

DESIGN OF BINDER COURSE BITUMINOUS  
CONCRETE PAVEMENT MIXTURES



MICHIGAN DEPARTMENT OF  
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CONCRETE PAVEMENT MIXTURES

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## Introduction

A study of bituminous binder and leveling course mixes conducted at the University of Michigan by Egons Tons (1) indicated that while these mixes have served quite well from the standpoint of stability and durability, they exhibit some cracking and raveling, and have a tendency to segregate under certain conditions of handling. The report suggested that a redesign of the mixes with emphasis towards "uniform, dense, gradation" may be beneficial. From the laboratory work it was concluded that two new mixes should be superior to the presently used 9A mix for the binder course in terms of stability, resistance to cracking at low temperatures, uniformity and appearance, less segregation, less crushing of rock particles during compaction, and reduced moisture effects and stripping of asphalt from particle surfaces.

A study of transverse cracking of flexible pavements in Michigan has just been completed by the Research Laboratory. In this study, roughly 300 miles of flexible pavement were surveyed to determine the frequency of occurrence of transverse cracks. During the survey it was noted that surface cracking of all types is the predominant source of flexible pavement failure. Samples of the binder and wearing course layers were collected and tested in the laboratory to determine the tensile strength of each layer. It was found that the tensile strength of the binder course layer is about one-half that of the wearing course layer.

It is the purpose of this paper to point out that it is the tensile strength properties of the bituminous concrete that determine its resistance to cracking failure and to support Ref. (1) in suggesting that field performance of flexible pavements can be improved by replacement of the presently used binder course mix with mixes of superior strength properties.

## Background Information

In general, flexible pavement design involves the determination of thicknesses and stabilities of the various layers in the pavement structure to ensure that traffic loads and environmental effects are within permissible limits. Defining stability and determining its permissible limits have long been problems for highway engineers but, for the last 10 years or so, it has been internationally accepted that stability can be defined in terms of the layers' elastic properties and permissible limits in terms of allowable stresses and strains. In other words, the pavement is considered a multi-layer elastic system for which stress and strain can be determined at any point in the system for any given applied load. Figure 1 is a typical three-layer system frequently used for rational pavement design. Extensive studies explained in Ref. (2) indicate that flexible pavements fail either as a result of excessive compressive strain in the subgrade which causes pavement failure in the form of rutting and shoving of its surface, or excessive

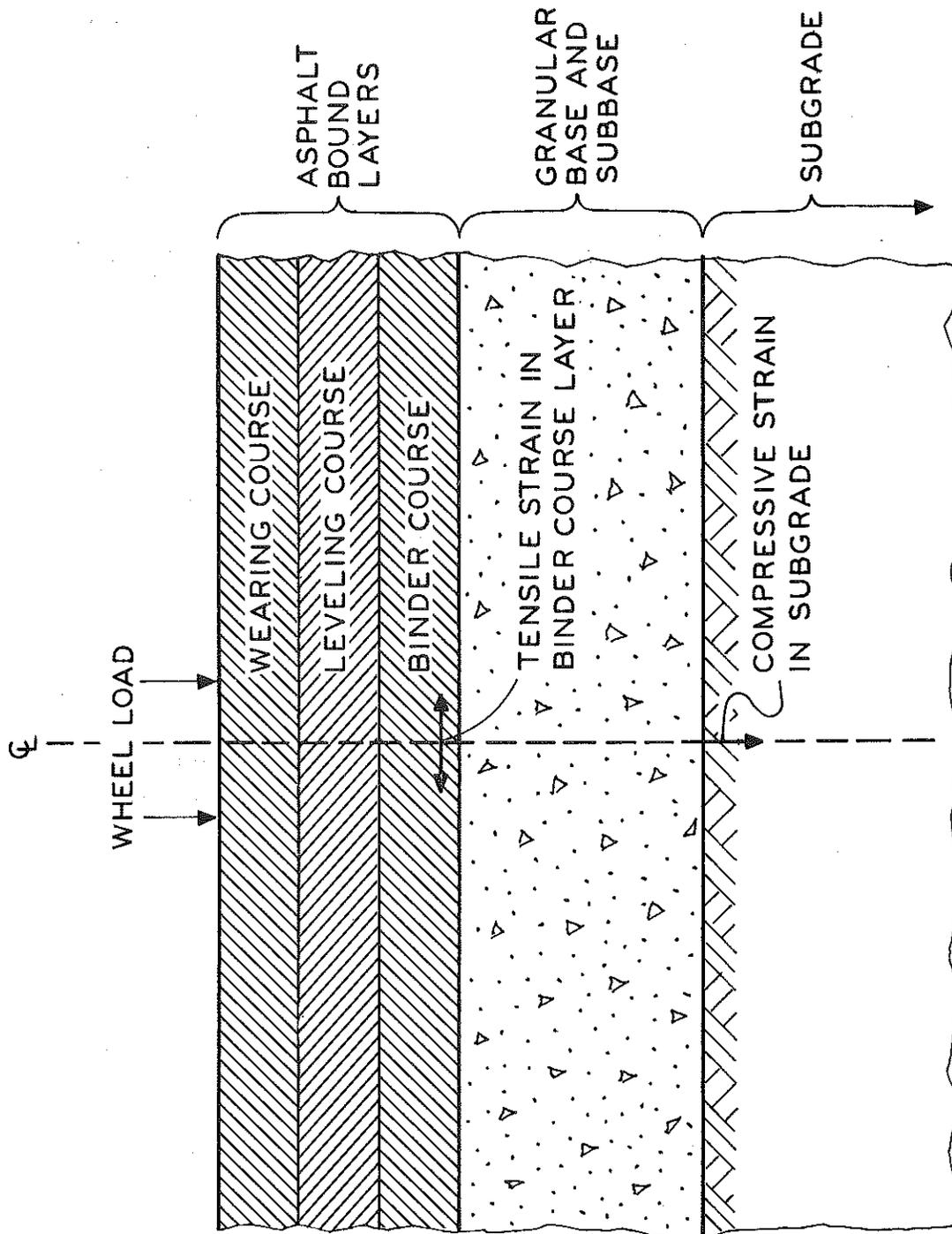


Figure 1. Schematic diagram of a three-layer pavement structure.

tensile strain in the bottom fiber of the asphalt bound layers in which case failure occurs as surface cracking. Since cracking is the predominant source of flexible pavement failure in Michigan it is clear that the source of failure is excessive strains in the bottom fibers of the binder course layer. However, present mix design methods do not consider the ability of binder course mixtures to resist tensile stress or strain.

#### Description of the Laboratory Study

Samples in the form of 6-in. diameter cores, were obtained from sections of Routes 31 and 27, and sawed into 1-1/2 by 1-1/2 by 4-in. prisms. Two side-by-side samples were cut from the wearing course layer and two from the binder course layer. Due to slight variations in layer thickness one side of the binder and wearing course samples include as much as 1/4-in. of the leveling course layer. This may affect the reported tensile strength of the samples but the total effect should not be large. Testing was conducted by subjecting the samples to a tensile load such that they should not break before a half-hour loading time. If the sample did not break within the first one hour loading time the load was increased by 100 lb increments for one hour intervals until the sample finally broke.

It is important to note that because the tensile strength of bituminous mixes is time dependent for any given breaking stress, the longer the loading time the greater is the material's tensile strength, i.e., if two samples have a breaking stress for 500 psi but loading times are one and two hours, respectively, the sample that broke in two hours has greater tensile strength. Since the tensile strength results indicate that samples with greater breaking stress generally have longer loading time the real difference between high and low breaking stress samples is greater than indicated. In the future, plans are to use a testing procedure which will enable reporting breaking stress at a given loading time, such as one hour. This would permit direct comparison of tensile strength values.

#### Analysis of Results

Strength tests of 44 binder and 55 wearing course samples indicate the mean tensile strengths, at 0 F, are 142.00 and 260.34 psi, respectively. That is, wearing course samples tested have on the average 1.8 times the tensile strength of the binder course samples. The significance of this finding is that the binder course layer, which is subjected to greatest tensile stress, has the weakest tensile strength. Hence, it would appear as if the cracking performance of Michigan flexible pavements could be improved by increasing the tensile strength of the binder course mixture.

Under moving traffic, the upper layers of the pavement flex with each load application. Calculations by Jones (3) and Dormon (4) using the elastic theory have shown that the critical tensile strain occurs at the bottom

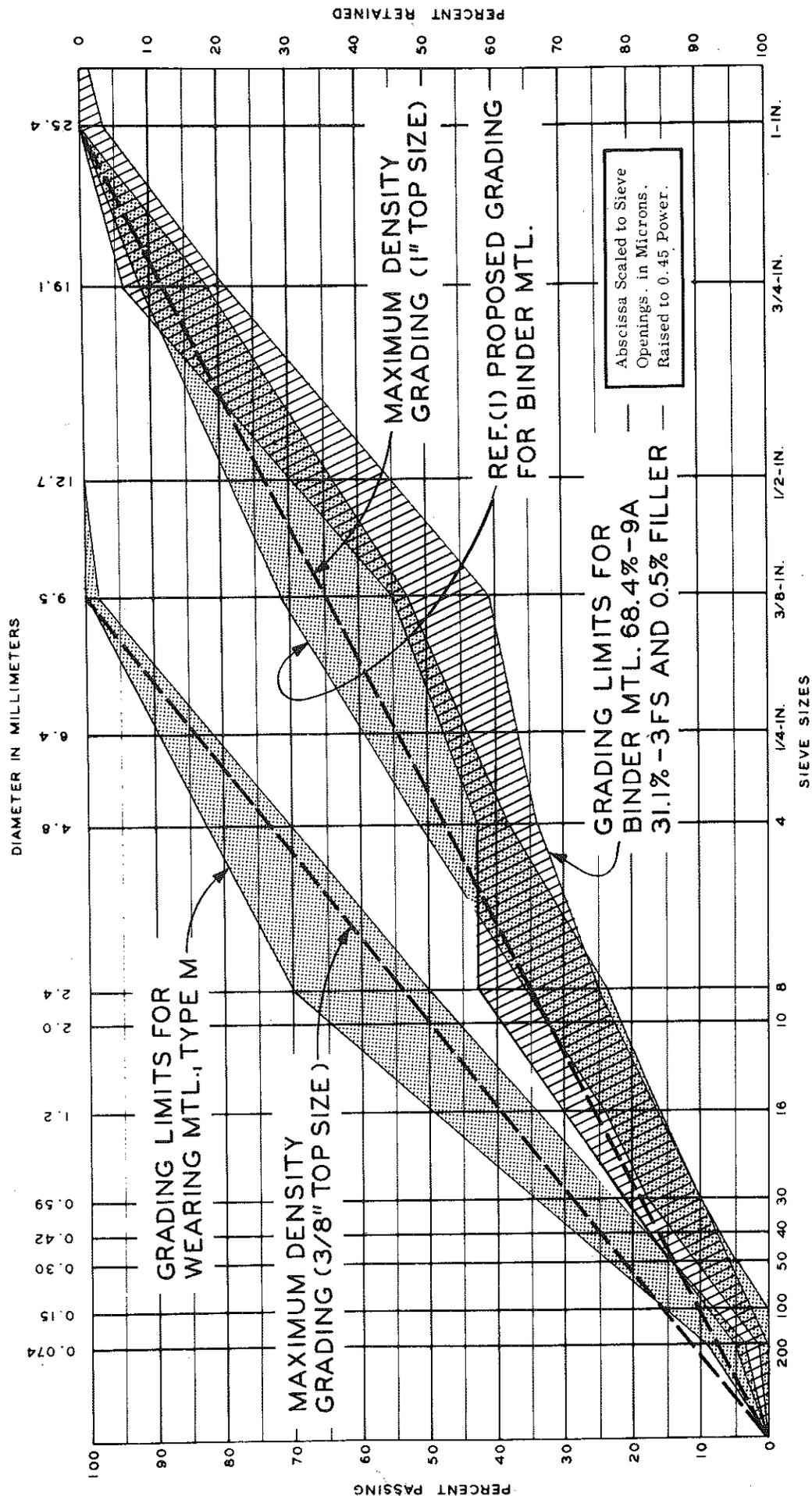


Figure 2. Aggregate gradations for bituminous mixes.

of the binder course, and if this strain is excessive, the surface will fail through cracking. Stresses and strains at other locations have been evaluated but they have not yet been found to be critical (2). Therefore, it is presently considered that a pavement structure will provide crack-free service if the allowable strain at the bottom of the binder course layer is not exceeded by the load induced strain. Allowable strains have been developed by Dormon and Metcalf (5) and are used for rational pavement design.

The fact that surface cracking is the predominant form of flexible pavement failure in Michigan indicates that traffic loading is exceeding the allowable tensile strain of the binder course layer. To correct this situation, load induced strains can be reduced by increasing the stiffness of the base, subgrade, or both. However, increasing base or subgrade stiffness is usually expensive. The same results may be achieved, at less cost, by increasing the tensile strength of the binder course which will in turn increase its allowable tensile strain. The easiest way to increase tensile strength is to use wearing course mixtures for the binder course layer. In this way the binder layer would have significantly greater tensile strength which is needed to improve cracking performance; moreover, Department personnel are accustomed to working with this material. Figure 2 illustrates the difference in gradation limits for specification binder and wearing course materials compared to the limits proposed by Ref. (1).

#### Discussion

The laboratory study conducted in Ref. (1), using conventional test methods, indicated that binder course performance may be improved through the use of densely graded aggregate. Such mixes should have the advantage of maximum tensile strength at minimum asphalt content but their tensile strength characteristics relative to other aggregate gradings is not known. That is why it is suggested that, for the present, flexible pavement performance can be improved by the use of wearing course mixtures for both wearing and binder course layers and that a laboratory study be conducted to determine if the advantages of using dense aggregate gradings recommended in Ref. (1) would result in obtaining greater tensile strength.

#### Conclusions

Specific conclusions are as follows:

1. Surface cracking is the most significant cause of flexible pavement failure in Michigan. However, the bituminous material properties which govern resistance to cracking, tensile strength and fatigue properties, are not considered in our mix designs.

2. Because bituminous concrete mixtures used for wearing courses have greater tensile strengths than do those used for binder mixtures, the

use of wearing mixtures for the binder course layer should improve cracking performance of flexible pavements.

3. The bituminous concrete pavement mixtures recommended in Ref. (1) appear to be desirable binder course mixtures because they should have high tensile strength, in addition to other stated advantages, at relatively low asphalt contents. However, another laboratory study should be conducted to determine if the recommended mixtures have a tensile strength advantage over other mix designs.

4. There is a need for research leading to mix designs which are more resistant to cracking.

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