Michigan Department of Transportation - M•DOT

# Mates

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## WHAT'S NEW IN FLEXIBLE PAVEMENT RESEARCH?

The soils and bituminous group in the Pavement Technology Unit is actively engaged in a project that should provide Michigan with a substantial amount of new information on the factors involved in the structural design of flexible pavements.

An earlier **MATES** article (**MATES** Issue No. 43) described Michigan's involvement in the Strategic Highway Research Program (SHRP). SHRP is a five-year, $150 million national research program that was initiated in 1987 and established to focus on the major pavement performance problems facing highway agencies. One of the study's categories is the long-term performance of pavements (LTPP), part of which is devoted to Specific Pavement Studies (SPS). A major part of the SPS study is to evaluate the relationships among the structural factors for designing flexible pavements.

Michigan has made a strong commitment to participate in and support SHRP. The future relocation of US 27 to the east of St. Johns will have SHRP-SPS bituminous pavement test sections constructed in the southbound lanes. The project is currently in the design phase and is scheduled for letting in the latter part of 1992. The project on US 27 will include 12 different pavement cross-sections with variation in layer thickness and types of materials. Each section will be 700 ft long and will be constructed at the same time, so all the sections will have the same traffic loading and environmental conditions. When combined with other special sections to be constructed in other regions of the country, SHRP researchers will examine how the combined effects of environment, subgrade soil type, and traffic loading affect the performance of different structural designs.

The sections on US 27 will have a combined bituminous wearing and leveling course thickness of either 4 or 7 in. Base materials will either be dense-graded gravel, open-graded asphalt-treated gravel, or dense-graded asphalt-treated gravel (similar to our bituminous base). Base thickness will be either 8 or 12 in. for undrained sections and 8, 12, or 16 in. for drained sections. Drainage will consist of internal pipe underdrains when open-graded bases are used.

Each nationwide SPS project site is selected geographically according to relative environmental factors that include rainfall frequency, temperature, and the number of freeze-thaw cycles. Michigan has been placed in the wet-freeze climatic region. Each SPS project site is also designed for either a sand or clay subgrade soil. The US 27 test pavement sections will be constructed directly on a clay soil subgrade without a sand subbase. Typically, the soil in the project area consists of silty clays (Morley, Blount, and Pewamo series).

It has been past practice in Michigan to construct a rigid pavement when these soil conditions are encountered because of the importance of proper subgrade support for flexible pavements. However, because of Michigan's commitment to be part of the national data base that will result from these SHRP-SPS projects, we are willing to accept the possibility that some designs will fail prematurely, while others will have longterm success. Only by doing this can a direct comparison be made of the performance of various designs. US 27 was the only Michigan project that met the criteria and time schedule established by SHRP.

A primary objective of the SHRP-LTPP program is to develop a method, or methods, to pass-on pavement performance know-how. Many aspects of how and why a particular pavement performs remain a mystery today despite an extensive amount of construction and study of different pavement cross-sections. The situation continues because there has not been a reliable method for carrying experience from one project to another while still considering the many factors that affect performance. Mixed results have occurred when a new technology has been tried without first having an understanding of the site circumstances under which it was constructed.

Michigan, along with many other states, relies on pavement performance and design relationships that were developed from the AASHO Road Test conducted between 1958 and 1960 near Ottawa, Illinois. This was a massive project that came at an important time in the nation's highway construction program. Additional projects across the nation were supposed to follow, in order to identify the effects that climatic and soil type differences had on performance. Unfortunately, these projects were not carried out and the states have had to adjust the results of the Test Road to fit their own conditions, mostly by trial and error. Michigan constructed a test road north of Clare on US 10 which provided data on sand subgrade, but the St. Johns project will be our first on clay subgrade. The SHRP-LTPP program could be considered an extension of the performance factors across geographic lines.

Because pavements age slowly, the SHRP-LTPP program is scheduled to continue for 20 years. Fortunately, it will not be necessary to wait until the program is finished to receive some benefits. There have already been some valuable benefits resulting from the SHRP program, namely: 1) engineers have had to agree on several definitions of terms to foster coherent communication in areas like traffic measurement, distress identification descriptions, pavement profile descriptions, and which material properties to evaluate; 2) there has been universal agreement at the national level to find solutions for common issues like rutting and stripping in bituminous surfaces, and aggregate durability in concrete pavements; and, 3) there is more recognition of the need to find analytical solutions for performance problems occurring with pavements. Many engineers involved with the SHRP program expect the final results to improve our ability to predict the future performance of pavements.

This is but one phase of M&T's involvement in bituminous studies. Subsequent articles will deal with a cooperative research project with Michigan State University on the problem of pavement rutting, and on the recently conducted federal demonstration project using SMA (stone mastic asphalt).

-Dave Smiley

## JOINTED PORTLAND CEMENT CONCRETE PAVEMENTS: MICHIGAN'S EXPERIENCE

Research on concrete pavements began 100 years ago and continues today, with nationwide efforts of the Strategic Highway Research Program (SHRP) as well as numerous experimental projects in the various states. MDOT is preparing plans for a modern concrete test road to be included in the national SHRP evaluation. It is scheduled for construction in 1992, on northbound US 23 just north of the Ohio state line. It will include sections of differing widths, strengths, and thicknesses, having various types of base and drainage beneath the pavement. These sections will be compared with each other, as well as with similar pavements in different environments throughout the country. The southbound roadway, scheduled for construction the following year, is to have experimental sections made with



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different types of coarse aggregates, to evaluate their relative performance in resisting freezing and thawing.

The very basic physical properties of concrete need to be understood and adequately addressed if pavements are to perform as intended. Concrete is very strong in compression, but comparatively weak in tension. Portland cement generates heat while setting and curing, so a pavement placed on a hot summer day may take its final solid shape at quite a high temperature (130 to 150 F). It then shrinks when it cools, and may crack in the process if the surface cools much faster than the interior. Curing of the concrete causes additional shrinkage, due to chemical reactions that occur.

Concrete also shrinks when it dries and expands again when wet, so the outdoor exposure causes continual changes in length of the pavement slabs. Curing and drying can cause length changes comparable to those caused by temperature. Length change in a 100-ft pavement slab caused by the temperature fluctuation between summer and winter, is about 1/2 in. Due to these various causes of shrinkage, along with the loading applied by traffic, concrete pavements tend to crack. It was determined many years ago that such pavements needed to have joints (that is, grooves cut part way through, and across the new concrete slab) which force the cracks to follow these weakened straight lines. Otherwise, the cracks would occur randomly across the pavement. These grooves are called contraction joints.

It soon became obvious that if such joints were not sealed, sand and other incompressible materials would get in during the winter, and there would not be enough room for the expansion that needed to occur the next summer. Tremendous pressures could build up, causing damage to the pavement or to adjacent bridges. Thrust of several million pounds is possible in a 24-ft roadway if there is no room to expand, when a wet pavement is heated by hot spring weather.

Therefore, joint seals have been developed to keep out incompressible materials. Expansion joints (joints that are formed completely through the fresh concrete, with a compressible filler installed across the entire pavement width) are used at some locations in the roadway. Additional expansion joints are installed if a pavement is built during cold weather because the concrete 'sets' at a low temperature. It then may expand beyond the as-cast length when heated by the summer sun. Early experience with concrete pavements was as follows: slabs crack, so use joints; joints are rough and troublesome, so make them far apart so there are fewer of them.

A test road was built in 1939 on M 115 between Clare and Cadillac to experiment with many different variations in concrete pavement. Slab length varied from about 20 ft to 99 ft between joints; short slabs had no steel reinforcement, long ones were reinforced; some joints had steel dowel bars to transfer load from one slab to another, while other joints had none; both expansion and contraction joints were used. The performance of the experimental roadways was monitored closely for several years.

Evaluation of the results of this pavement, along with other information from throughout the country, led MDOT to standardize on a 99-ft reinforced slab design, with 18-in. long steel dowel bars, 1-1/4 in. in diameter spaced 1 ft apart for load transfer across the joints. A metal baseplate was placed beneath each joint, evidently to keep sand and stones in the base from getting into the bottom of the joint. Joint grooves at the surface of the pavement were formed in the plastic concrete, 1/2 in. wide by about 2 in. deep, and filled later with asphalt sealant. Expansion joints were placed at the beginning and ending points of curves, and three such joints in a row were placed at each bridge approach to keep the pavement from applying excessive pressure to the bridge.

This design was used for many years. Experience with such pavements over about 20 years, revealed the following areas where improvements needed to be made:

1) The joint seals did not function adequately over the long run. Water, salt, and incompressible materials entered the joints.

2) Baseplates under the joints captured water and salt that caused 'rotting' of the concrete along the bottom of the joints due to freeze-thaw action. This was seriously accelerated in concrete made from certain materials that were most susceptible to such damage.

3) Joint crushing and 'blow-ups' occurred, causing traffic problems, requiring major repair efforts and sharply increasing maintenance costs.

4) Increased use of deicing chemicals caused rusting and seizure of the steel dowel (load transfer) bars in some of the joints. Pull-out loads in excess of 10,000 lb per bar caused the reinforcing steel to pull apart at mid-slab cracks, instead of permitting the joint to open when the pavement contracted.

Recognition of these problems by the early 1960s led to pavement redesign. Preformed neoprene 'compression type' joint seals were introduced in 1964-65, joint grooves were cut with diamond saws in the hardened concrete to improve ride quality, and baseplates no longer were placed beneath the joints. Specifications required more durable aggregates for concrete. Stainless steel-clad dowel bars were installed experimentally in 1958, though they became commercially unavailable before their use was widespread; and in 1975, requirements were added to mandate the use of epoxy or plastic coatings on dowel bars to improve corrosion resistance.

Nationally, experimental results have indicated improved performance for pavements with shorter slab lengths. Therefore, Michigan's reinforced concrete pavement slabs have been shortened progressively with lengths specified as follows: prior to 1964-65, 99 ft; 1964-65 to 1979, 71 ft; 1979 to 1989, 41 ft; and since 1989, freeways with heavy traffic have had slabs reduced to 27 ft.

Experience also has indicated a need for better drainage beneath the pavement and more durable aggregates. The US 10 test road at Clare, built in 1975, demonstrated the benefits of freely draining, 'open graded' drainage course (OGDC) in the base along with pipe edge-drain. Standards for concrete pavements were changed in 1980-81 to require such a base layer and edge drains beneath the pavements built since that time. Recent projects, especially those with heavy traffic volumes, have been built with aggregates having greater resistance to freeze-thaw damage.

Early freeway pavements were made 9 or 10 in. thick. However, truck volumes and weights increased more rapidly than was anticipated when these pavements were designed (in the 1940s and 50s). The pavements carried far more loading than they were designed for, and this adversely affected quality of service during the latter part of their service lives. During the past few years, new pavements on I 94 and I 75 have been made 11 and 12 in. thick, to improve their capacity for carrying present and future traffic.

Modern construction methods, such as slip-form paving, centrally mixed concrete, and more sophisticated paving equipment also have increased productivity and improved ride quality. Contractors, suppliers, and governmental agencies now are working on materials and methods to increase the speed with which concrete pavements can be placed, finished, cured, and opened to traffic. MDOT and the industry are continuing to work for high quality, long lasting pavements, to carry the traffic of Michigan's citizens, business, and industry.

-Chuck Arnold.

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