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# Dynamic testing of hot mix asphalt for moisture susceptibility assessment

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## HIGHLIGHTS

- A rutting prediction model (Ohio State Model) was used to predict moisture susceptibility of asphalt mixtures.
- The Ohio State Model showed promising results.
- Different testing and moisture conditions showed a difference in the model parameters.

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ABSTRACT

Moisture sensitivity testing of asphalt mixtures is critical for ensuring performance expectations are met. Moisture susceptibility is most commonly tested using the modified Lottman test. The shift towards mechanistic design calls for the utilization of a more fundamental test to evaluate moisture damage. This paper studies the possibility of using the flow number test with different ways of analysis to study its applicability for moisture susceptibility evaluation. Sixteen field procured mixtures were subjected to four different modes of moisture conditioning: (1) unconditioned without water submersion testing, (2) moisture saturation with water submersion testing, (3) moisture saturation with freeze/thaw conditioning without water submersion testing, and (4) moisture saturation with freeze/thaw conditioning and with water submersion testing. These samples were subjected to flow number testing. The Ohio State Model for rutting analysis was used to analyze the results. The results were then compared to the results from the modified Lottman test. Using the flow number test setup and analyzing the results using the Ohio State Model showed good potential in predicting moisture susceptibility. The data showed good consistency but a comparison to field performance is needed to identify whether the results are correlated to field performance or not.



## 1. Introduction

The presence of water in pavements can be detrimental if combined with other factors such as freeze–thaw cycling. Many factors can affect the moisture sensitivity of a mix, and can be divided into three main categories. The first category is the material properties, which include the physical and chemical properties of the asphalt and the aggregates. The second category is the mixture properties, which include asphalt content, film thickness, and the permeability of the mixture (interconnectivity of the air voids). The third category is the external factors; these factors include construction, traffic, and environmental factors [10]. This paper focuses on the use of flow number test to estimate the moisture susceptibility potential of asphalt mixtures using different analysis techniques. The Ohio State Model is used as an analysis tool for the test results.

## 2. Background

Moisture damage has been a major concern to asphalt technologists for many years. Researchers have been searching for a test that differentiates between good and poor performing asphalt concrete mixtures for stripping potential since the 1920's [12]. Since the 1920's, it has been known that the problem relates to the loss of adhesion between asphalt and aggregate and the loss of cohesion within the asphalt binder. The challenge has been to find a test that identifies moisture susceptible mixes [12]. The standard test in the United State used to identify the moisture susceptibility of asphalt mixtures is the modified Lottman test, American Association of State Highway and Transportation Officials (AASHTO) T283. AASHTO T283 was used with Marshall mix design methodology and with

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the development of the Superpave mix design methodology, the same method was adopted with the modification of the compaction method. Although AASHTO T283 has been used for many years as the standard test for moisture sensitivity, it assists in minimizing the problem by identifying some of the mixes susceptible to moisture damage and it does not appear to be a very accurate indicator of stripping [4]. Two of the tests that have the potential to replace indirect tensile strength testing contained within AASHTO T283 are the dynamic modulus and flow number tests. The advantage of using these two tests is that they are performed by the Asphalt Mixture Performance Tester (AMPT) and can be used to estimate the mixture performance within a pavement structure in mechanistic pavement design. The flow number test was studied in National Cooperative Highway Research Project (NCHRP) Report 589 [11] as a candidate test for moisture susceptibility evaluation and the results of that research were not in favor of using the flow number test in moisture susceptibility evaluation. The objective of this paper is to evaluate the use of the flow number tests in moisture susceptibility evaluation by applying the Ohio State Model in analyzing the results.

### 2.1. Repeated load creep test (flow number) test

The flow number test (i.e. repeated load test, dynamic creep test) is based on the repeated loading and unloading of an HMA specimen where the permanent deformation of a specimen is recorded as a function of the number of load cycles. The stress applied to the specimen is divided into two parts: seating stress and deviator stress. The deviator stress is applied for 0.1 s followed by a 0.9 s rest period for the specimen at the seating stress. There are three types of phases that occur during a repeated load test: primary, secondary, and tertiary flow. In the primary flow region, there is a decrease in strain rate with time followed by a constant strain rate in the secondary flow region, and finally an increase in strain rate in the tertiary flow region. Tertiary flow signifies that a specimen is beginning to deform significantly and the individual aggregate that makes up the skeleton of the mix is moving past each other or beginning to "flow". The flow number is based upon the onset of tertiary flow (or the minimum strain rate recorded during the course of the test; [13]. The following description is shown graphically in Fig. 1.

Flow number is defined as the number of load applications when shear deformation begins [13]. Flow number testing is similar to pavement loading because pavement loading is not continuous; there is a dwell period between loadings. This allows a pavement a certain amount of time to recover some strain induced by the loading. There is good correlation between field performance and the flow number. The flow number test could be used as a means of comparing mixes for rutting susceptibility [14]. It was reported in NCHRP Report 589 that flow number test results are not satisfactory when it comes to moisture damage prediction [11].

### 2.2. Ohio State Model

One way to analyze the flow number test results is by using the Ohio State Model. This model is presented by Huang [5]. It assumes a linear relationship between log of the strain and log of the number of load repetitions. The formula of this relationship is:

$$\frac{\varepsilon_p}{N} = A(N)^{-m} \quad (1)$$

where $\varepsilon_p$ is permanent strain at a specific loading cycle, $N$ is the loading cycle, and $A$ and $m$ are regression constants.

Khedr [6] analyzed the parameters of this relationship and concluded that the parameter ($m$) is dependent on the material type. Stress–strain pattern and intensity, stress level, and dissipated plastic strain energy during the dynamic loading affect the parameter ($A$). The lines achieved are nearly parallel, which means that ($m$) is constant for all samples of the same material tested under various conditions and is independent of the stress level and temperature, as shown in Fig. 2. Studying the parameter ($A$) and applying regression analysis, the result achieved showed that ($A$) is a function of the applied deviator stress and the resilient modulus.

The relationship between log $A$ and log ($M_R/\sigma_d$) is a straight line as presented in Fig. 3 [6].

$$A = a\left(\frac{M_R}{\sigma_d}\right)^{-b} \quad (2)$$

where $A$ is the regression constant from Eq. (1), $M_R$ is the resilient modulus, $\sigma_d$ is the applied deviator stress, and $a$ and $b$ are material dependent regression constants.

Majidzadeh et al. [7] applied these two relationships. They tested specimens by varying the deviator stress and the temperature. The variation in parameter ($m$) came out to be insignificant. They generalized the results by taking an average value for ($m$) which represents the all tested samples and then calculated the normalized value of the parameter ($A$). The relationship (2) was

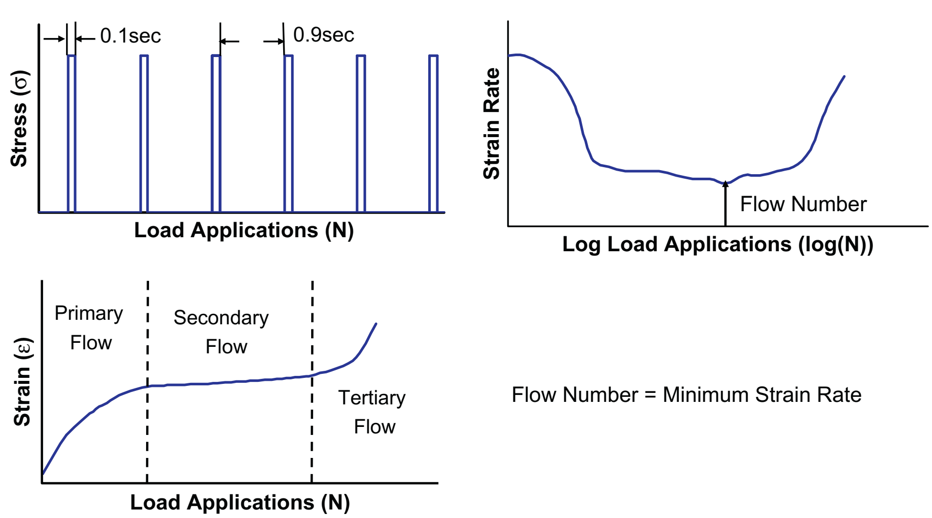


**Fig. 1.** Flow number loading ([9]).