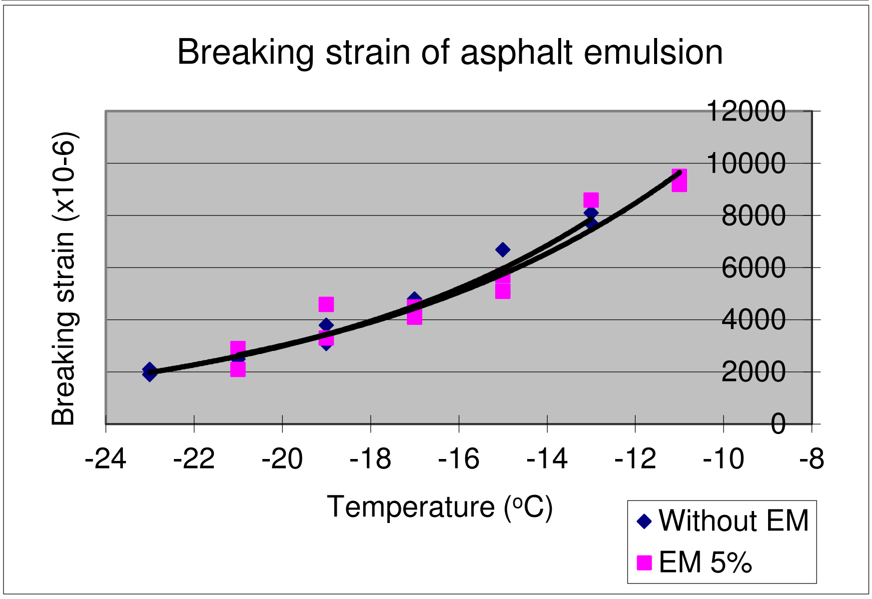


Figure 2 breaking strain vs temperature curves in for different asphalts mixed with EM.





5 . Conclusion

From the above experiment , the following conclusions were obtained:

1) There was almost no change in asphalt property when EM-1 was added to heating asphalt.

2) When EM-1 was added to asphalt emulsion, the breaking stress increased. As the modulus of elasticity at breaking also increased, the asphalt became brittle.

3) The effects on the Fraass breaking point by the addition of EM-1 could not be ascertained.

4) There is less variation in the strain than stress.

5) Should there be any effect from the addition of EM-1, it is expected to occur as changes in the property of asphalt after thin film heating.

Future experiments on the addition of EM-1 to heating asphalts should involve the study of their effects on dynamic properties of the thin film before and after heating. Also, it is recommended to clarify that the asphalt properties remain the same when asphalt are converted to asphalt pavement. The analysis of cracking and rutting phenomena in asphalt pavement is very important for determining the usefulness of EM addition.