Problem
Traffic along interstates and in cities continues to increase each year, forcing engineers to constantly search for new solutions to ease congestion. One possible solution is to construct long life pavements that will relieve traffic by reducing user delays caused by road construction and maintenance. New design methodologies for both flexible and rigid pavements are now making their way into highway construction projects across the country. The overall reduced construction, maintenance, and user delays on the long life pavements have the potential to save state and federal transportation agencies billions of dollars in the long term.

Objectives
ODOT selected a relocation of US Route 30 near Wooster in Wayne County, the WAY-30 project, as the site for testing the long life pavements. The eastbound lanes were constructed with a long-life Portland Cement Concrete (PCC) pavement, and the westbound lanes had an asphalt concrete (AC) perpetual pavement design. The project objectives were:

- Examine the response and initial performance of both pavements
- Review procedures used by ODOT to design the two experimental pavement systems.
- Develop comprehensive instrumentation plans to monitor environmental conditions in the pavement structures and response of the structures when exposed to dynamic loading.
- Purchase and install the instrumentation at the time of construction.
- Monitor environmental conditions continuously from the time the sensors are installed to one year thereafter.
- Monitor dynamic responses of the pavement structures during nondestructive testing and controlled vehicle load testing before the pavements are opened to traffic and again 6 months and one year later. Process the data and enter it into an existing database.
- Determine the mechanical properties of the materials used in the construction of the U.S. 30 test pavement.
- Validate and modify, if necessary, the design procedures for asphalt perpetual pavement and long-lasting PCC pavement.

Instrumentation of the WAY-30 Test Pavements

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Principal Investigator:
Shad M. Sargand

ODOT Contacts:
Technical:
Roger Green

Administrative:
Monique R. Evans, P.E.
Administrator, R & D
614-728-6048

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http://www.dot.state.oh.us/divplan/research
or call 614-644-8173

Ohio Department of Transportation
1980 West Broad Street
Columbus OH 43223
Description
The AC perpetual pavement consisted of a 6 inch (15 cm) DGAB base, covered by a 4 inch (10 cm) fatigue resistant layer, a 9 inch (23 cm) Asphalt Treated Base (ATB) layer, a 1.75 inch (4.45 cm) superpave layer, and topped by a 1.5 inch (3.8 cm) wearing course.

The PCC long-life pavement was built starting with a 4 inch (10 cm) DGAB with under drains, a 3 inch (7.5 cm) asphalt concrete base, and a 10 inch (25 cm) layer of jointed plain concrete pavement. The PCC included the substitution of either ground granular blast furnace slag or fly ash for cement. The pavement had 15 foot (4.6 m) slabs with 1.5 inch (3.8 cm) dowel bars at 12 inch spacings; one section featured some experimental dowel bar types.

Sections 664 and 876 on each side were instrumented to monitor relevant pressure (using Geokon 3500 pressure cells), displacement (Lucas Schaevitz GPD 121-500 and GPD 121-250 LVDT’s), strain (Dynatest PAST II Strain gages on AC only), and temperature (MRC Thermistors) parameters. Environmental data collected from the base and subgrade layers included temperature (MRC thermistors), moisture (Campbell Scientific FHWA TDR probe), frost depth (CRREL Resistivity probe), and groundwater table (piezometers).

Controlled Vehicle Load (CVL) testing was conducted in December 2005 on both AC and PCC, in July 2006 on AC, and in August 2006 on PCC. Tests were run at four speeds ranging from 5 mph (9 km/h) to 60 mph (97 km/h), using single axle and tandem axle vehicles with rear axle loads of up to 40.15 kips (178.6 kN) for tandem axle and 28.2 kips (125.44 kN) for single axle. Some of the 5 mph (8 km/h) loads on PCC in August 2006 were applied along the edge line of the pavement and at the edge of the slab, which was two feet into the shoulder (outside the edge line); otherwise all runs were along the wheel path.

Falling Weight Deflectometer (FWD) testing was conducted on the each layer during construction and on the finished pavement on both the AC and PCC sides. On the PCC side the FWD data were used to examine the load transfer capabilities of three types of experimental dowel bars used in Section 877.

Some samples of pavement materials were collected from the AC and PCC sections and were tested in ORITE’s laboratories. Some details are included in the project report as needed to augment field results, but most of this work is being conducted under a separate project entitled Determination of Mechanical Properties Used in WAY-30 Test Pavements (SJN 437046). Some of the material data for AC was used as inputs into an Elastic Layer System Analysis, where the CVL results were compared to computations using inputs based on a sigmoidal equation, on data collected from field cores, and on data from testing laboratory-prepared samples.

A preliminary analysis of the AC and PCC pavements was conducted using the Mechanistic/Empirical Pavement Design Guidelines (M-E PDG) Software. The performance of the road over twenty years was modeled considering both average behavior, i.e. performance at 50% reliability, for selected parameters. For PCC the analysis projected faulting, load transfer efficiency at joints, cumulative damage, percent slabs cracked, and the International Roughness Index (IRI). For AC, the analysis projected longitudinal cracking, alligator cracking, transverse strain in all axle configurations and loading conditions during the December tests, and for the single axle loads during the July tests.

The maximum pressure observed in the subgrade during CVL tests shouldered (outside the edge line); otherwise all runs were along the wheel path.

Conclusions and Recommendations
Subgrade: The results of FWD tests on the subgrade indicated that the subgrade stiffness was good in the test sections and at least fair elsewhere, meaning the subgrade stiffness was at least 6 ksi (41 MPa), exceeding the design specification of 5 ksi (34.5 MPa).

AC Pavement: In the December 2005 CVL test on the AC pavement, at low temperature, the longitudinal strain in the FRL was under 35 με, even at the slowest speeds. During the July CVL tests, at highway speeds of 45 mph (72 km/h) and 55 mph (88 km/h), the strain in the FRL was close to the design value, even under the heaviest loads. Given that the CVL used an unusually heavy load, it is expected that in everyday use, even during hot summer months, the WAY-30 perpetual pavement FRL will experience few maximum strains of this magnitude. While the slowest speeds, at 5 mph (8 km/h), had significantly higher strains, it is expected that these will be experienced only rarely, since such low speeds only occur during traffic stoppages and slowdowns, and the CVL loads were significantly higher than that found in most commercial truck traffic. Thus the road will experience such strains very rarely; the FRL is in fact designed to withstand a limited number (dozens or perhaps hundreds) of these loads with no ill effect.

Strains developed at the bottom of the ATB layer are lower than the strains developed at the bottom of the fatigue layer, as expected. Overall, the maximum longitudinal strains in the ATB layer are slightly higher than the maximum transverse strain in all axle configurations and loading conditions during the December tests, and for the single axle loads during the July tests.

The maximum pressure observed in the subgrade during CVL tests.
on the AC sections was 6.5 psi (44.8 kPa) at 45 mph (72 km/h) under a 40 kip (178 kN) tandem axle load.

An Elastic Layer System (ELS) analysis of the AC perpetual pavement generally saw agreement between computed and measured values of the longitudinal strain at the bottom of the FRL only when the resilient modulus obtained from field cores was used as input in the program, however no agreement was found when modeling the pavement response to lower speed CVL tests conducted during the summer.

The calculated longitudinal and transverse strains at the bottom of the ATB layer (ODOT Item 302) are always lower than the measured values. On the other hand, the calculated surface deflections are always higher than the measured ones irrespective of the truck speed. Both the calculated pavement deflection and the subgrade pressure are lower than the corresponding measured figures.

Using the dynamic modulus of laboratory-prepared specimens with a sigmoidal equation does not yield a reasonably close verification in any of the parameters used, nor does using the resilient modulus from laboratory-prepared specimens. It should be indicated however, that the trend as to whether a particular calculated or measured response parameter is higher is maintained as in the verification study using the resilient modulus of field cores. These findings indicate that the ELS theory is capable of matching one parameter but not all of them at once and is not appropriate to simulate the time-dependent effect of loading due to different truck speeds. Some of the discrepancies may be attributed to the difference in air voids content and density between the field cores and the laboratory-prepared samples.

**PCC Pavement:** The slight fluctuations in the LVDT readings on the PCC pavement were observed during the first eight days of curing. These were in response to daily temperature cycles. These LVDT fluctuations during the curing time remained small enough, a fraction of a mil (on the order of 10 μm), that the slab appears to be flat and has experienced no significant loss of support. Thus premature PCC pavement failure due to loss of support is not expected.

Successful controlled vehicle load testing was conducted on the PCC pavement only during August 2006. The results from these tests showed that the pressure in the subgrade was quite low, less than 1.4 psi (10 kPa) for Section 664, and considerably less, under 0.76 psi (5.2 kPa) for Section 876. Load-induced deflections of either slab were also quite small, less than 7 mils (0.18 mm), and did not vary significantly with speed.

A series of tests at 5 mph (8 km/h) in the wheel path, at the marked edge of the lane, and at the edge of the slab (2 ft (0.6 m) into the shoulder), showed as expected that the deflection of the edge-mounted LVDT increased as the load moved closer to the LVDT. Even under the worst case, Section 876 at a tandem axle load of 33.9 kip (150.8 kN), the displacement was only 12.7 mils (0.32 mm).

A Falling Weight Deflectometer (FWD) was used in August 2006 to test joints in section 877 that were equipped with experimental dowel bars and joints on adjacent sections with conventional epoxy-coated steel dowel bars. Measurements were taken at the centerline and near the wheel path (6 in (15 cm) inside the edge line). The centerline results indicated that all the joints had load transfers exceeding 80%. In the wheel path, however, one zinc coated dowel bar joint measurement (of six) was below 80%, while both measurements (approach and leave) of the single fiberglass dowel bar joint were below 80%. Since the centerline test was well over 80% and there was only one fiberglass dowel bar joint, these low results may simply be anomalies. Otherwise the load transfer results of the experimental bars were comparable to those of the standard joints on either side.

**Validation of Design Models:** The perpetual and long lasting flexible and rigid pavements constructed along WAY-30 have been designed to last a minimum of 40 years using the long-lived pavement design methods, such as the perpetual pavement (limiting strain) design procedure for the flexible pavement. With the impending release of the new Mechanistic/Empirical pavement design procedures, developed through project NCHRP 1-37A, it is appropriate to predict the performance of these pavements using a version of the new Mechanistic/Empirical Pavement Design Guide software released to the researchers by the development team. This initial effort will aid in the eventual calibration of the guide considering the traffic, weather, and environmental conditions prevalent in Ohio.

The preliminary verification used default material properties best matching the actual materials and thicknesses as currently known, actual truck traffic counts with expected growth, and the climatic conditions prevalent in Wooster, OH as input data. The analysis of the flexible perpetual pavement indicated that the mean International Roughness Index (IRI) stayed under the 0.00271 mi/mi (m/m) limit with a 97.41% reliability.

A similar analysis for the long-lasting rigid pavement section built at the WAY-30 site indicated the road mean IRI would reach 80% of the design limit after 20 years of service, and the mean IRI would stay below the design limit at 76.6% reliability. Faulting was
identified as the prevalent distress in the long-lasting rigid pavement, reaching the design limit of 0.12 in (0.305 cm), in 19 years and 8 months, and the reliability for the pavement to meet the design limit was only 48.6%.

These results of this preliminary verification of the new Design Guide may be termed inconclusive, however, given the fact that the analysis and design model was developed using general conditions and input data for all of the United States, and it has not been calibrated for specific conditions found in Ohio. A currently funded ODOT project is expected to yield the necessary model calibration to allow a closer verification of the performance of these pavements as well as others the software may be used to model.

**General recommendations:**
Perpetual pavement or long-lived PCC roads can be built wherever there is a need to completely reconstruct an existing pavement or to build a new pavement. It may also be possible to examine existing AC pavements around the state, including an examination of their maintenance and repair histories, to determine those that could be designated as perpetual pavements. It is foreseen that some existing AC pavements in good condition can be retrofitted to meet the perpetual pavement requirements by adding layers, thereby increasing their expected life. While the response measurements here provide only a hint of long-term performance of the US-30 pavements, they generally appear to be living up to their intent of reduced wear and damage from traffic, which promises an enhanced lifetime.

Additional data collection on these experimental pavements will help decide whether or not these sections will last even when occasionally subjected to stresses that exceed the strain threshold. Additional data will also help calibrate and refine the design models to more closely determine whether the reduced lifetimes observed are an artifact of the limited input data.

The Elastic Layer System model is not entirely suitable, and thus should not be implemented at this time. Alternative pavement analysis codes should be investigated for possible use.

**Implementation Potential**
Perpetual pavements can be built as needed. The design elements and specifications used in these pavements could be adapted to create new specifications, standard drawings, and other documents needed to establish perpetual AC pavements and long-lived concrete pavements as specific bid items that could be required for particular projects.

In addition, existing AC pavements can be studied to determine those that which may already qualify for perpetual pavement status, and those which may qualify with some relatively small and easy modifications.