UNIVERSITY OF MINNESOTA

Minne-ALF-2:
An Accelerated Load Test Facility for Pavements

Introduction

In 1993, the Minnesota Department of Transportation (Mn/DOT) commissioned the University of Minnesota Department of Civil Engineering to develop, construct and evaluate a laboratory-based test facility for rapidly applying repeated heavy vehicle loads (simulated) to pavement test structures. The purpose of this facility was to efficiently and accurately evaluate the long-term performance potential of new and experimental highway pavement designs and materials. This facility was dubbed "Minnesota Accelerated Loading Facility" or "Minne-ALF."

The original Minne-ALF (shown in figure 1) was originally designed to be useful for a wide variety of structural and environmental response studies for both asphalt and concrete pavements, although the initial test stand configuration and test program were developed to address concrete pavement testing needs. It was also designed to allow the simulation of moving wheel loads operating at higher speeds (40 mph or more) without the safety concerns that are inherent in the operation of heavy wheel load assemblies on typical round and linear tracks.

Figure 1. Original Minne-ALF with rocker beam.

After the Minne-ALF was constructed, there was an immediate need to evaluate several design and construction parameters related to retrofit dowel installations in concrete pavements. The Minne-ALF was chosen to rapidly evaluate the relative impacts of these parameters on long-term potential pavement performance. The information gained from this testing resulted in the development of improved specifications and materials for dowel bar retrofit operations in Minnesota without having to conduct lengthy field trials or constructing sections that would fail prematurely. This application of the Minne-ALF may have saved Mn/DOT millions of dollars in the long run.

Over the years, the Minne-ALF test facility has been updated and modified to better suit the tests needed at any given time. The current Minne-ALF is the result of more than 10 years of cooperation and coordination between the Minnesota Department of Transportation and the University of Minnesota.

Minne-ALF Test Configuration Options

The Minne-ALF can be configured in many different ways to address various test parameters, including a wide range of load magnitudes and travel speeds, slab restraint, environmental conditions, etc. This section describes the two test configurations that have been used to date.

Original Minne-ALF

The original Minne-ALF was built using an innovative rocker beam design that was driven by twin servo-controlled hydraulic actuators that controlled both load magnitude and the speed of movement of the contact patch. This arrangement is shown in figures 1 and 2. The original Minne-ALF test stand was capable of applying repeated loads along an 8-foot long wheel path over a section of pavement measuring up to 12 feet in width and 15 feet in length.

The pavement surface was placed on a composite foundation comprising 3-5 inches of dense-graded aggregate and 9 inches of AASHTO A-6 clay-loam, which were compacted over a ¼-in neoprene pad. The neoprene pad was selected with a specific compressibility to simulate the effects of deep foundations in the field. These layers were all placed within an 8 ft by 16-ft x 15-in deep rectangular steel channel enclosure, which rested on a 3/8-in steel plate and 27-in deep steel beam grid. Figure 3 illustrates a typical pavement test profile. It should be noted that any of the layer materials or thicknesses can be changed as necessary.

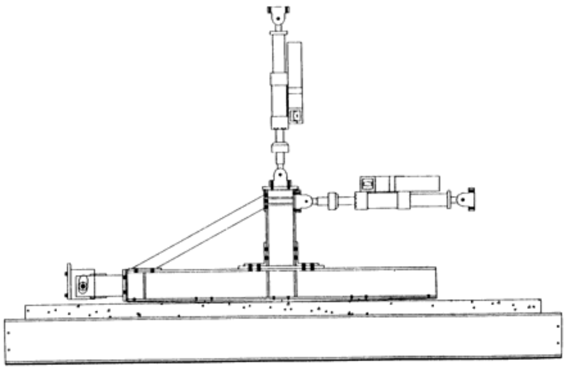

Figure 2. Actuator and rocker beam schematic.

On the original Minne-ALF, traffic loads were simulated using a steel rocker beam operated by a vertically oriented hydraulic actuator (to apply load) and a horizontally mounted actuator (to rock the beam and move the load). This mechanism was operated at frequencies of up to 2 Hz, which resulted in contact patch movements of up to 40 mph.

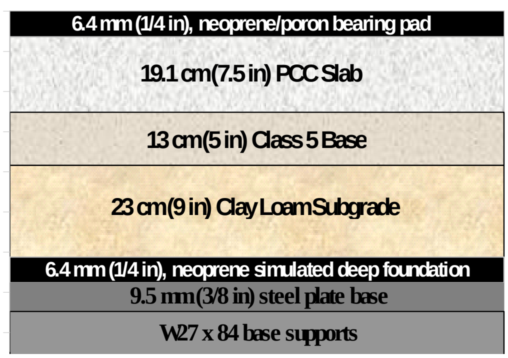

Figure 3. Typical Minne-ALF pavement test profile.

A full description of the design and construction of the original Minne-ALF can be found in: Beer, 1997; Mauritz, 1997; and Embacher and Snyder, 1999.

Minne-ALF-2

In 2004, the Minne-ALF was refurbished (after imparting more than 100 million load repetitions to 14 test specimens) and was redesigned to more quickly and efficiently perform tests of retrofit dowel installations. The new test stand (dubbed "Minne-ALF-2") was modified to adapt a simpler experimental setting that replaced the rocking beam with two sequentially operated vertical actuators. This arrangement was used successfully at Michigan State University in the late 1980s and early 1990s to simulate the passage of heavy wheel loads moving over a pavement joint.

The two vertical actuators act on load plates that are centered 13 inches apart and are positioned ½ inch away from the transverse slab joint. A schematic of the Minne-ALF-2 actuator configuration is shown in figure 4.

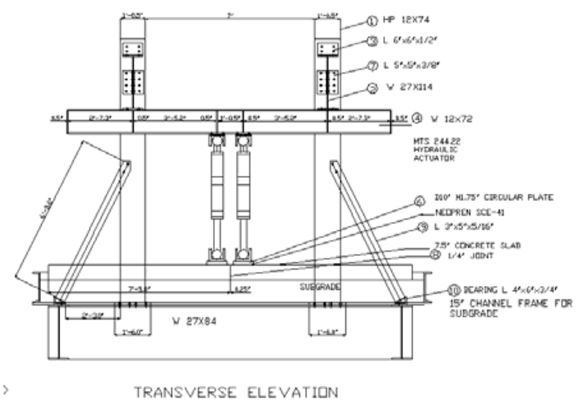

Figure 4. Minne-ALF-2 test frame elevation detail.

The actuators impart loads sequentially in a way that simulates the way that joint loads develop as heavy traffic loads approach. A typical actuator load profile for the Minne-ALF-2 is shown in figure 5.

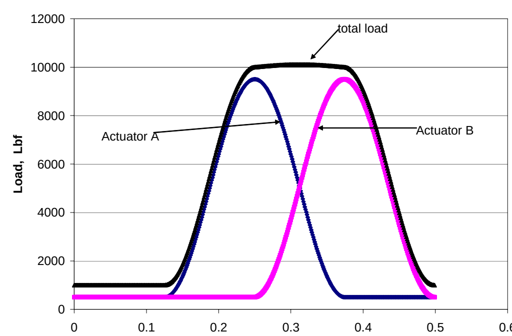

Figure 5. Typical Minne-ALF-2 load profile.

The load profile can be extended or compressed to simulate faster or slower vehicle passages. It is possible to simulate vehicle speeds of at least 55 mph with this arrangement. The currently installed actuators can simulate wheel loads of up to 22,000 lbs; actuators with higher capacities could be installed to simulate even larger loads.

Figure 6 is a photo of the Minne-ALF-2. This test stand configuration offers the advantages of rapid testing (4 or more load cycles per second) and low maintenance cost, making it especially useful for studies of concrete pavement joints and alternate dowel bar configurations and materials. It would also be useful for static and repeated load tests of asphalt pavement structures (e.g., deformation and settlement tests for parking lot mixtures and designs).

Figure 6. Photo of Minne-ALF-2.

Minne-ALF Instrumentation

The actuators used in the Minne-ALF allow direct measurement of applied load and stroke (an indicator of deflection). In addition, the test stand has been fitted with mounting brackets for deflection measurement devices (LVDTs) for direct measurement of slab deflections, deformations and differential movement across joints. The available data acquisition system can sample data from all of these instruments (along with additional test-specific instruments, such as embedded strain gages, thermocouples, etc.) at typical rates of 400 samples per second (or higher, depending upon the number of instruments in use).

Data can be collected and stored at predetermined load cycle counts or "on-demand."

Tests Performed to Date

As of August, 2005, a total of 17 concrete pavement specimens have been tested in the Minne-ALF (14 in the original configuration, 3 in the modified configuration). All tests have been performed on 7.5-inch thick slabs that are based on the design of Cell 6 at the Minnesota Road Research Project (MnROAD). The base design includes the installation of three 1.5-in diameter epoxy-coated mild steel dowels (15 inches long) at mid-depth with the outermost dowel centered 6 to 9 inches from the slab edge and the remaining dowels placed on 12-inch centers. The slab joint was generally formed ¼-in wide without aggregate interlock. The repair material was generally a specified PCC-based material.

A summary of parameters of the completed tests follows:

Slab 1: Tight joint with significant aggregate interlock.
Slab 2: Standard parameters.
Slab 3: Replicate of slab 2.
Slab 4: Proprietary repair material.
Slab 5: Proprietary repair material, 13-in dowels
Slab 6: Proprietary repair material, 18-in stainless steel (SS)-clad dowels
Slab 7: Replicate of slab 2.
Slab 8: FRP dowels.
Slab 9: Grout-filled stainless steel pipe dowels.
Slab 10: Shallow cut (2 inches of concrete cover).
Slab 11: Two dowels (instead of 3), shallow cut.
Slab 12: Replicate of slab 10.
Slab 13: Replicate of slab 11.
Slab 14: 1.75-in diameter FRP dowels
Slab 15: Hollow SS dowels (first Minne-ALF-2 specimen).
Slab 16: Zinc alloy-clad dowels.
Slab 17: Replicate of slab 2.

In each of these tests, testing continued until at least 7 million load cycles were completed or until load transfer measures fell below 70 percent (a typical failure threshold). Additional details concerning the specifics of these tests can be found in the references listed at the end of the bulletin.

Research Results and Findings

The results of tests conducted to date using the Minne-ALF have been used to refine and improve MnDOT specifications concerning retrofit dowel designs and construction techniques. A few representative performance comparisons and conclusions are presented below.

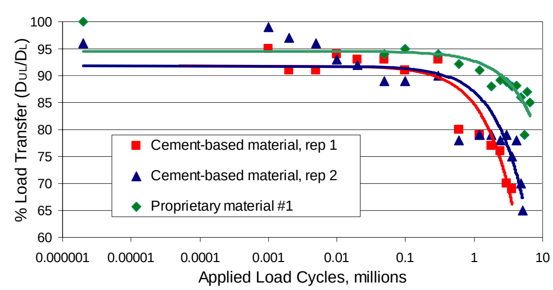

Figure 7. LTE v. load cycles for two repair materials.

Figure 7 compares the performance of dowels installed using two different repair materials. It can be seen that using the proprietary material resulted in better long-term joint performance. This was attributed to the more consistent quality of the proprietary material.

Figure 8 compares the performance of joints constructed using 3 different types of dowels. It is clear that the epoxy-coated steel dowels and cement-grouted stainless steel pipe dowels provide better initial and long-term joint performance than the solid FRP dowels (although the performance of all dowels was judged to be acceptable).

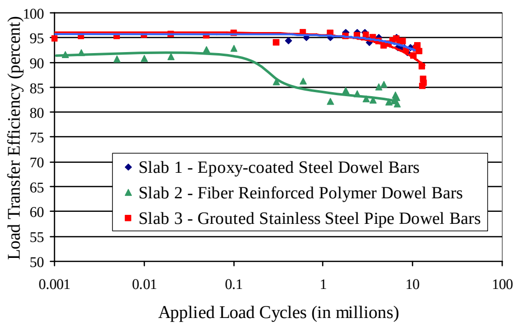

Figure 8. LTE v. loads for various dowel materials.

Figure 9 shows that the installation of retrofit dowels in shallow slots appears to offer comparable performance to full-depth slots while improving speed of construction with reduced construction costs.

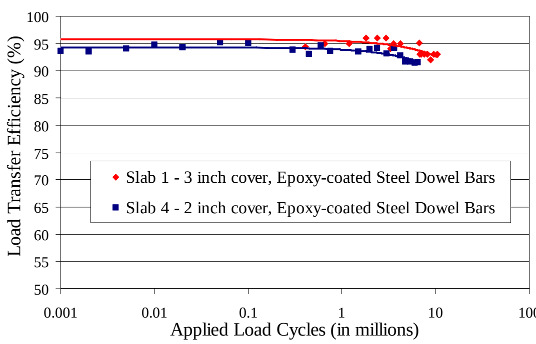

Figure 9. Effect of dowel cover thickness on LTE performance potential.

Potential Future Applications

The Minne-ALF can be used to investigate a wide range of pavement design, rehabilitation and behavior issues, including:

- Curl and warp studies through induced temperature and moisture gradients
- Effects of increased load limits and modified truck gear configurations
- "Optimize" dowel load transfer systems (i.e., material selection, dowel size, shape and location
- Foundation pumping and drainage studies
- Asphalt mix stability and deformation studies.
- Load equivalency studies

Some of the applications listed above would require further test stand modifications.

Summary

The Minne-ALF-2 has proven useful in rapidly evaluating the performance potential of many pavement design and rehabilitation features. It can be used to examine a wide range of design, construction and rehabilitation issues for both Portland cement and hot-mixed asphalt concrete pavements. For additional information, or to inquire about materials testing, please contact Dr. Lev Khazanovich (University of MN) at (612)624-4764 or Tom Burnham (Mn/DOT) at (651)779-5605.

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