EVALUATION OF HOT MIX ASPHALT WITH HIGH DURABILITY

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ABSTRACT

Straight-run asphalt has been used as a main binder for asphalt pavement in Japan. The Hot Mix Asphalt using polymer modified binder (MII-HMA) has set up to resist severe rutting with increasing heavy traffic and development of economic activity. Severe rutting has been still one of the problems, and then solutions including epoxy asphalt are proposed. Epoxy-containing Hot Mix Asphalt (E-HMA) was developed for the heavy traffic place. E-HMA have higher rutting resistance than asphalt pavement of polymer modified binder (PMB) but workers at asphalt plants are sometimes poisoned by epoxy resin. Therefore, the authors developed polyester additive that can solve the problem of workers safely using high performance E-HMA.

In this study, we carried out laboratory tests and field constructions to evaluate the performance of polyester-containing Hot Mix Asphalt (P-HMA). From the results of laboratory tests and field constructions, P-HMA is confirmed that this has higher performance than MII-HMA and has the equivalent performance of E-HMA. Therefore, it is considered that P-HMA can be applied to the similar construction sites for E-HMA, and this should be one of the solutions for the deteriorated sites paved with MII-HMA.

1. INTRODUTION

Hot Mix Asphalt using polymer modified binder (MII-HMA) has been generally used at highways and national roads that traffic is high volume and/or the logistics parking lots in Japan. However, MII-HMA has problems of severe rutting due to increasing heavy traffic volume accompanying the development of economic activity, and increase of cargo quantity in the logistics parking lots. Then, the authors developed epoxy-containing Hot Mix Asphalt (E-HMA) as a countermeasure against severe rutting. The E-HMA has high performance against mixture rutting, stripping, cracking and deflection. Therefore, the E-HMA has been used for high volume traffic roads and/or logistics parking lots. The epoxy resin used in E-HMA is a solid type and it is an oil resin composed of base resin and curing agent, and melts in high temperature environment. Also, when manufacturing E-HMA at the plant, workers throw the epoxy resin into a mixer. Then, E-HMA has problems that the epoxy must be put in the refrigerator with inventory below 20℃, and workers are sometimes poisoned by epoxy resin when manufacturing E-HMA at the plants. Then it is required to develop new materials for workers' safety and manageable materials.

The authors developed polyester as new material. It is safer and easier to handle than epoxy. It is expected that polyester-containing Hot Mix Asphalt (P-HMA) has high pavement performance. So, it is considered that has high performance as mixture rutting resistance, moisture-susceptibility, flexible deflection resistance, static load resistance.

The performance of P-HMA evaluate in this paper by comparing with E-HMA and MII-HMA through laboratory tests and field constructions.

2. BRIEF DESCRIPTION OF DEVELOPED POLYESTER ADDITIVE

The Picture-1 shows a condition of polyester. Polyester has high molecules, and it is composed of two kinds of molecules; average molecular weight (M_n) 3,800 and weight average molecular weight (M_w) 13,000.

The polyester's characteristics are powder type with particle size of 1~2mm, glass-transition temperature (Tg) is 57.8℃ and melting point (Tn) is 103.6℃. This is hardened after paving because this is a thermoplastic resin.

Picture-1 Polyester

3. LABORATORY TEST

Table-1 shows the evaluated mixtures. The performance of developed P-HMA is evaluated and compared by using other two kinds of binders.

Table-1　Evaluated Mixtures

Mixtures type		Note
A	・Hot mix asphalt using polyester (P-HMA)	—
B	・Hot mix asphalt using polymer-modified Ⅱtype (MⅡ-HMA)	Comparison Mixture 1
C	・Hot mix asphalt using epoxy (E-HMA)	Comparison Mixture 2

3.1. Test outline

3.1.1. *HWT test*

Rutting resistance has been generally evaluated using a wheel tracking test which was originally developed by Transport Research Laboratory (TRL) in Japan. The wheel tracking test is executed at a temperature of 60℃ and on the dry condition only.

However, in this study, rutting resistance and moisture-susceptibility are evaluated with HWT test as Picture-2 shows. The HWT test is carried out according to AASHTO T324-04 [1], and the test temperature is set at 60℃. This test was carried out using specimens with a diameter of 15cm, a thickness of 6cm, and air void 7% compacted using Superpave Gyratory Compactor. The HWT test condition is listed in the Table-2. Results of HWT test are evaluated by rutting depth at the travel completion of 10,000 cycles and stripping inflection point (SIP). Moreover, rutting resistance index (RRI) is applied to evaluate characteristic of rutting resistance and moisture-susceptibility resistance of each mixture in this study. RRI is showed in Equation 1 [2].

Picture-2 HWT test

Table-2 HWT test condition

Wheel load (N)	Travel speed (cycle/min)	Completion travel (cycle)	Temperature (℃)	Air voids of specimen (%)	Condition	Tire
705	25	10,000	60	7	Dry and Water	Stainless steel

$RRI = N \times (1 - RD)$ · Equation 1.

Where,

RRI : rutting resistance Index

RD : rut depth at completion of the test in, inch. The *RD* is typically less than 1inch.

N : number of cycles at completion of the test. The maximum *N* is 10,000 cycles in the test.

3.1.2. *Bending test*

To evaluate the cracking resistance at low temperature, the bending test [3] has been conducted in japan. The bending test uses specimens as Figure-1 shows. 30cm×30cm×5cm size of specimens is prepared first, and this is cut into 4 parts as Figure-1. Then two 30cm×10cm×5cm size of specimens are used for the bending test. The test is done after curing at chamber temperature of -10℃ for more than 6 hours. Loading speed is 50mm/min. Notion of the bending test show in Figure-2.

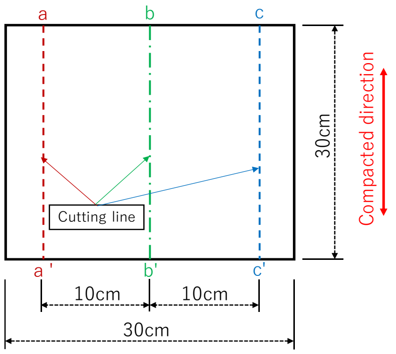


Figure-1 Cutting method of specimen

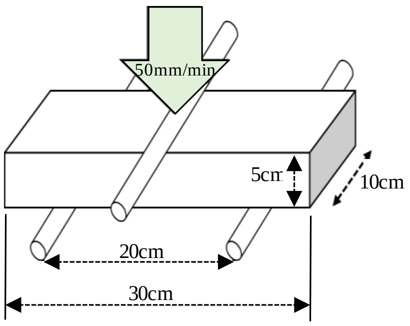


Figure-2 Notion of bending test

From test results, the load and the deformation at the time of breaking are obtained. And the bending strength and strain at break can be got from Equation 2. and 3. with reference to Figure-3.

σ (Pa) = $(3l/(2bh^2)) \times P$ · · · · Equation 2.

ε (mm/mm) = $(6h/l^2) \times d$ · · · · Equation 3.

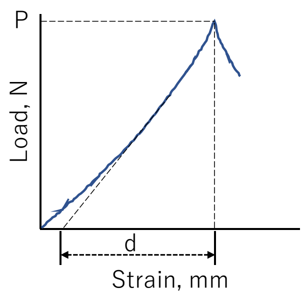


Figure-3 Example of load-strain curve

Where σ is the bending strength of when breaking, *b* is the width of specimen (mm), ε is strain of when breaking, *h* is the thickness of specimen (mm), *l* is distance between supporting points (mm), *P* is the load when breaking (N), *d* is the center deformation of when breaking (mm)

3.1.3. *Bending Creep test*

In order to evaluate the static loading resistance of the asphalt concrete mixture, a bending creep test was carried out. Applied load is 1/10 of the bending strength, and the constant load is maintained until specimen breaks. The specimens are evaluated by time and deformation amount to specimen broke. Figure-4 is conceptual of bending creep test, and Table-3 shows conditions of the bending creep test.

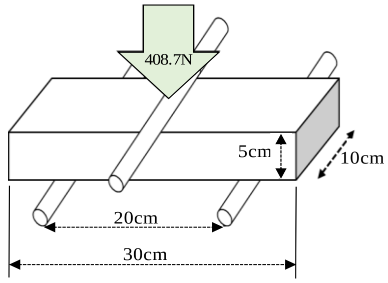


Figure-4 Conceptual bending creep test

Table-3 Conditions of bending creep test

Bending Strength (MPa)	Occured Stress (MPa)	Span *L* (cm)	Specimen thickness *h* (cm)	Specimen width *b* (cm)	Loaded load *P* (N)	Test temperature(℃)
5	0.5	20	5	10	408.7	20

3.1.4. *Oil resistance test*

Figure-5 shows oil resistance test. The specimens for the Marshall stability test are prepared. The test specimens for this test have 3 specimens per mixtures. These specimens are immersed into gasoline at 20℃ for 48 hours and these specimens are immersed into water at 60℃ for 30 minutes. Finally Marshall stability test [4] is carried out.

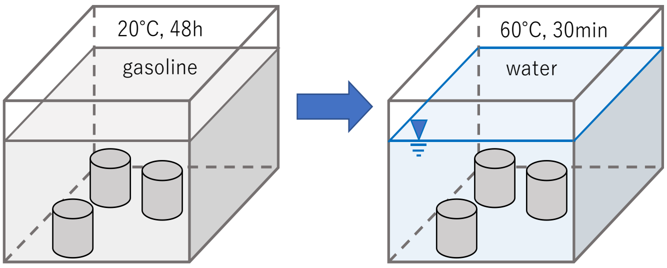


Figure-5 Oil-resistance test

3.2. Test results

The results of the HWT test, bending test, bending creep test, and oil-resistance test are described below.

3.2.1. *HWT test*

HWT test results in the condition of water and dry are shown in Figure-6. From the HWT test results on the dry condition, P-HMA showed 1/2 of rutting depth or less of MII-HMA, and has the same rutting depth as E-HMA. From the HWT test results on the water condition, MII-HMA occurred the SIP at 4,500 cycles and the rutting depth of 4,500 cycles was 5.2mm (0.2inch). E-HMA and P-HMA do not occurred SIP, and P-HMA was 1.3mm less than E-HMA. From the above results, RRI is taken and shown in Figure-7. From the Figure-7, P-HMA had the high performance than MII-HMA, and P-HMA and E-HMA were found to have high of the mixture rutting resistance and the moisture-susceptibility resistance.

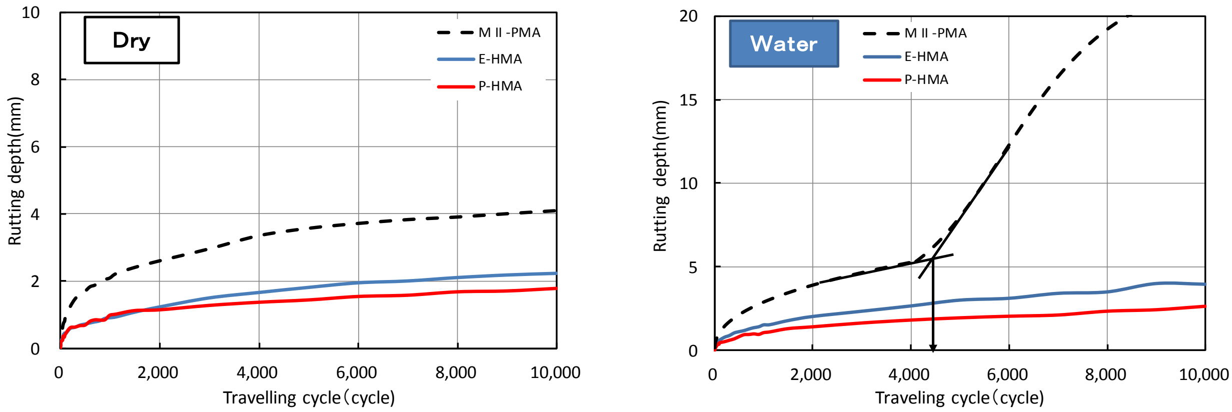


Figure-6 HWT test results on the condition of dry and water

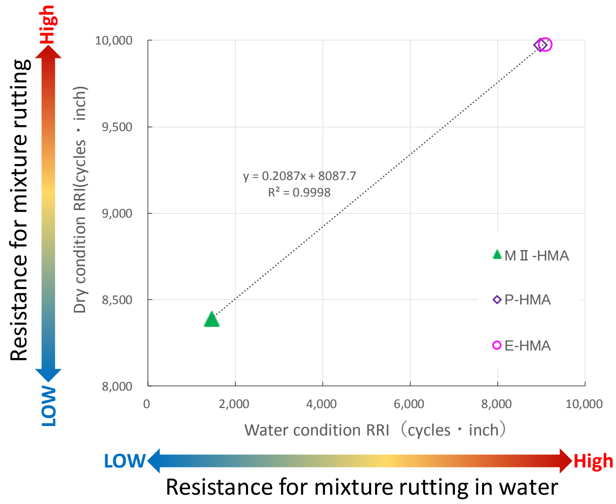


Figure-7 RRI with HWT test

3.2.2. *Bending test*

The results of the bending test are showed in Table-4. The P-HMA showed as same breaking stain as MII-HMA. it showed the similar level of bending strength and breaking strain as the MII-HMA. On the other hand, P-HMA is almost the same as the bending strength of the E-HMA, but the breaking strain is somewhat low.

From the above, it is considered that the P-HMA has as same cracking resistance as MII-HMA at low temperature.

Table-4 Results of bending test

	Mixture Type	Bending Strength (MPa)	Breaking Strain ($\times 10^3$)
A	P-HMA	11.5	4.9
B	M II －HMA	11.4	5.1
C	E-HMA	12.3	7.2

3.2.3. *Bending creep test*

The status and results of bending creep test are shown in Figure-8. From the Figure-8, it was found that the deformation resistance of the P-HMA has relatively lower resistance against static load of E-HMA but has about 2 times higher resistance against static load than the MII-HMA. Then it is considered that P-HMA has a harder performance than the MII-HMA.

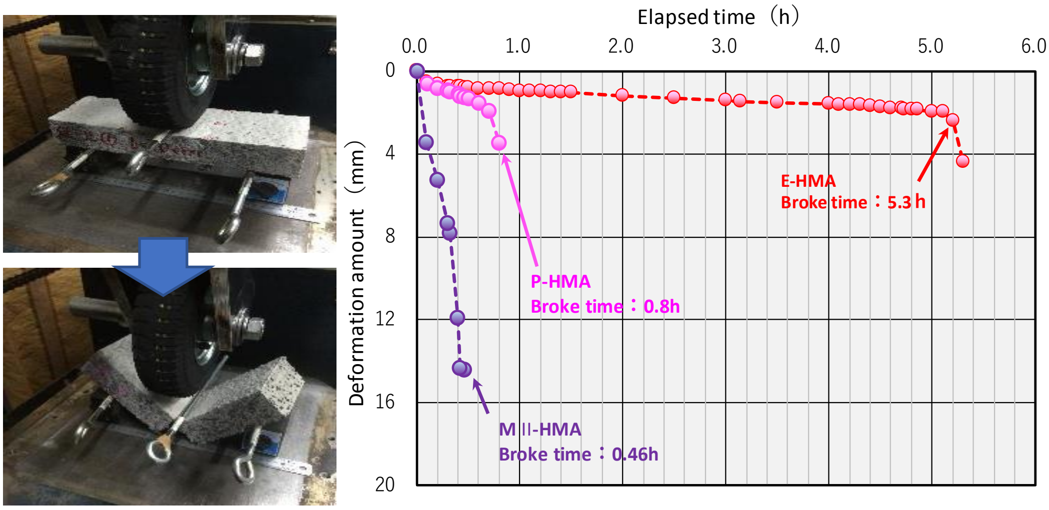
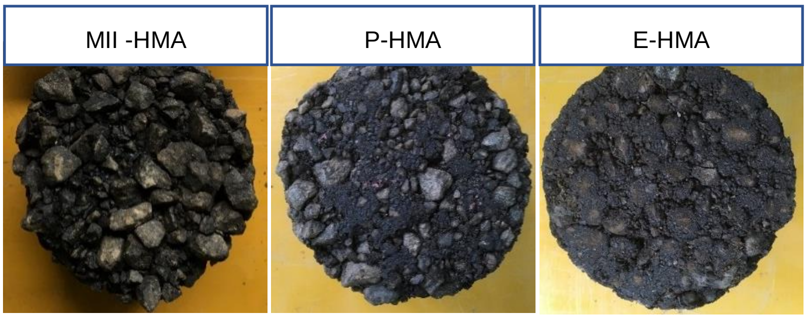


Figure-8 Results of bending creep test

3.2.4. *Oil-resistance test*

Picture-3 shows the top surface of specimens after the oil-resistance test and Figure-9 shows the test results. P-HMA has lower oil immersion Marshall stability and oil immersion residual stability than E-HMA. However, P-HMA showed 3.5 times oil immersion Marshall stability and 1.5 times oil immersion residual stability compared to MII-HMA. As a result, the oil-resistance of P-HMA was confirmed higher performance than MII-HMA and P-HMA can be applied to a construction site where high oil-resistance is required.



Picture-3　The specimens after test

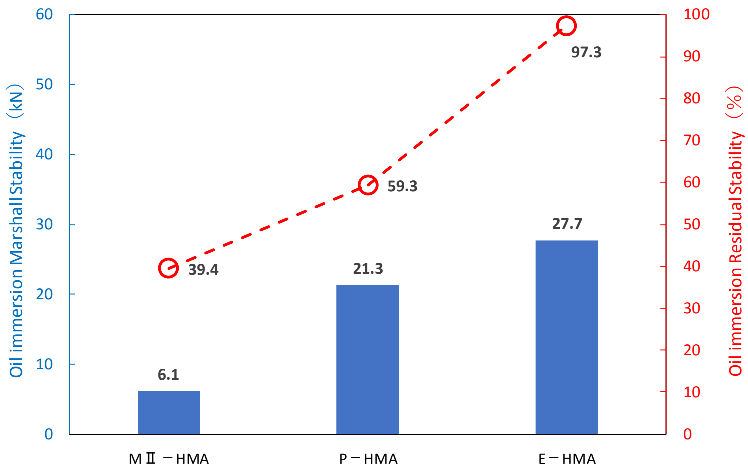


Figure-9　Result of resistance-oil test

4. EXAMPLE OF FIELD APPLICATIONS

From the results of laboratory tests, it was confirmed that P-HMA has high performance. So, the authors applied P-HMA to the field and logistics center parking lot were selected at Sakata city and Saitama city in Japan.

In the logistics center parking lot where loading and unloading of cargo are repeated at designated places and severe rutting occurred (Figure-10). Therefore, the authors applied P-HMA there. In this construction, MII-HMA also paved as a comparative object in order to evaluate P-HMA performance in the field.

Figure-11 shows the results of the survey after 13 months service of E-HMA and P-HMA. Few rutting and cracking were found at not only parking area of E-HMA but also parking area of P-HMA. E-HMA and P-HMA are considered having the similar performance.

Figure-12 shows the results of the survey after 6 months service of MII-HMA and P-HMA. The rutting occurred at the tire position of heavy truck within the parking area of MII-HMA, and rutting depth was about 8 mm and no cracking was found. The authors could not find rutting and cracking from the parking area of P-HMA.

Figure-10 Condition before construction

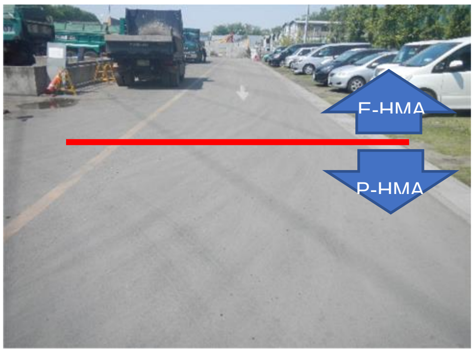


Figure-11 The survey results after 13months of E-HMA and P-HMA

Figure-12 The survey results after 6 months of MII-HMA and P-HMA

5. CONCLUSION

This paper is concluded as follows,
1. From the laboratory test, P-HMA has high performance as mixture rutting resistance, moisture-susceptibility resistance, flexible deflection resistance, static load resistance.
2. Based on the results of field constructions and survey, P-HMA showed significantly higher performance than MII-HMA, and showed the same performance as E-HMA.

3. Application of P-HMA is effective for the field requiring high pavement performance.

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