Development of Test Method of Estimating Residual Durability of Existing Binder Layer for Porous Asphalt

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ABSTRACT: Unfamiliar distress types of porous asphalt, such as partial plastic flow and particles of binder layer mix blowing up from its porosity, have been observed in Japan. This is considered due to stripping of the underlying mix under immersed condition with wider ranges of temperature in Japan. Since evaluation of existing binder layer's condition is important in advance of a porous layer paving project, an efficient and appropriate diagnosing test that can evaluate the remained durability of the binder layer was really needed in NEXCO. Judging from field cut surveys, it was found that binder layer's stripping is going to proceed downward to the underlying bitumen-treated base layer. Thus use of cores sampled from existing binder layer in the field was judged appropriate as test specimen. The next step was development of a test method that can appropriately estimate the residual durability of existing binder layer, if it is still to use under porous layer. Since the binder layer will be in an immersed condition, the sampled cores should be simulated with some accelerating process. From this view, use of pressurized tri-axial test with 60°C hot water was judged appropriate. By comparing indirect tensile strength of sampled cores that had accelerated process and not, the former cores showed lower resistance, similarly as in a problematic field with stripping of binder layer. This paper introduces how to develop a new test method that can estimate residual durability of existing binder layer for porous asphalt.

KEY WORDS: Porous asphalt, binder layer, residual durability, pressurized test, indirect tensile test

1 INTRODUCTION

Porous asphalt mix has been implemented as a standard surface layer in the Japanese nationwide toll motorways in order to provide road users with upgraded safety and comfort since 1998. A few years after implementation, however, unfamiliar distress types of porous asphalt rather than dense graded pavement, such as partial plastic flow and particles of underlying binder layer's mix blowing up from its porosity, have been observed all over in Japan, as already reported in the 3rd Eurasphalt & Eurobitume Congress and in Zurich ISAP symposium (Motomatsu et al. 2004; Kamiya et al. 2008).

Photo 1 and Photo 2 respectively show partial plastic flow and blowing up of particles of the binder layer's mix, which was weakened by remained water on the layer. The reason of these distresses wide spread is considered due to stripping of the binder mix under immersed condition with wider ranges of temperature higher annual rainfall in Japan, compared with overseas countries.

Photo 1: Partial plastic flow (left) and blowing up of particles from porosity (right)

Although resistance against the stripping of binder layer was recognized vital for keeping porous asphalt structurally healthy, there is no test method of estimating residual durability of existing binder layer mix, in advance of a porous layer repaving project. Because use of porous asphalt is a strong policy for East, Central and West Nippon Expressway Company Limited (NEXCO) who are the nationwide toll road operators, an efficient and appropriate diagnosing test that can evaluate the remained durability of the existing layer mix was longed for development.

2 MECHANISM OF DISTRESS

Figure 1 compares the differences in structural mechanism of dense graded and porous asphalt pavements. The design concept of the former is that rainwater drains on road surface and is never allowed to penetrate inside the pavement. On the other hand the latter allows it through surface layer, although it must be retained directly on binder layer.

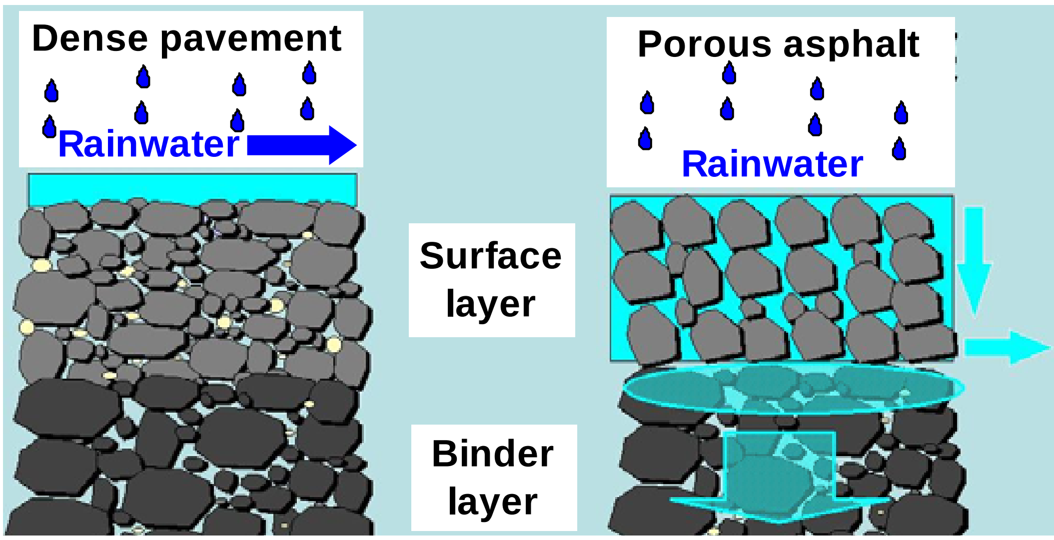

Figure 1: Comparison of structural mechanism

In short binder layer is never exposed to rainwater for the dense graded pavement, but it is directly exposed for the porous asphalt. Because binder layer is basically composed of coarse graded materials, rainwater is easy to penetrate inside the mix and gradually go into the lower layer. This is especially true, in case that the binder layer's durability is less sufficient. Photo 2 implies the process of distress.

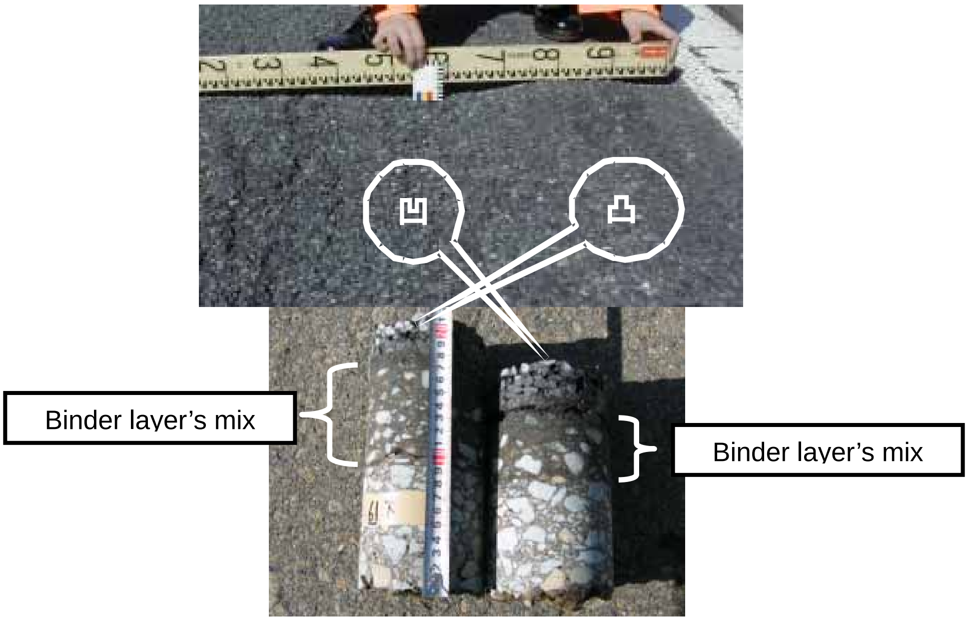

Photo 2: Cores from rutted and swelled part

There are several cracks in a rutted wheel path, and also swelled flow sideward the path. The left core was sampled from the top of swelled part, while the right one from the rutted part. There is quite difference between the binder layer's thicknesses of the two cores, in spite of having almost the same thickness of the underlying base layers. Besides in the rutted right cores, there is no bonding between surface and binder layers. The lack of this bonding may induce the stripping of binder layer's mix, which gradually may cause plastic flow of the layer and finally come up with cracking in the surface layer.

3 DEVELOPMENT OF ACCELERATED STRIPPING TEST

3.1 Simulation Device

Although there is not a test method that can handle field cores for diagnosing their durability, the specimen to be used for diagnosing residual durability of binder layer should be existing cores sampled from a project site. Because the stripping of the layer mix occurs from its top surface, test water needs to pour down from the top of specimen. For appropriately simulating this mechanism, a pressurized permeability test device was newly developed, as shown in Figure 2.

In the course of development of this new test system, Environmental Conditioning System as a SHRP product was referred for arrangement (TRB Executive Committee, 2003). However the ECS test prescribes air void of the specimen to be prepared at 7 to 8%, which is much higher than generally observed levels of 4 to 5% for field cores of binder layer under NEXCO. Moreover it takes 6 to 18 hours only for conditioning and later needs resilient modulus testing, which is not familiarized among practitioners at asphalt plants in Japan. Therefore a less time consuming and easier test system needs to be developed.

For shortening test hours, higher pressures than in ECS are judged to put from top and side in Figure 2. Also instead of resilient modulus test, a more widely spread test needs to be selected.

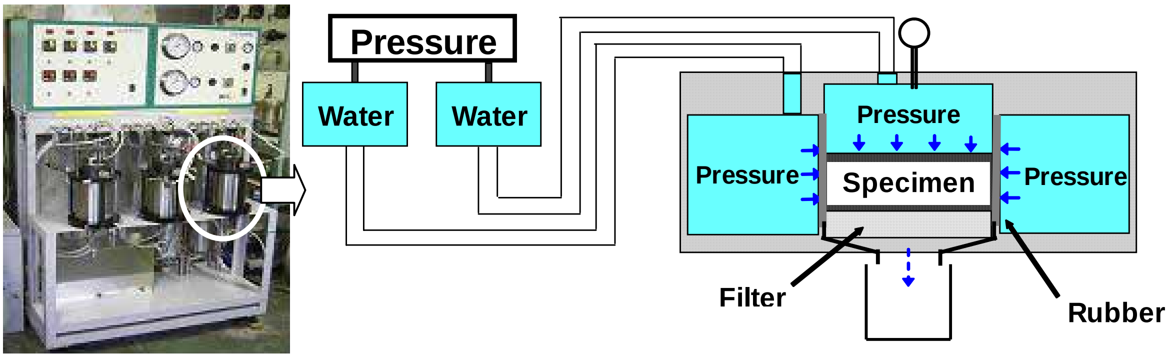

Figure 2: Arrangement of pressurized permeability test

This test can hold specimen the side of which is covered with rubber sleeve, and subject it to pressurized water from top and side of the specimen. Just like tri-axial compression test for soil materials, the conditioned specimen can be used for another strength test, which is a big merit. Moreover since asphalt mix becomes weakened in hot water, water at 60°C can be retained in the test, as in immersed Marshall stability and immersed wheel tracking tests.

3.2 Evaluation of Stripping

Table 1 shows a tentative conditioning for specimen fabricated in laboratory. After this conditioning is over, to what test method the specimen is to be subjected needs to be determined in order to evaluate the degree of stripping. From availability at asphalt plants, Marshall stability and indirect tensile tests were selected and compared for the evaluation. Table 2 shows elapsed time until residual Marshall stability and indirect tensile strength of conditioned specimen respectively reach 75% of the strength of unconditioned.

Table 1: Tentative conditioning

Condition of pressure				Evaluation method		
Top	Side	Water temperature	Time	Test method	Immersion time	Test temperature
100 kPa 150 kPa 200 kPa	Top pressure × 1.5	60°C	1 hr 2 hr 3 hr	Marshall stability test	30 min	60°C 25°C
				Indirect tensile test	1 hr	25°C 5°C

Table 2: Elapsed time until 75% of strength of unconditioned specimen

Evaluation	Top pressure	Elapsed time until 75% of unconditioned specimen		
		60°C	25°C	5°C
Marshall stability	100 kPa	4 hr	4 hr	-
	150 kPa	3 hr	2 hr	-
	200 kPa	3 hr	2 hr	-
Indirect tensile strength	100 kPa	-	≧ 4 hr	≧ 4 hr
	150 kPa	-	≧ 4 hr	2 hr
	200 kPa	-	3 hr	3 hr

Photo 3 is a cross section of conditioned specimen after Marshall Stability Test. Although all the stability of conditioned specimen decreased 75% of unconditioned, none of the conditioning gave stripping phenomenon in the field, like this photo.

Photo 3: Conditioned specimen after Marshall Stability Test

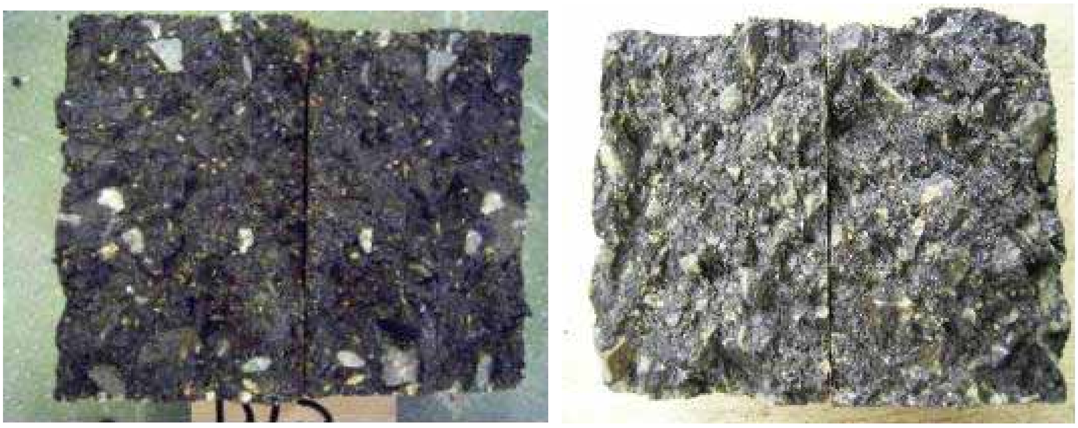

Photo 4: Conditioned specimen after indirect tensile test

Photo 4 shows cross sections of conditioned specimen after indirect tensile strength tests at 5 and 25°C. Although there is not stripping with aggregates broken at 5°C, there is it successfully at 25°C. This supports the condition of Modified Lottman test procedure, as prescribed in AASHTO T283 (1982 and 1995) and ASTM D4867 (TRB Executive Committee, 2003). Finally indirect tensile test at 25°C was selected for the evaluation of stripping.

3.3 Conditioning for Stripping

In order to find the most effective conditioning that can appropriately cause the stripping of specimen as in the field, how to apply water pressure to specimen needs to be determined. As confirmed from Table 2, the higher the permeable pressure is, the faster the indirect tensile strength of conditioned specimen decreases. Also according to Buchanan, the effectiveness of repeated cycling of different permeable pressure was reported (Buchanan et al. 2004). Based on these facts, Figure 3 summarizes the relationship between indirect tensile strength and combinations of permeable and side pressures. The elapsed conditioning hour was 4 hours.

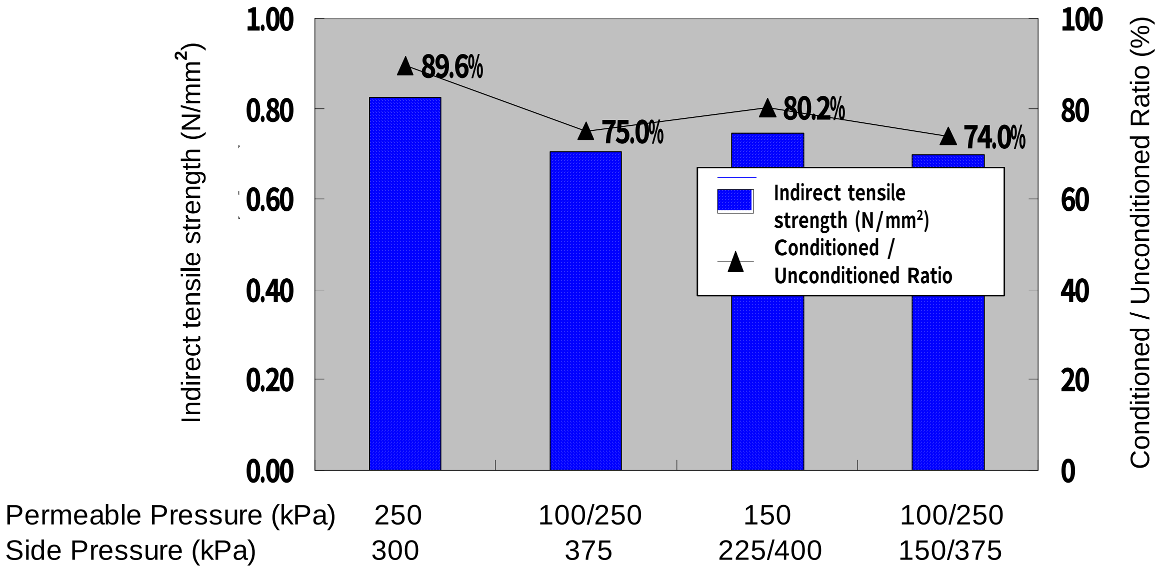

Figure 3: Effectiveness of repeated cycling of pressures (4 hours)

The highest reduction in the ratio of indirect tensile strength for conditioned specimen to unconditioned was obtained in the forth case, where repeated cycling was applied for both permeable and side pressures. However this reduction does not differ so much from the second case, where repeated cycling was applied only for permeable pressure. Therefore the second combination was selected as the most effective for the water pressure condition.

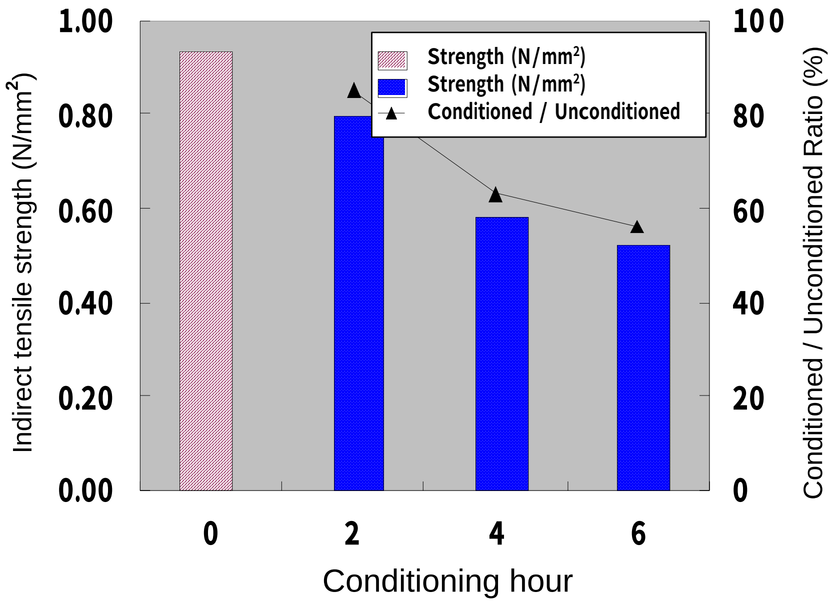

Figure 4: Comparison of conditioning hour

Figure 4 compares the ratios of indirect tensile strength for different conditioning hours. Since there is not much difference between 4 and 6 hours, 4hours was judged sufficient for conditioning hour.

As mentioned above, Table 3 finally summarizes the whole procedures for Accelerated Stripping Test Method, newly developed in this study.

Table 3: Procedures for Accelerated Stripping Test

Item	Specified value	Remarks
Permeable pressure	100, 250 kPa	24 cycle for each 5 minutes
Side pressure	375 kPa	Maximum top pressure×1.5
Water temperature	60°C	Pressurized water for above
Conditioning time	4 hr	5 min × 2 pressure × 24 cycle
Evaluation	25°C	Indirect tensile test

4 FIELD VALIDATION

Because every item in Table 3 was developed using laboratory fabricated specimen, in order to evaluate whether or not Table 3 truly simulates distress in the field, field validation was conducted. Field cores were sampled from a problematic site with partial plastic flow and a sound site in a porous asphalt section. Both cores were sampled between wheel paths in order to evaluate potential residual durability. The binder layer's cores were adjusted to 4cm by cutting every 1cm from top and bottom. After applying all the procedures in Table 3, Figure 5 compares the indirect tensile strength of those field cores.

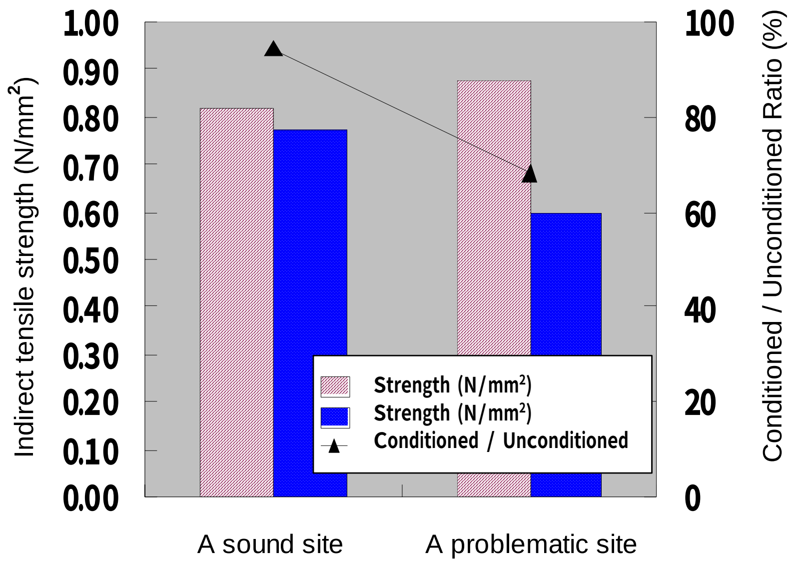

Figure 5: Comparison of sound and problematic sites in the field

Both unconditioned field cores showed the same level of indirect tensile strength. However the sound site provided the strength ratio of 95% between conditioned and unconditioned cores, while the problematic site did higher reduction with 68%.

In this way Table 3 was validated to be practically appropriate.

5 CONCLUSION

A new test method of estimating residual durability of existing binder layer for porous asphalt was successfully developed. The findings are summarized as follows.

1. Test specimen for diagnosing residual durability of binder layer should be existing cores sampled from a project site. In order to well simulate the stripping of the layer mix, a pressurized permeability test device can be arranged. The specimen the side of which is covered with rubber sleeve is subjected to pressurized hot water from top and side of the specimen. The hot water is kept 60°C for weakening the mix.
2. For the purpose of selecting a user friendly test that can appropriately evaluate the degree of stripping, Marshall Stability and indirect tensile tests were compared. Finally indirect tensile test at 25°C was selected for the evaluation of stripping.
3. Judging from the relationship between indirect tensile strength and combinations of permeable and side pressures for 4 hours, the most effective pressure condition was selected. The finally selected condition is repeated cycling only for permeable pressure, while side pressure is constant.
4. By comparing the ratios of indirect tensile strength for different conditioning hours, 4 hours was judged sufficient for conditioning hour.
5. According to the comparison of sound and problematic sites, the former site provided the strength ratio of 95% between conditioned and unconditioned cores, while the latter site did higher reduction with 68%. All the procedures for Accelerated Stripping Test were validated to be practically appropriate.

The new test system takes only four hours for conditioning for stripping as in the field, and also can use indirect tensile strength test which is user-friendly for practitioners on project basis. Therefore it can be a promising test method for estimating residual durability of existing binder layer for porous asphalt.

Further validation needs to be conducted by collecting field cores from various project sites in order to find out variability of the new test and finally set criteria for whether or not to replace the existing binder layer.

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