Ohio Research Institute
for Transportation
and the Environment

ORITE

Early SPS-1 Performance on the Ohio SHRP Test Road

ORITE–2(ODOT)

Introduction

Governmental agencies responsible for providing a safe and serviceable pavement infrastructure utilize construction and material specifications to maintain some minimum level of quality and uniformity throughout their system. These specifications evolve over time and, in general, are written to achieve the best overall results with currently available resources in terms of materials, technology, and funding. Since entire construction projects cannot be tested for compliance, sampling techniques have been established to control quality. Despite these efforts, localized areas in the completed pavement structure can exhibit premature distress resulting from material deficiencies, construction oversights, excess moisture, or variability within the underlying support layers. Preliminary results from the Ohio SHRP Test Road point to the Falling Weight Deflectometer (FWD) as being an effective tool for monitoring the stiffness of individual layers in the pavement structure during construction and, thereby, providing the opportunity for repairing areas of reduced support prior to completion of the pavement. By eliminating these potential problems before the pavement is opened to traffic, performance will be greatly enhanced.

Variability in subgrade and base stiffness is a major contributor to premature distress on asphalt concrete pavements, as evidenced by localized failures where heavy traffic loads either punch through the pavement or cause severe wheel path rutting and cracking associated with poor support. To illustrate the amount of variability that can occur on a given project, Falling Weight Deflectometer (FWD) data obtained on four experimental SPS-1 sections on the Ohio SHRP Test Road which failed by the summer of 1998 were examined in detail. Design parameters included in these sections are as shown at the bottom of this page.

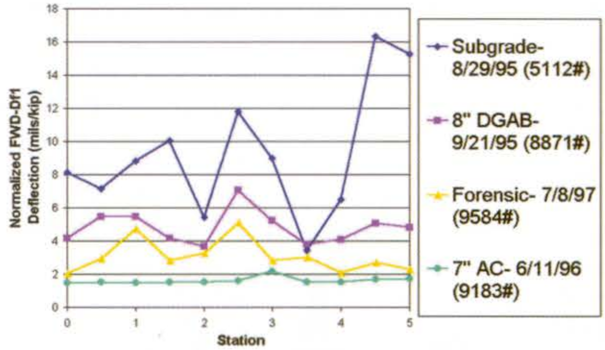
Test sections in this particular pavement, constructed for the Specific Pavement Studies (SPS) experiment in the SHRP Long Term Pavement Performance (LTPP) Program, should have exhibited excellent uniformity because of the high profile of this project and because of the following conditions surrounding it:

1. The project was located in an area of very flat topography.
2. Preliminary borings suggested a relatively uniform subgrade along the three-mile project length.
3. The project was part of a national experiment, and ODOT and LTPP placed a strong emphasis on the importance of having uniform test sections. Localized areas of weakness in any pavement layer resulting in premature failure of the section would skew the results of the experiment.
4. Provisions were made to replace any subgrade material that failed to meet ODOT specifications.
5. Extensive sampling and testing was performed throughout each phase of construction.

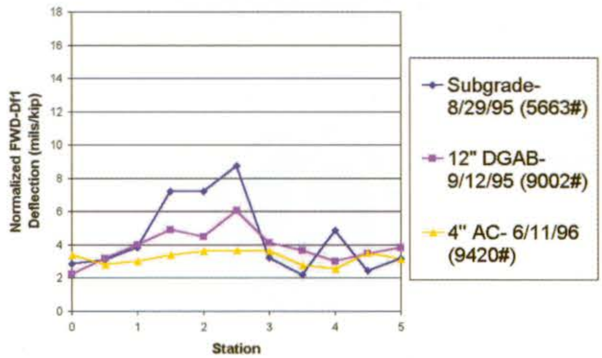
Design Parameters of Failed SPS–1 Sections

Section No.	Thickness (in.) AC	Thickness (in.) Base	Base Type	Drainage Present
390101	7	8	Dense graded aggregate	No
390102	4	12	Dense graded aggregate	No
390105	4	8	4″ ATB/ 4″ DGAB	No
390107	4	8	4″ PATB/ 4″ DGAB	Yes

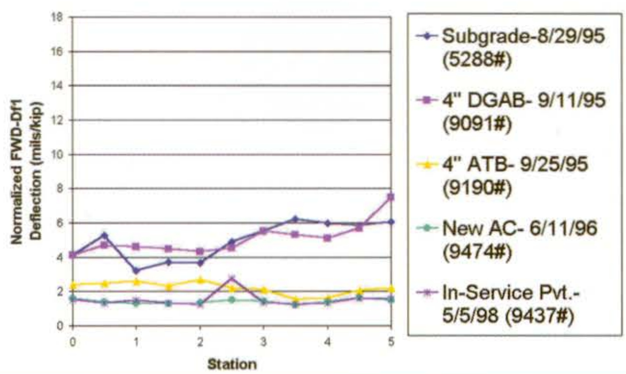
Section 390101



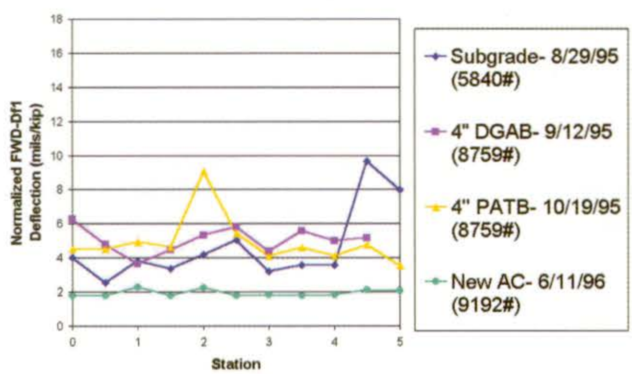
Section 390102



Section 390105



Section 390107



Construction

During subgrade construction on the Ohio SHRP Test Road, any wet, organic or otherwise unsuitable material was removed and replaced with borrow from a pit adjoining the project. Under specifications used on the project, moisture and density were monitored with a nuclear density gauge as the excavated areas were built up to grade. The subgrade was then proof rolled to identify areas of weakness where corrective action might be required. Proof rolling certainly is a more comprehensive test of the stiffness and uniformity of the subgrade surface than widely spaced nuclear density tests, but the results are subjective, it is unreliable as indicated by variations noted later with the FWD, and it is not economical on small projects. Final acceptance of the subgrade in each 152.4-meter (500-ft.) long test section was typically based on two or three randomly spaced nuclear density measurements obtained in the middle of the test lane and 0.30 meters (12 in.) below the finished surface.

FWD Testing

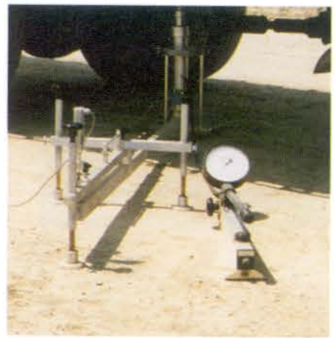
Because the SPS-1 experiment was designed to evaluate the structural effectiveness of various design parameters in asphalt concrete (AC) pavement, the FWD was used to monitor in-situ composite stiffness as individual layers within the test sections were completed. The FWD applies a haversine load to the surface being tested through a 300mm (11.8 in.) diameter plate, and vertical deflections of the surface are measured at seven radial distances within the resulting basin generated by the load. These deflections reflect the stiffness of the pavement structure under the load, with lower deflections indicating a stiffer pavement. When more than one layer is present, back calculation techniques can be used to quantify the stiffness of individual layers within the pavement structure at the time of testing in terms of their moduli of elasticity.

Different FWD load packages are used on the various layers within a pavement structure during construction. Lighter loads are applied to the subgrade than on the base and finished pavement. Even when testing with a single load package on any one layer, some differences in applied load will occur due to variations in pavement stiffness and variations inherent within the FWD system itself.
For this reason, it is often convenient to normalize measured deflections to a standard load of 450 kg (1000 lbs.) to simplify data analysis or, perhaps, to compare FWD data with Dynaflect deflection data which are obtained with a sinusoidal load of 450 kg (1000 lbs.). All FWD data discussed in this paper have been normalized in this manner.

Performance

The enclosed graphs show normalized FWD deflection profiles measured along the right wheelpath in the four failed SPS-1 test sections at various points in time, i.e. completion of the subgrade, completion of the base layer(s) and completion of the finished pavement prior to being opened to traffic. One additional profile is provided for Sections 390101 and 390105 around the time of failure.

Sections 390102 and 390107 were rutted throughout their length within a few weeks after being opened to traffic on August 14, 1996. Section 390101 showed severe rutting a short time later. The entire SPS-1 pavement was closed on December 3, 1996 to allow for the passage of winter, the reconstruction of the three distressed sections, and the completion of a third set of controlled vehicle tests in 1997. It was reopened on November 11, 1997. Section 390105 experienced a rather dramatic localized failure at Station 2+30 on May 29, 1998, about three weeks after FWD measurements indicated a localized weakness in that area. Dates on the graphs indicate when the FWD measurements were taken which, during construction, was soon after the particular pavement layer had been completed and accepted. On Sections 390101 and 390105 respectively, final readings were taken just after being taken out if service and just



before failure. The numbers in parentheses are the average FWD load in pounds applied during that particular series of tests. Several observations can be made from these graphs, including:

1. Despite the efforts made to provide uniform support on this test pavement using ODOT and SHRP specifications, and nuclear density tests, subgrade stiffness was highly variable within and between the four failed 152.4-meter (500-ft.) long test sections. It is likely, therefore, that subgrade stiffness on typical pavement projects is also highly variable
2. While FWD measurements in the right wheel path were offset approximately three feet laterally from the middle of the lane where nuclear density measurements were taken for approval of the subgrade, satisfactory moisture/ density readings were not indicative of uniform subgrade stiffness.
3. As new layers were added to the pavement structures, the magnitude and uniformity of stiffness in the total pavement structure generally improved in accordance with the stiffness of these new layers.
4. The addition of dense graded aggregate base (DGAB) on the subgrade did not increase the composite stiffness of the structure at every location. This was especially true in areas where FWD-Df1measurements on the subgrade were less than about 4 mils/kip.
5. Sections 390102 and 390107, which had the highest average initial deflections of any of the 36 mainline sections on the test road when they were newly completed, failed first.
6. Section 390101, with the third highest initial deflection, failed soon after Sections 390102 and 390107 failed. During a forensic investigation, the most severely distressed location in this section was Station 2+65, which was between the highest deflection measured on the DGAB (Station 2+50) and the highest initial deflection measured on the completed pavement (Station 3+00).
7. The fourth highest average initial deflection on the project was measured in Section 390105. This section failed next at Station 2+30, near where FWD readings taken three weeks earlier indicated severe localized weakness in the pavement structure. Measurements obtained elsewhere in the section were very similar to those recorded two years earlier when the pavement was new. There were no obvious indications from earlier FWD data of unusually low stiffness anywhere in Section 390105.
8. Based upon FWD measurements obtained in these four AC test sections designed for limited service, severe pavement distress occurred when normalized deflection under the load plate (Df1) approached 2 mils/kip on the completed pavement.
9. Failure did not always occur at specific locations where high FWD deflections were measured on the subgrade or base. This may, in part, be due to other weaker areas not being detected between these test points, which were spaced 15.2 meters (50-ft.) apart. While FWD sampling on these sections was much more comprehensive than the nuclear density sampling, it still represented a small percentage of the surface being evaluated.

Conclusions

In summary, FWD measurements are an early indicator of the structural integrity of AC pavements and it appears they may be used to predict future performance. As of June 1998, failures had occurred on the four SPS-1 sections with the highest average deflection measured on the newly completed pavement and in the order of increasing stiffness. In Sections 390101 and 390105, the earliest and most severe distresses were located in specific areas with the highest individual FWD measurements at the approximate time of the failures. These early section failures cannot be attributed solely to any particular pavement layer, but to the combination of parameters in the SPS-1 matrix which, by design, limited performance. Distress appears to be imminent, at least on thin section in-service pavements, when normalized deflection under the FWD load plate approaches 2 mils/kip with a 4050 kg (9,000 lb.) load.

Although somewhat related, soil density is not a reliable indicator of in-situ subgrade stiffness. While the addition of moisture may increase soil density, it may at the same time reduce in-situ stiffness. Also, nuclear density measurements are labor intensive, the depth of sampling is limited to 0.30 meters (12 in.), and tests taken every 45 – 75 meters (150 – 250 ft.) constitute a very small sample of the total subgrade area being evaluated. FWD measurements can be taken rapidly, thereby allowing a broader sampling of the subgrade surface, and, on subsequent layers, stiffness is integrated over the total depth of the pavement structure supporting the applied load. FWD measurements also provide a better representation of how pavement structures actually carry traffic loads.

Items of equipment other than the FWD that offer some potential benefits in measuring subgrade, base and pavement stiffness are the Dynaflect trailer, which operates very much like the FWD, the Humboldt Soil Stiffness Gauge (HSSG) and the Dynamic Cone Penetrometer (DCP). The HSSG is a hand-held device, which measures stiffness at the rate of about one test per minute. Because the HSSG only measures stiffness in the upper six inches of the subgrade, measurements need to made in individual layers as subgrade is built up to grade. The DCP applies a standard amount of energy to a rod as it is driven into unstabilized base or subgrade. The rate of penetration is continuously monitored such that specific layers of weakness within the structure which permit the rod to pass through easily can be identified for corrective action. It requires approximately five minutes to test the subgrade to a depth of four feet at a given location.

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