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# Evaluating fatigue behavior of asphalt mixtures under alternate tension–compression loading model using new alternate biaxial splitting method

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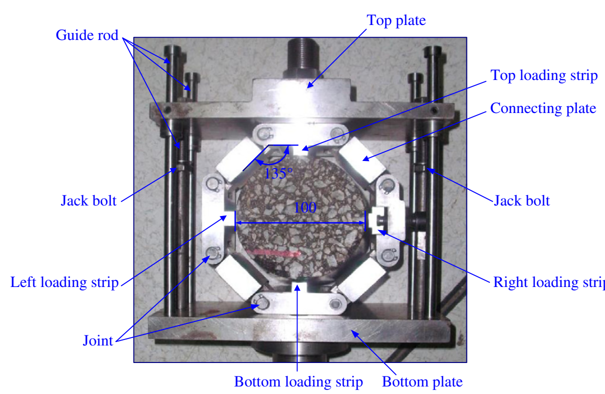
## HIGHLIGHTS

- An alternative biaxial splitting (ABS) fixture has been developed.
- Fatigue behavior of asphalt mixtures under a tension–compression loading mode has been analyzed.
- The laboratory fatigue life of the ABS test samples was longer than that of the IDT test.
- The creep effect of compressive stress produced increased fatigue life of asphalt mixtures.

## GRAPHICAL ABSTRACT

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## ABSTRACT

The primary purpose of this study is to develop a new test method with a self-developed alternate biaxial splitting (ABS) fixture for evaluating fatigue behavior of asphalt mixtures under a tension–compression loading mode using new alternate biaxial splitting method. A comparison was performed in the indirect tension (IDT) and ABS test on laboratory-mixed asphalt concrete (AC-13) with an optimum asphalt content of 4.7%. The results showed that the strain growth rate of the asphalt samples in the ABS fatigue test increased slower than that of in the IDT fatigue test with an increase in loading cycles. When the damage evolution in the asphalt samples under fatigue loading reached the steady state, the ratio of damage change (RDC) of IDT fatigue testing samples changed little maintaining greater than zero all the time. In contrast, the RDC of ABS fatigue testing samples had an alternate positive–negative variation. The laboratory fatigue life of the ABS test was 4–23 times more than that of the IDT test at a constant temperature of 20 °C. It demonstrated that the creep effect of compressive stress promoted the healing of micro-cracks and produced increased fatigue life.



## 1. Introduction

Fatigue cracking is one of the most influential distresses that govern the service life of asphalt pavements. Fatigue is a phenomenon in which a pavement is subjected to cyclic stress levels typically less than the ultimate failure stress. Overall understanding of this cracking phenomenon suggests that these cycles create areas of tensile stresses at the bottom of the pavement layer, which cause the initiation of micro-cracks. Under repeated loadings, these micro-cracks densify, propagate, and eventually develop into more visible macro-cracks on the pavement surface [1–3]. A precise

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**Table 1**
Volume index of AC-13.

| Sample ID | Gyrations | $G_m$ | $G_t$ | $V_v$ | VMA | VFA |
|---|---|---|---|---|---|---|
| 1 | 100 | 2.449 | 2.551 | 3.998 | 15.08 | 73.49 |
| 2 | 100 | 2.447 | 2.551 | 4.077 | 15.22 | 73.21 |
| 3 | 100 | 2.447 | 2.551 | 4.077 | 15.15 | 73.09 |
| 4 | 100 | 2.448 | 2.551 | 4.038 | 15.13 | 73.31 |
| 5 | 100 | 2.449 | 2.551 | 3.998 | 15.21 | 73.71 |
| Average | 100 | 2.448 | 2.551 | 4.038 | 15.16 | 73.36 |

where $G_m$ is the bulk specific gravity; $G_t$ the theoretical specific gravity; $V_v$ the air voids (%); VMA the voids in mineral aggregate (%); and VFA is the voids filled with asphalt (%).

understanding of the fatigue behavior of asphalt mixtures is required in order to improve asphalt mixture design and performance. However, accurate prediction and evaluation of fatigue is a difficult task not only because of the complex nature of fatigue phenomena but also because of characteristics of fatigue testing [4–6]. Over the past 40 years, many diverse fatigue tests have been developed to simulate the fatigue behavior of asphalt mixtures with varying success. These fatigue tests can be basically categorized into the following types according to experimental samples, beam sample (two-, three-, and four-point bending and fracture mechanics tests), cylinder sample (direct tension, indirect tension and triaxial tests), full-scale testing pavement (wheel tracking test). Among the above fatigue tests, the indirect tension (IDT) test is a practical and cheap configuration for testing of asphalt concrete, as asphalt concrete samples are often cylindrical in shape. Moreover, the cylinder sample can be produced by a laboratory cylindrical shaped mold during compaction or taken from the field by a core barrel. Considering from the cost, simplicity and convenience, the IDT fatigue test had been adopted widely by

**Table 2**
Results of the spitting strength.

| Test sample # | Maximum load/N | Std. dev | COV (Coefficient of Variation)/% | Average load/N |
|---|---|---|---|---|
| 1 | 12,525 | 524.74 | 4.47 | 11,736 |
| 2 | 11,083 | | | |
| 3 | 11,681 | | | |
| 4 | 11,358 | | | |
| 5 | 12,147 | | | |
| 6 | 11,622 | | | |

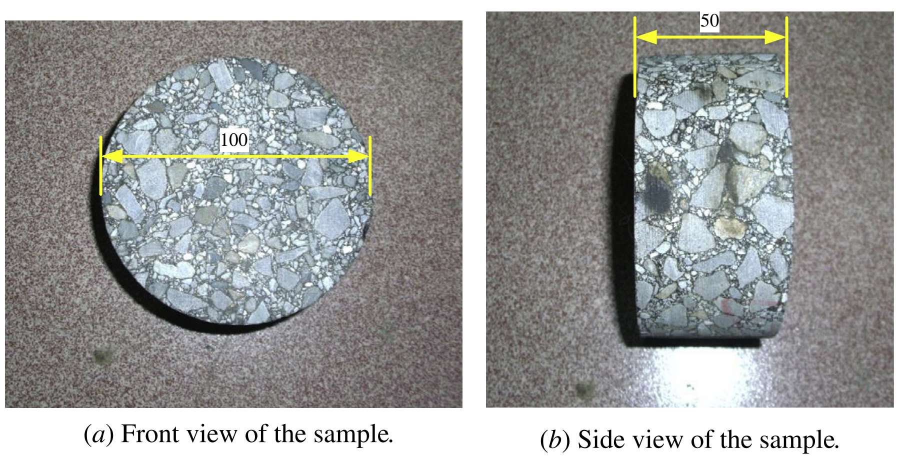


**Fig. 1.** Representational samples used in the fatigue test (scale unit, mm).

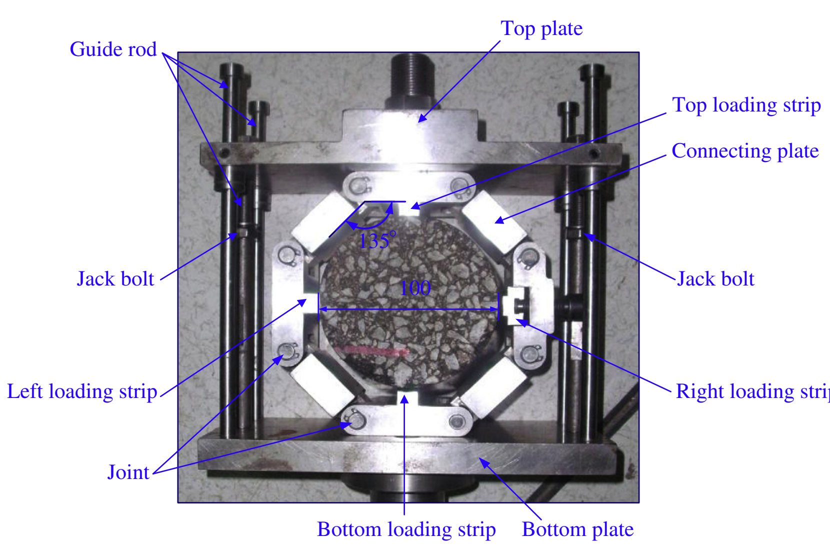


**Fig. 2.** Front view of the ABS fixture (units: degree for angle, mm for length).