Evaluation Method for Moisture-Induced Damage of Binder Course Mixtures under Porous Asphalt Pavements, Including Digital Image Analysis

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ABSTRACT: In Japan, it is frequently reported that the failure, so called, the moisture-induced damage of binder course mixtures mainly caused by asphalt stripping when the existing dense-graded layer located on the binder course was re-surfaced by the porous asphalt mixtures. In order to prevent such failure, it is essential to establish an evaluation method of material durability of the existing binder course mixtures against moisture-induced damage. In the research, specimens of saturated and accelerated condition of immersing compacted asphalt mixtures have been studied and it has been focusing the relationship between the change of indirect tensile strength and stripping rate after the immersion in the laboratory. In this paper, a proposed method of estimating moisture susceptibility of binder course mixtures just below porous asphalt mixtures paved newly will be presented along with a method of estimating stripping rate by digital image analysis.

KEY WORDS: Tensile strength ratio, stripping rate, digital image analysis

1 INTRODUCTION

In Japan, the porous asphalt pavement has been rapidly increased with the aim of tire/road noise reduction and safety driving. Porous asphalt mixtures are often placed on the existing binder course for cut and overlay in the pavement rehabilitation projects. In such cases, it is sometimes reported that moisture-induced damage of the binder course mixtures produced serious pavement distress (rutting and pot hole). The cause of these damages has not been yet found out completely and there has been no established way to evaluate the moisture susceptibility of the asphalt mixtures just below the porous asphalt pavements in Japan.

2 TESTS CURRENTLY IN USE

Four test methods are currently used to identify moisture susceptible asphalt mixtures in Japan, shown as follows.

2.1 Immersed Wheel Tracking Test

The wheel tracking device is shown in Figure 1. A specimen is typically 300 mm wide, 300 mm long and 50 mm thick. The specimen is compacted to 100±1 percent of standard density using a roller compactor. The specimen is placed on the mock base material (porous concrete plate). The mock base material is submerged under water at 60^{o}C equal to the room temperature. A solid tire wheel, 50mm wide, loads the specimen with 686 N. The wheel makes 42 passes over the specimen per minute, moving to the transverse direction by velocity of 10 cm/min. The velocity of the wheel is 160 mm/sec. The specimen is loaded for 6 hours or until disintegration occurs. The stripping rate on split exposed surface of the tested specimens is usually required to be less than 5 %.

Figure 1: Immersed wheel tracking device

2.2 Pressurized Stripping Test (PST)

This test procedure was developed by the former Research Institute of Japan Highway Public Corporation (the current Nippon Expressway Research Institute Co., Ltd.). The test device using pressurized water is shown in Figure 2. Six specimens are prepared. The lateral sides of three specimens are wrapped with the rubber sleeves and restrained by the pressure (375kPa) with water, and then the pressure is applied on the upper surface with water changing into 100 kPa and 250 kPa every 5 minutes for 4 hours. The water temperature is 60^{o}C. The other three specimens remain unconditioned. All of the specimens are brought to a constant temperature and the indirect tensile strength is measured. The criterion for the stripping which is shown in figure 3 is used in the expressway projects (Motomatsu et al. 2004).

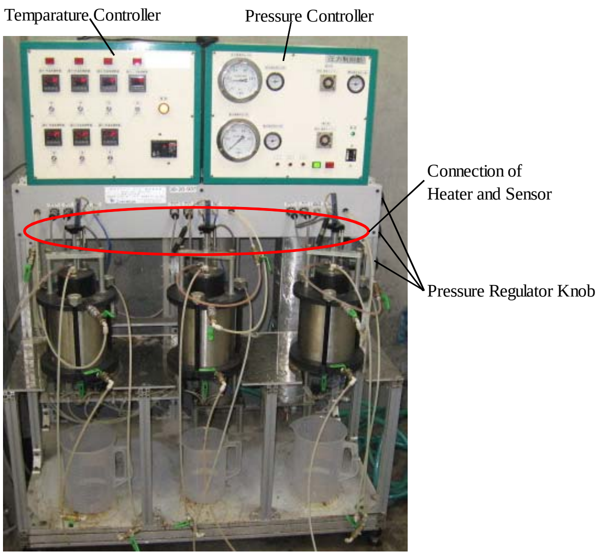


Figure 2: Pressurized stripping test device

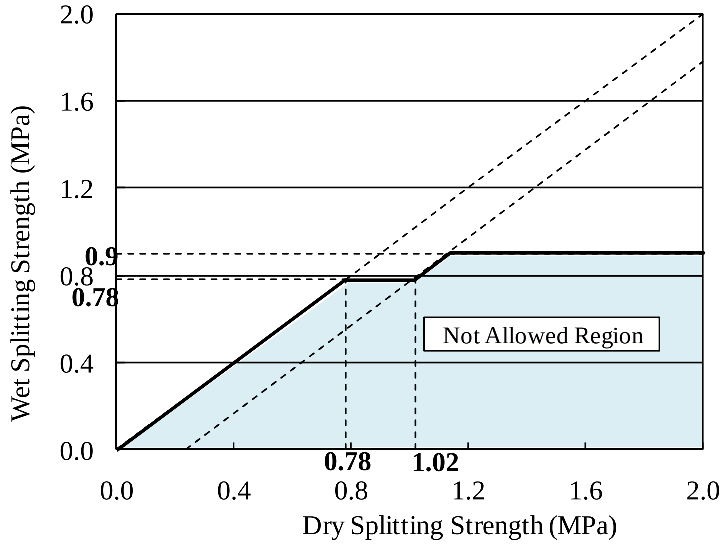


Figure 3: Criterion for pressurized stripping test

2.3 Modified Lottman Test (MLT)

This test procedure includes short-term aging, freezing, and limits on air voids (6 to 8 percent) and saturation (55 to 80 percent). Six specimens are prepared. Three specimens are subjected to vacuum saturation, frozen, and placed in a hot water bath. The other three specimens remain unconditioned. All of the specimens are brought to a constant temperature and the indirect tensile strength is measured. The ratio of the tensile strengths of the conditioned to unconditioned specimens is the tensile strength ratio (TSR) and is usually required to be more than 0.70. The criterion shown in figure 3 is proposed by Higashi and others, and is possible to apply to cores which are taken from the field and have air voids less than 6 % (Higashi et al. 2004).

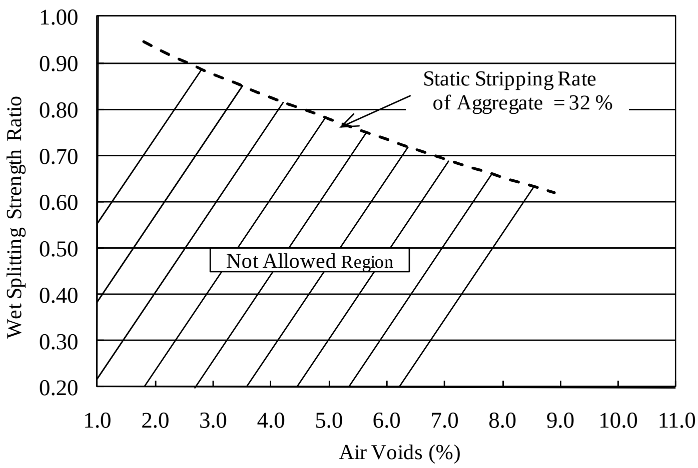


Figure 4: Criterion for modified Lottoman test

2.4 Immersed Marshall Stability Test

Six specimens are prepared. Three specimens are submerged under water at 60^{o}C for 48 hours. The other three specimens remain unconditioned. All of the specimens are brought to a constant temperature and the Marshall stability is measured. The ratio of the stability of the conditioned to unconditioned specimens is the retained Marshall stability and is usually required to be more than 75 %.

3 NEW METHOD OF STRIPPING RATE ESTIMATION

3.1 Need for Stripping Rate

Moisture damage includes both cohesive (softening) and adhesive (stripping) components. Stripping is the physical separation of the asphalt cement and the aggregate produced by the loss of adhesion between the asphalt cement and aggregate surface, primarily due to the action of water or water vapor. Stripping is accentuated by the presence of aggregate surface coatings and by smooth aggregate surface-textured aggregates. Softening is a general loss of stability of a mixture due to a loss of cohesion caused by the action of moisture within the asphalt or asphalt matrix (Kennedy 1983).

The strength ratio of unconditioned and conditioned is used to evaluate moisture damage of asphalt mixtures except for the immersed wheel tracking test. Air void is applied between 6 % and 8 % so that the water can penetrate easily. However, when air void of the mixture is smaller than 4 %, it is substantially impermeable and temperature conditions might result in a higher rate of softening. In this case, even if two strength ratios are the same, each stripping rate might differ greatly.

Thus, in order to evaluate moisture-induced damage of the asphalt mixtures and cores taken from the field, not only the strength ratio but also the stripping rate should be used.

3.2 New Estimation Method of Stripping Rate

Visual evaluation of asphalt mixtures is the method used to determine the percent of retained asphalt coating on the aggregate after the specimen has been water conditioned. Even though the procedure includes the use of rating boards or patterns and more than one rater to aid the rater and help establish consistency, the primary shortcoming with this method is the subjective nature of the results. Because of this subjectivity, visual evaluation is not really used to differentiate between the stripping and nonstripping mixtures as compared with the tensile strength ratio.

In order to exclude the subjective nature of visual evaluation as described previously, the method to measure the stripping rate using digital image analysis is proposed. The method is shown in figure 5.

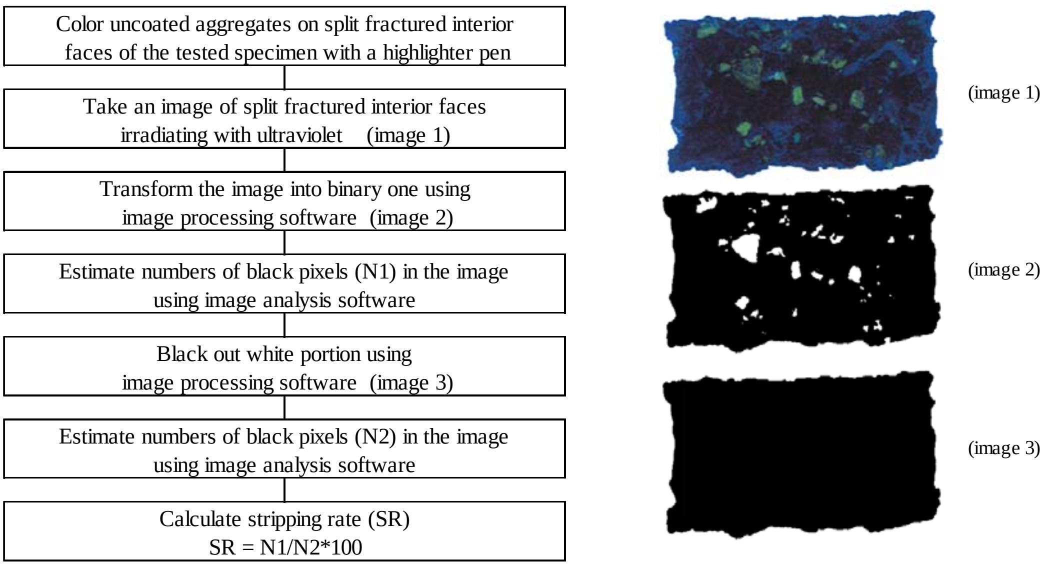


Figure 5: Method of stripping rate estimation by digital image analysis

4 LABORATORY INVESTIGATION

The laboratory investigation was implemented to compare three moisture susceptibility tests.

4.1 Selection of Test Methods

PST and MLT can be easily used (a) to test asphalt mixtures in conjunction with mixture design testing, (lab mixed, lab compacted), (b) to test asphalt mixtures produced at mixing plants, (field mixed, lab compacted), and (c) to test the cores obtained from completed pavements of any age (field mixed, field compacted). However, the immersed wheel tracking test can't be easily used in the field investigation, because it is very difficult to obtain the specimens from completed pavements and arrange the required shape.

It is only required that the specimens are soaked in hot water for 48 hours in the immersed Marshall stability test, so this test is considerably less severe than the other three tests. Thus PST and MLT were selected for this study.

4.2 Compaction Method

Specimens compacted by the Marshall impact compactor are usually used in three laboratory tests except for the immersed wheel tracking test. These specimens are not subjected to the kneading action. The roller compactor is currently in widespread use or will be in widespread use in the future in Japan. Therefore, the method preparing of specimens that is described below was selected for this laboratory investigation.

A specimen is compacted to the standard density using the roller compactor, which is 300 mm wide, 300 mm long, and 50 mm thick. Three cores are taken from the specimen. Using this preparation of specimens, it becomes that much easier to evaluate three test methods for ascertaining the moisture susceptibility of asphalt mixtures.

4.3 AASHTO T 283

In Japan specimens for MLT are prepared and tested in accordance with AASHTO T 283-89, but the loading strip with a flat surface is used in the tensile strength test. Use of the loading strip with a concave surface having a radius of curvature equal to the nominal radius of the test specimen is required to generate a uniform tensile stress.

The latest method for MLT is standardized by AASHTO T 283-99, not T 283-89. The current AASHTO T 283-99 test procedure includes freezing cycles in requisite process and freezing cycles is not optional in contrast to the former T 283-89. T283-89 reflects field performance up to 4 years and T283-99 reflects performance from 4 to 12 years. The laboratory tests were implemented in accordance with AASHTO T 283-99 in this study.

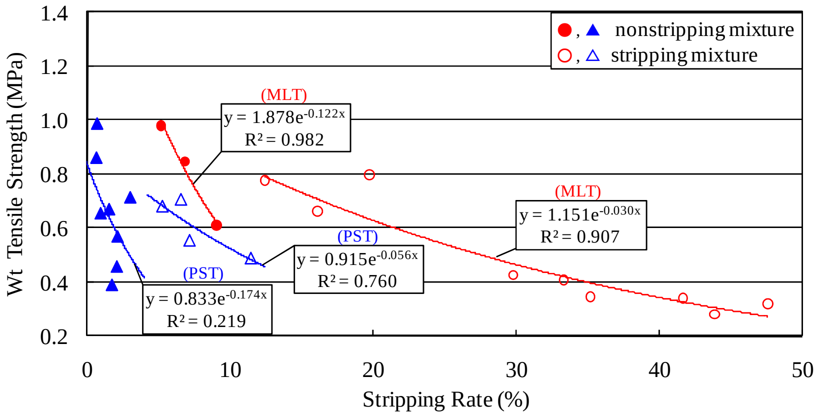
4.4 Test Result

Stripping coarse graded mixture and nonstripping dense graded mixture were used in laboratory tests and the results of two tests were compared.

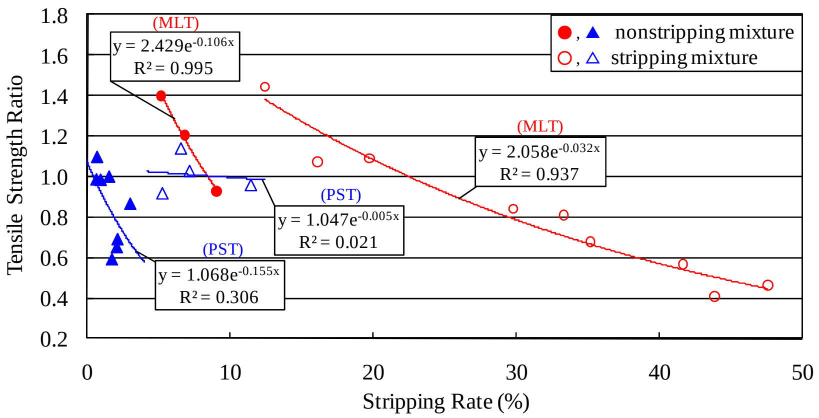
The correlation of the test results from PST and MLT is shown in Figure 6. There are good correlations not only between the stripping rate and the tensile strength after conditioning (wet tensile strength), but also between the stripping rate and TSR of both stripping and nonstripping mixtures in MLT. There is only correlation between the stripping rate and the wet the tensile strength of nonstripping mixtures in PST.

The deterioration of the tensile strength from PST is larger than that of MLT though the stripping rate from PST is lower than that of MLT. It is assumed that softening is more severe than stripping under the conditioning of PST as compared with that of MLT.

The criterion for PST as shown in Figure 3 is originally made based on the test results of the cores taken from fields. The asphalt mixtures in laboratory are softer than cores taken from fields which are subjected to aging, and are susceptible to the effect of softening. Thus some consideration is necessary when this criterion is applied to the asphalt mixtures.



(a) Wet Tensile Strength



(b) Tensile Strength Ratio

Figure 6: Correlation of test results from PST and MLT

The test results from MLT are shown in Figure 7. There are good correlations between air voids and both the wet tensile strength and TSR of stripping and nonstripping mixtures.

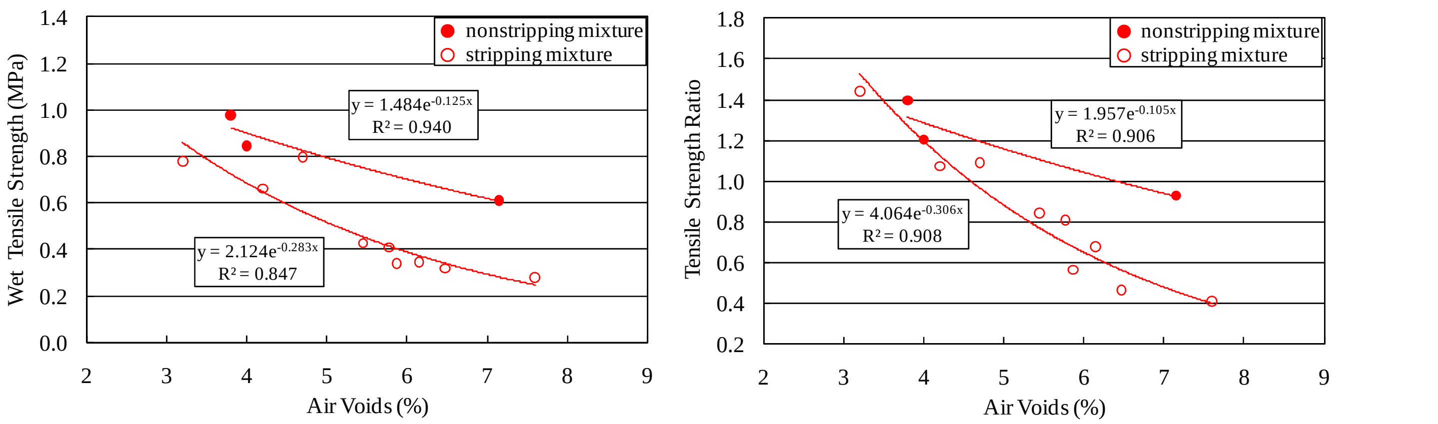


Figure 7: Correlation between air voids and strength in MLT

5 FIERD INVESTIGATION

In a pavement rehabilitation project, Porous asphalt pavement was planned to be placed on the existing binder course for cut and overlay, and many cores were taken from fields in order to check the moisture susceptibility of binder course mixtures in MLT.

The test results are shown in Table 1 and Figure 8. There are good correlations not only between the stripping rate and the wet tensile strength, but also between the stripping rate and TSR. There is no correlation between air voids and the strength.

The criterion for MLT as shown in Figure 4 is originally made based on the results of laboratory tests. From these test results, some consideration is necessary when this criterion is applied to the cores taken from fields.

Table 1: Correlation between air voids and tensile strength

Site	Air voids (%)	Stripping Rate (%)	Tensile Strengh Dry (MPa)	Tensile Strengh Wet (MPa)	TSR
Sta. 17L	2.4	47.9	1.671	0.437	0.262
Sta. 22R	3.0	45.6	1.263	0.300	0.238
Sta. 29L	4.2	25.8	1.357	0.649	0.478
Sta. 33R	3.7	13.6	1.343	0.922	0.687
Sta. 45L	3.2	17.4	1.342	0.900	0.671
Sta. 58R	3.4	41.8	1.294	0.413	0.319
Sta. 81R	3.9	24.4	0.798	0.424	0.531
Sta. 89R	5.6	20.5	0.983	0.621	0.632
Sta. 105R	6.6	25.1	0.756	0.280	0.370
Sta. 115L	4.7	46.3	1.090	0.286	0.262
Sta. 120R	5.2	33.0	1.159	0.488	0.421

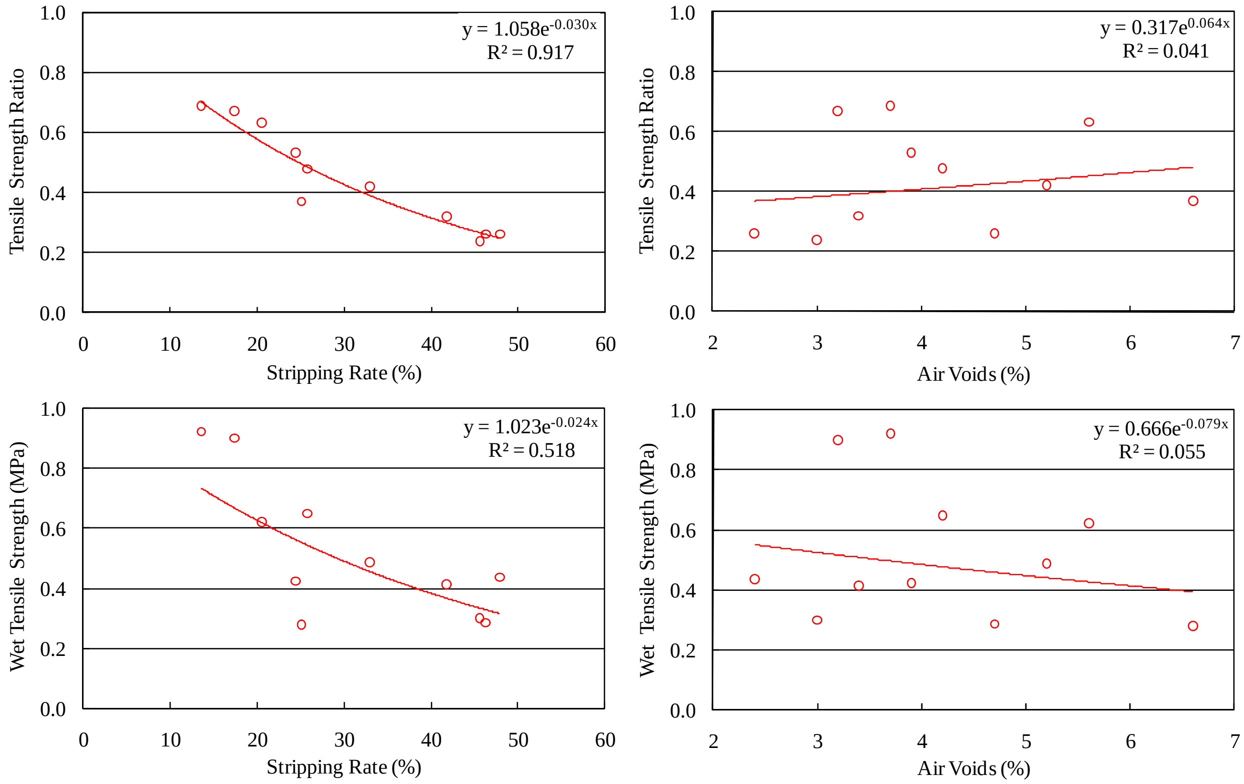


Figure 8: Test results of cores

6 CONCLUSION

The purpose of this study was to compare four tests (immersed wheel tracking test, pressurized stripping test, modified Lottman test and immersed Marshall stability test) which are currently used to evaluate the moisture susceptibility of the asphalt mixtures in Japan, and to investigate adaptability of their tests for evaluation of the binder course mixtures just below the porous asphalt pavements paved newly.

In order to exclude the subjective nature of the visual evaluation, the method to measure the stripping rate using digital image analysis was proposed.

The two tests (the pressurized stripping test and the modified Lottman test) were selected and the laboratory and field investigation were conducted. The modified Lottman test was implemented strictly in accordance with AASHTO T 283-99 using cores taken from specimens compacted to the standard density by the roller compactor, and cores taken from the roadway in a pavement rehabilitation project.

From the laboratory investigation, there were good correlations not only between the stripping rate and wet tensile strength, but also between the stripping rate and TSR of both stripping and nonstripping mixtures in the modified Lottman test. However, there was only correlation between the stripping rate and the wet tensile strength of nonstripping mixtures in the pressurized stripping test.

From the field investigation, there were good correlations not only between the stripping rate and the wet tensile strength, but also between the stripping rate and the tensile strength ratio in the modified Lottman test. However, there was no correlation between air voids and the strength.

It was found out that each criterion for the pressurized stripping test and the modified Lottman test is necessary to be reviewed from the standpoint of the stripping rate.

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