

# MATES

## MICHIGAN DEPARTMENT OF TRANSPORTATION



October 1990

Issue No. 47

### ROAD PROFILE—THE BOTTOM LINE

It is a good bet that hours after the first wheel was invented, concern arose about the surface it was rolling on. Roman highway engineers tried to develop 'profile' measuring devices to determine roughness on the Appian Way. Two thousand years later, road surfaces still are difficult to measure and interpret. Despite the problems, progress has been made as we are about to describe.

Profile is the sole determinant of ride quality and is the first thing most people notice about any road. Rough roads must be identified since they are the chief cause of complaint from the motoring public. Rough roads also may cause increased cargo damage, vehicle wear, and may subject the highway agency to lawsuits due to accidents.

#### Profile In Theory

The road profile is defined as that contour of the surface over which a vehicle tire passes. Although the complete profile view of a road would include everything from hills and valleys on the larger perspective, to 1/8-in. deep pavement grooving or fine texturing of the surface in the other extreme, our interest is in the part of the profile that actually affects the way the pavement feels to the motorist who travels over it. Several types of instruments are used to measure and record pavement roughness or ride quality. The profile usually appears in the laboratory as a wavy inked line, or trace on chart paper, showing vertical elevation plotted against distance along the roadway for a single wheel path. It is viewed as if your eyes were looking across the surface of the road at ground level. Figure 1 shows a trace of a pavement with faulted joints. Unfortunately, it is not a simple process to measure road profile in a reliable and repeatable manner, or to transform a roadway surface to a profile trace in the laboratory.

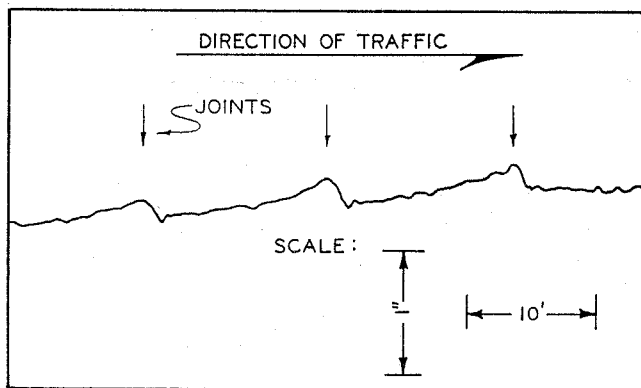


Figure 1. Profile of a county road where the short pavement slabs have tipped, causing a 'step' effect at a joint. Note compressed horizontal scale.

One obvious way to obtain a road profile is with a survey crew using a precise level and rod. It turns out, however, that modern analysis techniques would require about 30,000 individual readings per mile. This, too, is unfortunate because precise level profiles provide the most complete picture of the pavements obtainable. They are, in fact, used as the standard against which all other profiling methods are compared and verified. It is the almost perfect reference plane that sets precise level profiles apart from all others.

The precise level establishes a line of sight at right angles to the earth's gravity. This is the reference against which road profile elevations are measured. All other methods of profile measurement fall short of this ideal because they can't measure with respect to the fixed plane of reference. Indeed, the problem of how to establish any reference at all, is central to the persistent search for better profile measuring devices. After many decades of study, only two types of reference have emerged from the public and private research communities for use in practical roughness measuring devices. These are the rigid reference as exemplified by rolling straightedges, and the inertial reference typified by the old Bureau of Public Roads Roughometer, and the General Motors Rapid Travel Profilometer.

A rolling straightedge consists of a frame, riding on numerous 'bogie' wheels, from which a measuring wheel is suspended to roll along the pavement surface. The Bureau of Public Roads Roughometer was a specially designed one-wheeled trailer with unusually constant shock absorbers. It was constructed so that a measurement was made of the amount of movement that occurred between the wheel and the trailer frame, when the trailer was towed at 20 mph. The General Motors Rapid Travel Profilometer (GM RTP) uses a space-age accelerometer instrument to determine the motion of the truck frame, while a small measuring wheel follows the roadway, and an instrument measures the motion of the follower-wheel relative to the truck.

#### Profiling In Practice

So far, the only accurate implementation of one of these reference types is the inertial reference as developed for the GM RTP. This system can record profile measured with respect to an electronically established reference in space, with characteristics that can be tailored to the job at hand. The Materials and Technology Division currently operates two units built in our laboratories based on the GM principle. Both trucks have been enhanced in two ways:

- 1) The mechanical follower wheel used in the original device has been replaced by an optical light-beam distance sensing unit developed by M&T (the original follower wheel assembly limited vehicle speed, and was not very durable).

- 2) The second modification provides a continuous approximate rut depth measurement that is recorded along with pavement profile. This involved the addition of a second light-beam distance measuring device along with additional motion sensors to correct for the tilt of the truck body.

Both RTPs have computer-based data gathering systems. These convert electrical signals from the sensors into the proper format for storage and processing. The older vehicle uses a concept that requires more expensive computing equipment. The laboratory has modified this design to produce a second RTP that utilizes much less expensive personal computer (PC) units. Moreover, this new system actually performs profile analysis on-the-run rather than requiring later processing. Once a profile is computed, recorded, and stored ('in-the-can,' so to speak), any number of analysis techniques can be employed. On the older vehicle, profiles are stored on magnetic tape in the form of digitized versions of the original instrument signals. Our new RTP

stores the original signals without converting to digital format. This adds one additional processing step if further analysis or actual print-out of the profile is required, but it allows faster processing of the ride quality data that are used for most applications.

### Evaluating the Profile

The Department makes extensive use of its profiling capabilities. One project employs the older RTP on a full-time basis. This is the Pavement Management System (PMS). In this program a two-person crew surveys the entire 12,000-mile State trunkline network annually (roads with I, US, or M designations). Processing the data generates a roughness measurement called the 'International Roughness Index' (IRI), and an average rut depth measurement, for each tenth-mile segment of the highway. These data are used as part of a pavement management program developed by the laboratory's Roadway Management Development Unit. The roughness values enable District personnel to evaluate the ride quality of the roadways under their jurisdiction, and plan necessary improvements.

Many pavement profile studies were performed when the older RTP was used as a research vehicle. The new RTP is now assigned that role. These projects fall into three broad categories; namely, research projects, special studies, and acceptance testing. Research projects may use the RTP to keep track of yearly changes in the ride quality of various test roads, or experimentally prepared pavement repairs or surfaces. Special studies usually involve determining why a pavement exhibits unusual ride characteristics. These have included the effects of improper reinforcement mat placement, slab curling, faulted joints, 'galloping' surfaces which bounce vehicles in a rhythmic fashion, and analysis of airport runways for improvements in ride quality for aircraft. In most cases, inspection or analysis of plotted profiles reveals the problem, and solutions can then be developed.

Acceptance testing, with rewards to the contractor for new roadways with better ride quality and penalties for those with poorer quality, was performed by computing a Ride Quality Index (RQI) from the profile. The IRI number we spoke of previously represents a test vehicle's response to the road, while the RQI number represents the 'feel' of the road to the motorist or passenger. This RQI measure was developed at the laboratory through an extensive subjective ride quality study, where participants rated the 'feel' of selected sections of pavement. Recently, the task of acceptance testing has been supplanted by a rolling straightedge device called the California Profilograph. It produces a rating called the Inches-Per-Mile Roughness Index. The profilograph can be used on new concrete pavements, just hours after placement. Thus, contractors can buy a profilograph and check their work as it progresses. This is an important advantage since operational corrections can be made on the job to ensure ride quality that results in a bonus payment.

Fundamentally, however, the newer RTP is designed and used for the development of new measurement, recording, and analysis equipment and methods, to more effectively and efficiently evaluate the needed ride quality factors, as we move toward the 21st century. More efficient, specialized computer circuits and analytical methods will continue to be developed and applied to Michigan's pavement evaluation programs.

Profile measurement and analysis at freeway speeds require use of powerful tools from the cutting edge of modern science. These include ever higher-speed computers, random signal analysis, statistics, psychometry, and computer programming in the most up-to-date computer languages. It is an example of how 'simple' highway problems can require sophisticated instrumentation and analysis. There are constant challenges and many interesting avenues to explore in this rapidly changing technology.

-John Darlington

## **TECHADVISORIES**

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

### **MDOT RESEARCH PUBLICATIONS**

**Performance Evaluation of Concrete Pavement Overlays: Final Report**, Research Report No. R-1303, by J. E. Simonsen and A. W. Price. This report describes the performance of two 7-in. reinforced, unbonded, and dowelled concrete overlays constructed in 1984 (US 23 at Dundee, and I 96 at Portland). Both are separated from the underlying pavement by a 3/4-in. sand-asphalt layer. The original US 23 pavement is a reinforced jointed concrete pavement in relatively poor condition; i.e., many of the joints and cracks were heavily patched with bituminous cold-patch material. Portions of the I 96 pavement are continuously reinforced and were sawed into 100-ft slabs to reduce the movement at previously placed repairs, and the conventionally reinforced portions of the pavement were in reasonably good condition. Observations, measurements, examination of cores, and load tests indicate that the overall performance of the overlays to date has been satisfactory, and that concrete overlays are a viable alternative to recycling when the existing pavement conditions and bridge under-clearances can accommodate the extra thickness. Careful consideration of the traffic volume and condition of the existing pavement is necessary to ensure that an overlay of sufficient thickness is specified.

**Evaluation of 'Glasgrid' Bituminous Pavement Reinforcement Mesh and a Bituminous Separation Course With and Without Latex: Construction Report**, Research Report No. R-1305,

by V. T. Barnhart. This describes the experimental installation of 'Glasgrid,' a high-strength grid reinforcement mesh for bituminous pavements, and also the use of a Modified Bituminous Base Course (9A) (both with and without a latex additive) as a separation course to reduce reflection cracking in the bituminous overlay of an existing pavement. Test sections of these two designs, along with a control section of conventional overlay, were installed on M 52 in Saginaw County. This report describes the problems encountered in the two installations, none of which are expected to affect the integrity of the two types of installation. During the next three years, condition surveys and performance evaluations will be made of the test sections, and core samples will be taken to determine the effectiveness of these installations.

### **PERSONNEL NOTES**

Four new people were recently welcomed to our staff. **Chris Byrum** is a new engineer in our Soils and Foundation Analysis Unit of the Geotechnical and Geoenvironmental Section, and joining him in a similar position in that Unit is **Dave Gauthier**. **Carrie Geyer** joins the Environmental Services Unit of the same Section as an engineer. And, **Dennis Dodson** is our new statistician in the Roadway Management Systems Development Unit of the District Support Section. We welcome them to our staff, and look forward to working with them.

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

Technology Transfer Unit  
Materials and Technology Division  
Michigan DOT  
P.O. Box 30049  
Lansing, Michigan 48909  
Telephone (517) 322-1637