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Analysis of the Influence of Velocity Effect on the Indirect Tensile Strength Test Results of Asphalt Concrete

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Abstract: The asphalt mixture AC-20C was compacted by standard method, and the physical and mechanical properties of asphalt concrete specimens were tested. In the test process, the difference of indirect tensile strength is investigated by using different loading rates, so as to evaluate the correlation between the test process and the test results of asphalt mixture. The test results show that: when the appropriate loading speed is adopted, the asphalt mixture test can achieve more ideal test results, and different test conditions will produce completely different results, so that the test data are completely distorted. Under the condition of excluding other factors, more real test data can be obtained, so the test should be carried out in strict accordance with the requirements of the specification.

Key words: asphalt mixture; mixing; indirect tensile strength; compaction speed

1. Introduction

Asphalt concrete pavement stands as a cornerstone among modern high-grade road pavement structures, offering unparalleled advantages compared to cement concrete pavements. The longevity of asphalt concrete pavement critically hinges upon the quality of the pavement base material. This is due to the pavement's susceptibility to bending deformation under repetitive vehicular loads, leading to subgrade deformation and consequent damage to the asphalt surface layer. Moreover, as a viscoelastic material, asphalt concrete is highly sensitive to temperature fluctuations, particularly during winter months when significant temperature drops induce contraction deformation. When this contraction-induced tensile stress surpasses the material's tensile strength, it culminates in crack formation.

Among the myriad performance metrics of asphalt concrete, tensile strength emerges as a pivotal gauge, accurately reflecting the material's ability to withstand strain under vehicular loads and its resistance to cracking in low-temperature environments. In engineering praxis, cracking remains a prominent distress phenomenon, primarily attributable to the inadequate tensile strength of asphalt concrete. This directly impairs the service life and safety of asphalt pavements. Consequently, the tensile strength of asphalt concrete profoundly influences pavement durability and safety, serving as a hallmark parameter widely embraced by both the engineering fraternity and academia worldwide, including in China, the European Union, the United Kingdom, and the United States.

2. Asphalt Mixture Mixing and Specimen Preparation

Given asphalt's thermosensitivity, temperature management assumes paramount importance during asphalt mixture

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preparation, necessitating meticulous control over aggregate, asphalt, and ambient temperatures. Preceding asphalt mixture mixing, coarse and fine aggregates, asphalt, and mineral powder are meticulously weighed according to prescribed mix proportions. Subsequently, aggregates are heated to approximately 120°C, while asphalt is elevated to about 160°C. Sequentially, they are introduced into the mixing vessel for comprehensive blending, typically spanning around 30 minutes. Upon completion, the mixture is shaped into specimens for experimental evaluation (see Figure 1).

Figure 1. Asphalt mixture mixing and specimen formation

3. Preparation for Various Tests

The experiments in this study were conducted in accordance with the European standard EN12697-23. The indirect tensile strength is determined as the maximum tensile stress calculated based on the peak load applied to cylindrical specimens. The test method involves compacting asphalt mixture into cylindrical specimens of certain dimensions using the gyratory compaction method. The size of the cylindrical specimens depends on the maximum particle size of the aggregates. The type of mixture used in this experiment is modified asphalt mixture AC-20. According to the provisions of EN12697-23, considering the influence of the physical properties of the mixture on its mechanical performance, dimensional and density indicators of the specimens were also tested after specimen formation (refer to Table 1).

Table 1. Size measurement and density testing of specimens

Experimental result	Spec 1	Spec 2	Spec 3	Spec 4
Diameter (mm)	100.19	100.83	100.16	100.23
Height (mm)	67.55	64.02	64.65	68.70
Density (g/cm^3)	2.209	2.201	2.212	2.208

The specimens cannot be immediately used for tensile testing after molding. According to the specifications, the specimens must first be placed in conditions not exceeding 25°C for storage for 48 hours to 42 days. Specimens exceeding 42 days of storage cannot be used for testing because the storage time can affect the mechanical properties of the mixture.

4. Indirect Tensile Strength Test and Data Analysis

During the indirect tensile strength test, all specimens should be preheated in a constant temperature water bath to the specified temperature (25°C in this experiment). The equipment used in this experiment is the Marshall testing machine, and the selected loading strip has a measured width of 12.8 mm, which complies with the specifications of EN12697-23. When placing the specimens in the constant temperature water bath, the loading strip should also be placed in the bath for preheating. During loading, each specimen is subjected to compression at loading rates of 2 mm, 5 mm, 10 mm, and 50 mm respectively. As the load increases continuously, cracks appear at the center of the specimen and gradually extend to both sides until the specimen fails (refer to Figure 2).

Figure 2. Compression diagram of indirect tensile strength specimens

When the testing apparatus ceases operation, the failure strength and deformation data are promptly extracted from the computer screen, and the indirect tensile strength of the specimen is subsequently computed based on the test outcomes. The calculation of the indirect tensile strength for each specimen is determined by the following formula, utilizing the peak load P acquired from the experimental results, along with the height H and diameter D of the specimen:

$$ITS = \frac{2P}{\pi DH} \cdot 1000$$

ITS is the indirect tensile strength, expressed in kilopascals (kPa), rounded to three significant figures;

P is the peak load , expressed in newtons (N), rounded to the whole number;

D is the diameter of the specimen, expressed in millimetres (mm), toone decimal place;

H is the height of the specimen, expressed in millimetres (mm), to one decimal place.

Indirect tensile strength tests were conducted on all specimens subjected to room temperature conditioning and water bath treatment. The specimens were pressurized to failure at the respective rates described above, and the failure outcomes were observed and recorded as presented in Tables 2 and 3. Concurrently, the failure curves of each asphalt mixture were reviewed, and the curve results are documented in Table 4.

Table 2. Specimen test loading situation

Experimental condition	Spec 1	Spec2	Spec 3	Spec 4
Test temperature (°C)	23	23	23	23
Loading rate (mm/s)	50	10	5	2
Type of failure	c	a	c	b

Table 3. Test results of failure load and deformation of specimens

Experimental result	Spec 1	Spec 2	Spec 3	Spec 4
Loading rate (mm/s)	50	10	5	2
Peak load (N)	12,199	6,935	5,718	2,778
Displacement at peak load (mm)	1.987	2.527	3.547	3.962
Indirect tensile strength (kPa)	1,203	641.2	522.0	282.2

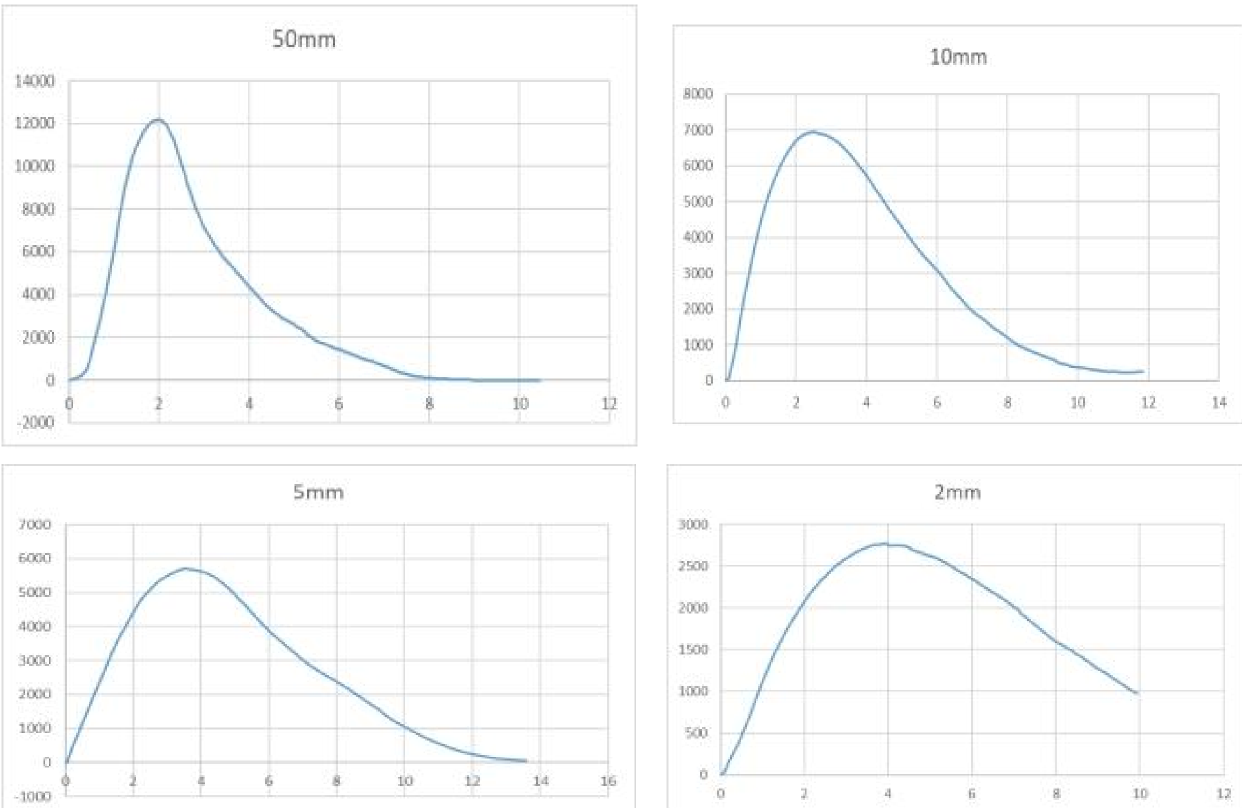

Figure 3. Loading pressure deformation curve of the specimen

From Tables 2 and 3 and Figure 3, it can be observed that the dimensions of the asphalt mixture specimens in this experiment were approximately Φ100×63.5, with an average density of 2.208 g/cm³. However, there was a significant variation in the results of the indirect tensile strength tests, and the deformation upon failure varied greatly among specimens, exhibiting certain regularities.

Firstly, it is evident that the loading rate greatly influenced the results of both the indirect tensile strength and the deformation. Under the same mix proportions, dimensions, and identical temperature conditions, the discrepancy in indirect tensile strength could reach several times. For instance, when the loading rate was 50 mm/s, the indirect tensile strength reached 1,203 kPa, whereas adjusting the loading rate to 5 mm/s resulted in an indirect tensile strength of only 282.2 kPa, a difference of 4.26 times. Conversely, the deformation of the specimens exhibited the opposite trend: at a loading rate of 50 mm/s, the deformation was only 1.987 mm, while at a loading rate of 5 mm/s, the deformation increased to 3.962 mm. Furthermore, there were significant differences in the failure modes of the asphalt mixture specimens.

Therefore, in scientific research experiments or production practices, to ensure the accuracy of asphalt mixture data and to avoid distortion of results due to human factors, it is imperative not only to strictly control conditions such as temperature and compaction load according to specifications but also to conduct pre-testing of equipment loading rates to ensure the accuracy of scientific research data and the instructiveness of test data.

5. Conclusion

In this experiment, dense-graded asphalt mixture AC-20C was studied, and European standards were adopted for compaction and molding. By determining the failure load and deformation data of specimens under different loading rate conditions, it is evident that the loading rate effect has a significant impact on the test results. Comparing the indirect tensile strength and deformation results of AC-20C asphalt mixture, it is demonstrated that under conditions where all other factors are kept constant, an appropriate loading rate can yield reliable and realistic test results while ensuring accurate mix proportions and specimen dimensions, thereby avoiding the use of non-standard loading rates in testing.

In summary, the results of indirect tensile strength tests are greatly influenced by specimen size effects, shape effects, temperature effects, and loading rate effects. Suitable test conditions can accurately reflect the technical status of asphalt mixtures, providing better guidance for research and production activities.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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