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A NEW TOOL FOR RIDE QUALITY ASSURANCE

A chronic problem faced by paving contractors provided a unique opportunity for the Materials and Technology Division to enhance control of pavement ride quality. This was achieved through technological development that invoked both the research and testing missions of the Division. Beginning in 1980, the Department paid bonuses to contractors who built portland cement concrete roads with excellent ride quality. Likewise, poor performance was penalized because the contractor was required to meet minimum standards by correcting the surface after initial construction. Average ride quality resulted in no reward or penalty. Unfortunately, contractors could not monitor workmanship during construction. They had to wait until the project was complete, and thus too late to modify their construction methods. After completion, Materials and Technology personnel would deploy the Michigan Rapid Travel Profilometer (RTP). This is a truck-mounted unit, consisting of sensors and electronics, that measures and records the actual profile of the pavement. After the Profilometer transverses a job, the stored profile data are reduced to a number called the Michigan Ride Quality Index (RQI). The concept for this process was first developed by the General Motors Corporation (GMC) in the late 1960s. The GMC process was modified and expanded upon by our own research and development staff for use on new and old highways.

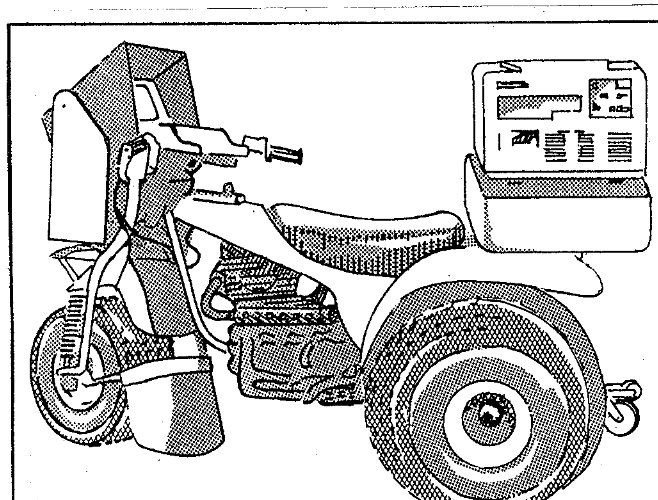
As noted above, under the RQI program contractors had no way to monitor pavement surface smoothness during construction. If the job was below average, the contractor could obtain a profilometric plot that showed where to grind off high spots in the concrete pavement to meet minimum acceptable standards. Needless to say, the contractors were soon requesting a way to check newly laid concrete pavement on a daily or frequent basis. This would require a special profile measuring vehicle that was agile on any terrain and light enough to not damage new concrete pavement.

After requests from the industry, the Materials and Technology Division submitted a proposal to the Federal Highway Administration under the Highway Planning and Research (HPR) program to "...develop a lightweight profiling vehicle (500 lb including driver) which is capable of travelling over recently placed concrete. The vehicle, with its associated equipment, would be capable of obtaining the true pavement profile. From this profile data a complete analysis of ride quality would be obtained." The intent, of course, was to provide the RQI numbers that were then available only from the Department's RTP vehicle. The proposal was accepted and development work began in 1984.

In 1984 the task was somewhat daunting. We had to design a computer because the IBM PC was only two years old and not nearly fast enough for our purposes or application. In addition, there was a desire to eliminate a troublesome and expensive part that was not necessary for the limited task of getting only the RQI number. This was the vehicle-to-ground distance sensor. These requirements and the press of other duties slowed development of the project but this may have been a blessing in disguise.

In 1989, MDOT permitted use of the California Profilograph (CALPRO) for acceptance testing of pavement smoothness. This was primarily due to increasing availability and use of CALPRO by other states. The CALPRO (a rolling straight-edge) was difficult and slow to use and required hand-reduction of endless feet of graph paper. Nevertheless, it did allow contractors to monitor performance during construction. There was still a demand for the speed and convenience of the proposed lightweight device; now, however, it had to produce an accurate California inches-per-mile statistic instead of the traditional RQI value. This required changes in the lightweight device's mechanical, electronic, and computer program systems. By this time the modern personal computer (PC) had come of age and was fast enough for the task. In addition, aftermarket suppliers could provide powerful digitizing cards for the PC that made it a superb data acquisition machine. A further development was the availability of a compact distance sensor using laser light to provide a non-contacting probe.

The lightweight device underwent a radical change. The all-terrain vehicle now sported an IBM PC complete with monitor screen and keyboard. A metal box attached to the PC lid provides electronic calculation of the profile to unburden the PC. A second box provides auxiliary support for the odometer and handlebar control switches. Two more boxes control the laser distance sensor and provide a special pulse train to a digitizing card inside the computer. Transducers consist of a precision accelerometer and a laser distance sensor mounted under the rear axle. Distance down the roadway is measured with a precision odometer wheel riding on top of an intermediate wheel. This was designed to eliminate frequent calibration runs that would be necessary if the odometer wheel rode directly on the pavement, to compensate for wheel wear.



The Lightweight Pavement Profile Instrument.

The lightweight device now produces a profile identical to that produced by the full-size RTP truck except that it gets this information at 8 to 12 mph instead of 60 mph. A major programming task was required, however, to first convert the true RTP type profile to that produced by the

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CALPRO rolling straight-edge. This required development of a computer model of the CALPRO that would 'roll over' the stored profile to produce a modified profile. Then came the task of emulating the highly subjective operations of a human trace reducer (as required by the CALPRO device) at work on the 'trace.' This was successfully completed and now the lightweight device can run down the road and produce in minutes what the CALPRO takes hours to produce. It stores the true RTP profile data on a floppy or hard disk for further analysis and scrutiny. The lightweight device provides a new Michigan Ride Quality Index that is a better predictor of ride quality than the old RQI, and this will be presented in an upcoming MATES article.

On the subject of ride quality index, recent experience indicates that all is not well with the CALPRO and its inches-per-mile statistic. Certain roads that passed muster based on inches-per-mile have been found subjectively rough by human riders. There are three reasons for this problem. First, the inches-per-mile statistic itself has never been adequately correlated with subjective ride quality through a study involving many drivers. Second, the statistic is affected by both power and frequency instead of just power alone. It's as if a sound pressure meter showed increasing loudness when the source got louder, as it should, but also showed increasing loudness when the pitch went up. A sound pressure meter that did this would go in for repair! The third reason involves the CALPRO rolling straight-edge itself. This device severely distorts the true profile. Some wavelength components are multiplied by two, while others nearby are attenuated to zero. This is an unavoidable consequence of using any rolling straight-edge to provide a measurement reference plane.

As mentioned above, under our current specification, the lightweight vehicle's true profile must be altered to provide an equivalent CALPRO trace. This leads us back to a discussion of the Michigan Ride Quality Index. The RQI was developed by comparing various measures derived from the RTP true profile against the judgments of a large group of typical drivers. These subjects were recruited for a major ride study performed here in the mid-1970s. One measure, total power in a wavelength band, was found to correlate well with subjective response to ride quality. The band selected included all wavelike profile features from a length of 2 ft to a length of 50 ft. The wavelength viewpoint is an outgrowth of modern signal analysis techniques. The Michigan RQI correlates very highly with a ride quality measure derived in similar fashion by another HPR study (Janoff, 1988). The point to be made here is that any measure, current or future, can be derived from the lightweight device's true profile just as from the RTP truck. Widespread use of the lightweight or similar units based on the GMC RTP concept will ensure that accurate profiles are obtained. This is a necessary and crucial first step in generating measures like RQI that truly characterize ride quality. Obviously there are many uses for a true profile other than just ride quality, e.g., identifying regions of pavement distress.

A detailed Research Report (R-1318) has just been published (see below) on this new unit describing its development, calibration, etc. Once again, cooperation between the Federal government, MDOT, and Michigan's contractors has culminated in a 'better mousetrap.'

-John Darlington

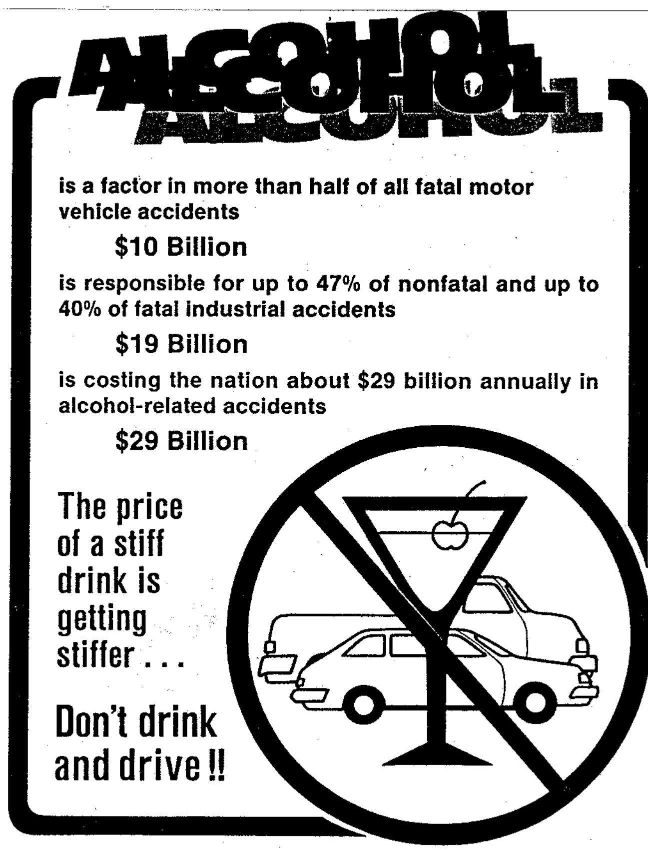
TECHADVISORIES

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.

The Lightweight Pavement Profile Instrument, Research Report No. R-1318, by John Darlington. This is the final report on the Highway Planning and Research Project described in the article above. The article describes the problems that generated the research and the vehicle that was ultimately developed. This report goes into detail on the selection of the vehicle and electrical generator, the development of the odometer, accelerometer, optical sensor and isolation mount, computing and conversion equipment, profile computation board, auxiliary board and handlebar pod, and the burst generator board. The section that follows describes the development of the necessary software. The next section describes the validation tests: viz, comparison with the RQI and profile traces from the new unit with the Department's RTP, verification that the profile traces from the CALPRO computer model are essentially the same as the actual CALPRO-generated traces, and verify that the inchesper-mile computed by the new unit matches that from hand reduction of the CALPRO trace. The final section discusses such problems, and suggested resolutions, as all terrain vehicle, vibration, static charge and ignition noise, odometer problems, temperature control, and monitor problems. Appendices depict operational computer screens, sample output files, schematic circuit diagrams, system check computer screens, and calibration computer screens.

OOPS!

In the last **Personnel Notes**, an employee's name was inadvertently mis-spelled. Somehow **Tom Hohm**'s came out as **'Holm.'** Sorry 'bout that Tom!



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