Exploration in the test of splitting resilient modulus of asphalt mixture

Peihong Li*
School of Traffic and Transportation Engineering, Changsha University of Science and Technology, Changsha, 410114, China
*Corresponding author e-mail: road-engineering@foxmail.com

Abstract. In terms of the non-correspondence about the bottom layer tensile stress provided by the compressive resilient modulus and the allowable tensile stress obtained by the splitting test, this paper puts forward the methods about splitting stepping testing by contrasting the compressive resilient modulus testing methods. Both the stepping load and resilient deformation are recorded. With the help of the concept of splitting stiffness modulus, the expression of splitting resilient modulus can be obtained to gain the splitting resilient testing flow. The results show that the resilient modulus which is measured by splitting stepping load can meet the design ranges of asphalt mixture and the stepping loading methods about splitting resilient modulus are worth popularizing.

1. Introduction
The structure design about asphalt pavement makes reference to the values about elastic modulus parameters of asphalt mixtures. The elastic modulus values in exiting specification adopt the compressive resilient modulus which can be measured from stepping loading. The stipulation in specification shows that the bottom layer tensile stress provided by the compressive resilient modulus must be less than or equal to the allowable tensile stress. Besides, the allowable tensile stress can be obtained by means that the splitting strength value is divided by the structure coefficient of tensile strength in splitting test. There are not correspondences between the compressive resilient modulus and the splitting strength value. This is a major deficiency about exiting specification of asphalt pavement and it is necessary to improve this weakness.

The elastic modulus of asphalt mixture has different values in different acting experiments and there are more differences about elastic modulus in different conditions. To correspond the pavement design parameters and improve the structure designs, the splitting resilient modulus is selected as the modulus parameter of asphalt mixture so that the splitting resilient modulus in calculating the bottom layer tensile stress can coincide with the allowable tensile stress. Nevertheless, the researches about elastic modulus in splitting condition are very few currently and the reason lies in lacking of equation about splitting modulus. Aiming at this puzzle, the article acquires the loading values and the resilient deformations in splitting stepping loading by contrasting with the testing method about compressive resilient modulus. By the lights of the concept about stiffness modulus of asphalt mixture, the mathematical expression about splitting resilient modulus is derived to obtain the splitting resilient testing method.
2. Defining methods of splitting resilient modulus

In the material mechanics method, the modulus is defined as the capacity to resist deformation and its modulus expression is \( E = \sigma / \varepsilon \). The concept about \( \sigma \) is the stress in the range of elastic deformation and then the symbol about \( \varepsilon \) refers to the strain as the relative settlement. Asphalt mixture is a multivariate material and the external environment including temperature, traffic load and humidity have influences on its modulus. Therefore, the testing temperature should get command of fifteen degree centigrade in splitting strength and resilient modulus tests. In this temperature, the splitting resilient modulus can maintain stabilization relatively.

According to the uniaxial compression test in Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering JTG E20-2011, the resilient deformation values from stepping loading are measured to calculation the compressive resilient modulus. The splitting resilient modulus test can be put forward on the basis of compression method.

3. Testing methods of splitting resilient modulus

From the comparison of the method about compressive resilient modulus, the testing processes in AC-13 asphalt mixture splitting resilient modulus are described.

(1) The AC-13C Marshall specimens are shaped and the fixture containing 12.7mm wide and 50.8mm inner curvature is chosen. The specimens are kept by the temperature for more than 6 hours in fifteen degree centigrade.

(2) The process of splitting test are as follows. The loading rate in material machine is 50mm/min. The curves about load-time and vertical deformation-time are recalled in succession. Turn on the material machine, keep the load head on the fixture and adjust the data system. The specimens are loaded to destroy at a specified rate. The splitting test is in Figure 1:

![Figure 1. Splitting test](image.jpg)

(3) Many groups of corresponding splitting experiments are implemented to record the average of maximum splitting strength PT. The value about splitting strength is divided into ten ranks and then the first seventh are selected as stepping loading including 0.1P, 0.2P, 0.3P, 0.4P, 0.5P, 0.6P and 0.7P. The loading procedure is set as 2mm/min loading rate in material machine. The splitting resilient test is in Figure 2:
(4) There has a compaction lasting one minute with the rate of 2mm/min to 0.2P. The material machine can read the vertical displacement automatically without using dial gauge to record the loading and unloading numbers.

(5) Being turned the first load 0.1P in the rate of 2mm/min and then discharged to zero, the specimen is waited for a bounce lasting for thirty seconds. The testing system can draw a deformation-time curve in this loading circulation by itself. Besides, the processes about loading and unloading including the second to seventh stage are carrying out. The resilient deformation is the difference between the deformation in certain load and the unloading deformation after thirty seconds resilience. The material properties appear not full elasticity but partial irrecoverable deformation. The stepping loading curve is in Figure 3 and the deformation curve is in Figure 4:

![Figure 3. Stepping Load](image1.jpg)  ![Figure 4. Stepping deformation](image2.jpg)

(6) Both the grade five load (N) and the resilient deformation (mm) are recorded. According to the Standard Test Methods, the stiffness modulus expression in splitting condition is as follows:

\[ ST = PT \times \left(0.27 + \mu\right) / \left(h \times XT\right) \]  

This expression is applied to the splitting test in 50mm/min loading rate. The loading rate is too quick to reflect the plasticity and creep properties. The modulus status appear as elastic condition. The stiffness modulus is related to the loading time and testing temperature. The testing conditions include the fifteen degree centigrade about temperature and fifty millimeter per minute about loading rate. Every samples are being tested under the same conditions. \( PT \) in stiffness modulus expression represents the maximum load in splitting destruction and \( XT \) stands for the horizontal displacement which is correlated with \( Y_T \) vertical deformation. Similarly, \( P_T \) reflects the grade five load and \( Y_T \) is the grade five resilient deformation. In terms of the above relationships, \( ST \) can correspond to the splitting resilient modulus \( E \) in stepping load:

\[ E = ST = PT \times \left(0.27 + \mu\right) / \left(h \times XT\right) \]
\[ XT = YT \times \frac{(0.135+0.5\mu)}{(1.794+0.0314\mu)} \]  

(3)

The testing temperature should be strictly controlled in fifteen degree centigrade so that the Poisson’s ratio of asphalt mixture is 0.3. The mathematical expression can be deduced:

\[ E = \frac{3.608 \times PT}{(h \times YT)} \]  

(4)

\( P_T \) is the grade five load (N); \( Y_T \) is the grade five resilient deformation (mm); \( h \) is specimen height (mm).

4. Results of splitting resilient modulus

In line with the above mentioned testing flow, the values about the grade five load and resilient deformation can be obtained. Contrasting the testing results and the design parameters about asphalt mixture compressive resilient modulus \( E \) is in Table 1.

| Asphalt Mixture | Specimen | Grade five load(N) | Grade five resilient deformation(mm) | Splitting resilient modulus(MPa) |
|-----------------|----------|--------------------|--------------------------------------|--------------------------------|
| AC-13           | Sample1  | 6240               | 0.192                                | 1847                           |
|                 | Sample2  | 6310               | 0.186                                | 1928                           |
|                 | Sample3  | 6290               | 0.173                                | 2066                           |
|                 | Sample4  | 6360               | 0.193                                | 1872                           |

Design parameter ranges of AC-13 asphalt mixture(15℃ tensile stress) 1800MPa-2200MPa

According to the Table 1 analysis, the results show that the splitting resilient modulus are in the context of tensile stress in fifteen degree centigrade and it is effective to measure the splitting resilient modulus by using stepping load method.

5. Conclusion

(1) Contrasting with testing methods of compressive resilient modulus, the methods of splitting resilient modulus are put forward tentatively. The splitting modulus mathematical expression -- \( E = \frac{3.608 \times PT}{(h \times YT)} \) can be deduced to calculate the values about splitting resilient modulus in stepping load. But both the loading rate and testing temperature should be strictly controlled when using this expression.

(2) The resilient modulus values which are measured by splitting resilient methods can meet the ranges of design parameters. This calculating methods about splitting testing can be available to compare the bottom layer tensile stress in splitting model with the allowable tensile stress in splitting test.

Acknowledgments
This work is supported by National Natural Science Foundation of China (NSFC) Grants (11072041), by Hunan province Natural Science Foundation Grants of China (10JJ6065) and by educational reform key project of Changsha University of Science and Technology (JG1102).

References
[1] JTG D50-2006, Specifications for Design of Highway Asphalt Pavement [S]. Beijing:China Communications Press, 2006: 30-35.
[2] LUO Zuo-fen,ZHENG Zhuan-chao. Research on the Resilient Modulus of the Asphalt Mixture under Splitting Loading [J]. JOURNAL OF HEBEI UNIVERSITY OF TECHNOLOGY, 2010, 39(3): 107-111.
[3] A.M.Hartman ect.Effect of Mixture Compaction on Indirect Tensile Stiffness and Fatigue [J]. Journal of Transportation Engineering, 2001, 9:370-378.
[4] LU Song-tao,CHEN Jie. Study on Stiffness Decay Regularity of Asphalt Mixture Based on
Accelerated Loading Test [J]. Journal of Highway and Transportation Research and Development, 2016, 33(5): 1-5.

[5] JTG E20-2011, Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering [S]. Beijing: China Communications Press, 2011: 253-258.

[6] TAN Zhi-ming, YU Xin-hua. Calculation of Sectional Flexural Stiffness Equivalent Modulus of Asphalt Pavement [J]. China Journal of Highway and Transport, 2012, 25(6): 37-42.

[7] SHRP Designation: M-009. Standard Method of Test for Determining the Fatigue Life of Compacted Bituminous Mixtures Subjected to Repeated Flexural Bending [M]. NCHRP. 1995.

[8] LI Yan-wei, MU Ke, SHI Xin, WANG Xuan-cang. Impact of Base-surface Contact Conditions on Mechanical Response of Asphalt Pavement [J]. Journal of Chang’an University (Natural Science Edition), 2014, 34(2): 38-44.

[9] Research Institute of Highway, Ministry of Communication Study of Dynamic Characteristic of Pavement Structure [R]. Beijing: Research Institute of Highway Ministry of Communications, 1999.