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Kathleen M. Jones

WET WEATHER POTHOLE REPAIR

*From **Implementation Manual for the Rapid Repair of Wet Asphaltic Concrete,** Research Report 359-3F, by David Cherem-Sacal, David A. Price, Brian Osterndorf, Alvin H. Meyer, and David W. Fowler. Excerpted by Jeanine Cadena.*

Anyone who has ever tried patching potholes in cold, wet asphaltic pavement knows it does not work very well. In 1981, the Lubbock District pioneered the use of fly ash in wet weather pothole repair. The results of the simple fly ash and water repairs were so successful, the Center for Transportation Research (CTR) at the University of Texas was prompted to make a scientific investigation of this easily obtained by-product of coal-burning power plants. Tests made at CTR show that a mortar of fly ash, sand and water can be used successfully to repair potholes during wet weather. The mortar can harden in the presence of excess moisture and can cure properly even if submerged. It forms an extremely strong fly-ash-to-asphalt bond. It is also less expensive than commercially available pothole patching products.

Typically, fly ash is the finest part of the residue that is formed as a result of combustion of coal. It is a natural pozzolan; however, some types are cementitious as well as pozzolanic. Various types of pollution control systems can be used to collect fly ash from the stacks of coal-fired generators. Fly ash is classified according to its coal source: in reference to coal from *eastern* U.S.A., class F is for ashes of bituminous coal, and class C is for ashes of sub-bituminous and lignite coals. Texas fly ash, the type researched in this study, comes from Wyoming or other *western* sources. Texas class A refers to fly ash that is pozzolanic only and must be activated with slaked lime in the presence of moisture to cause it to set. Texas class B refers to naturally cementitious fly ashes, many of which are also rapid setting. The fly ashes tested in this project are Texas class B. They came from three plants in Texas located near the cities of San Antonio (Deely), Amarillo (Harrington) and Cason (Welch). Coal sources for coal-burning generators do change, so contact Mr. Reg Rogers [(512) 465-7928] or Mr. Joe Raska [(512) 465-7469] in Materials and Tests (D-9) to determine if the fly ash from a particular plant is currently a suitable class B, rapid-setting one.

CTR researchers concentrated on finding the optimum strength ratios of fly ash, sand, coarse aggregate and water. They found a mortar of one part fly ash to two parts sand results in a very weak final product regardless of the kind of fly ash used or the amount of aggregate added. They consider this discovery important because the natural tendency would be to mix the fly ash in the same manner as portland cement,

INSIDE...

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roughly 1 part cement: 2 parts sand: 3 parts coarse aggregate. Their results show a ratio of 2 parts fly ash: 1 part sand: 2 parts coarse aggregate appears optimum. Even if too much water is added, the chances are good that this ratio will develop 4000 psi (see Fig. 1).

An important feature of fly ash is that it hardens very rapidly. Within 15 minutes, it is strong enough to support the weight of a car. Within 24 hours, over 50 percent of the ultimate 28-day strength has been achieved. This rate may be somewhat slower during cold weather; however, in hot weather, the rapidly setting fly ashes can present a problem since thorough mixing is difficult to accomplish.

Polypropylene fibers were examined as a possible component of the fly ash mortar. The fibers did not greatly reduce the amount of shrinkage of the mortar, nor did they increase the ultimate compressive strength. The fibers did, however, hold the fly ash patches together after failure had occurred. Without fibers, patches quickly came apart after a failure. This observation implies that a road repair containing fibers will probably have a longer life span.

Several methods of hand mixing were used in an effort to determine a fast and simple method for placing the material. Field tests indicate that it is not necessary to square up the sides of the pothole for a fly ash repair. The method that seemed to be the most efficient was mixing the fly ash right in the pothole itself using a hand tool known as a "Swoe" (trademark of True Temper, Allegheny International Hardware Group, Shiremanstown, PA). The blade of this tool is smaller than that of a hoe and is positioned at a slight angle. The combination gave it more versatility and better mixing characteristics than most of the other tools tried. Some of the advantages of this method are that no expensive equipment needs to be transported or maintained, and clean up is very simple. Disadvantages include difficulty in preventing the fly ash or water from splashing out of the hole, and the occasional difficulty in mixing in a jagged hole.

The following conclusions and recommendations are made based on laboratory and field studies.

- Use a ratio of two parts fly ash: one part sand: two parts coarse aggregate.
- Estimate the volume of material needed (Fig. 2).
- Sweep the loose debris from the pothole (Fig. 3).
- Premix all of the dry ingredients before starting the repair; fly ash starts to set in about 4 minutes after mixing with water. Add polypropylene fibers to control cracking, if desired.
- Fill or drain the pothole so that the water level is approximately one fifth of the total volume (Fig. 4).
- Add the fly ash premix directly into the pothole and begin stirring rapidly with a hand tool; continue stirring and adding fly ash until the mixture has a fairly stiff consistency (Figs. 5 and 6).
- Understand that fly ash mortar might not have the consistency and workability of "typical" wet portland cement.
- Trowel the surface of the repair (Fig. 7).
- Wait about 15 minutes for the fly ash to harden before allowing traffic on it (Fig. 8).
- Regard fly ash as a temporary repair lasting from one to three years.

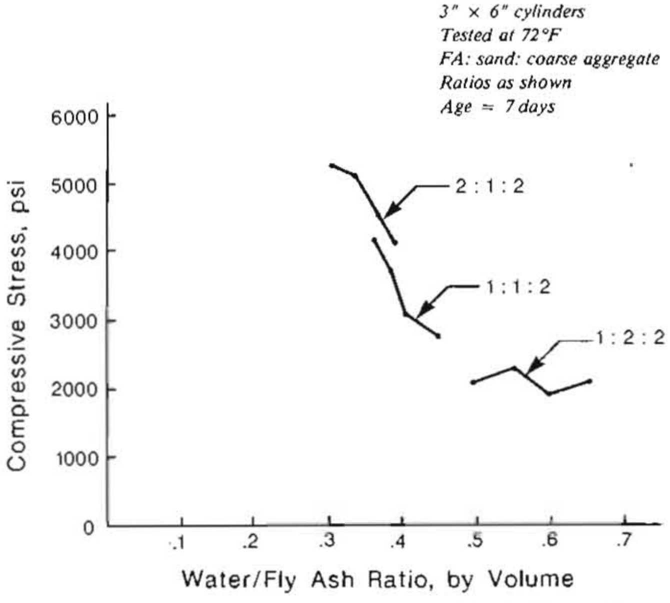

FIG. 1: Optimal water-to-fly-ash ratio for different ingredient ratios of Welch fly ash.

FIGURE 2: Estimate volume.

FIGURE 3: Sweep out loose debris.

FIGURE 4: Check water level.

FIGURE 5: Add fly ash premix.

FIGURE 6: Stir while adding fly ash.

FIGURE 7: Trowel surface.

FIGURE 8: Allow fly ash to harden.

UPGRADING THE 690D PROFILOMETER WITH LASER PROBES

by Kathleen Jones
D-10 Research

True road profile: how can it accurately be measured without using a rod and level at very small intervals (in the range of 0.25 ft)? For twenty years this question has been plaguing highway maintenance people and researchers alike. In the early 1960s, Spangler and Kelly developed an inertial design profilometer for General Motors Research for analyzing road surfaces and roughness. Most profilometers in use in the U.S.A. are based on this GM design (Fig. 1). The original design relied on road-following sensor wheels to sample roughness. At least three types of problems can be induced by this type of mechanical system: rolling nonuniformities (a problem at smooth sites only); wheel bounce which limits measurement speed to about 20 mph; and mechanical resonances of the tire and loading suspension. The urethane following wheels and their potentiometers are also easily damaged and require a lot of maintenance. Research in Texas and Michigan clearly showed that these problems are eliminated by refitting profilometers with noncontact probes [*1, 2*]. Because noncontact probes could reduce problems, the Texas State Department of Highways and Public Transportation decided to refit its profilometer with laser probes (Fig. 2). The refit was to include an upgrading of the profilometer computer as well, which would enable profile and serviceability index to be provided within minutes of measuring a section. The combination of the laser probes and the more powerful computer allows .2-mile sections to be measured at speeds of up to 50 mph (see Table 1) making it possible to operate the profilometer in high traffic urban areas.

FIGURE 1: 690D profilometer.

BACKGROUND

In 1966, Texas SDHPT bought its first GM Surface Dynamics Profilometer. This unit was assigned to the University of Texas at Austin. U.T. was directed to develop techniques for its use in pavement condition monitoring. During the next several years, K.J. Law Engineers, Inc., which was commercially manufacturing GM profilometers under patent license, made improvements

TABLE 1: Comparison of SI's obtained November 18, 19, 20 1987

	20 MPH				50 MPH			
Section	Run 1	Run 2	Run 3	Avg	Avg	Run 3	Run 2	Run 1
1	1.93	1.85	1.92	1.90	2.09	2.01	2.09	2.17
2	1.70	1.60	1.85	1.72	1.80	1.87	1.73	1.80
3	3.88	3.84	3.84	3.85	3.79	3.75	3.79	3.83
4	1.73	1.89	1.81	1.81	1.60	1.59	1.59	1.62
6	1.63	1.94	1.82	1.80	1.89	1.89	1.95	1.82
7	4.40	4.42	4.41	4.41	4.30	4.31	4.29	4.30
8	4.09	4.05	4.00	4.05	3.90	3.90	3.89	3.92
9	3.72	3.72	3.68	3.71	3.52	3.70	3.48	3.39
11	2.97	2.97	2.98	2.97	3.12	3.06	3.21	3.09
14	4.21	4.09	4.13	4.14	3.96	3.98	3.96	3.95
15	4.05	4.09	4.12	4.09	4.09	4.06	4.09	4.13
19	3.99	3.92	3.97	3.96	3.89	3.89	3.91	3.88
23	4.07	4.00	4.22	4.10	3.95	3.97	3.97	3.92
28	3.41	3.33	3.31	3.35	2.84	2.88	2.83	2.82
30	2.38	2.35	2.26	2.33	2.36	2.34	2.34	2.41
31	3.59	3.59	3.50	3.56	3.60	3.74	3.60	3.47
32	4.07	4.14	4.01	4.07	4.10	4.10	4.06	4.13
33	4.51	4.55	4.65	4.57	4.51	4.49	4.51	4.53
34	4.54	4.57	4.55	4.55	4.36	4.31	4.38	4.38
35	2.80	2.90	2.81	2.84	2.84	2.86	2.82	2.85
36	4.61	4.57	4.61	4.60	4.56	4.57	4.57	4.53
38	2.58	2.65	2.59	2.61	2.66	2.56	2.64	2.79
40	3.73	3.79	3.73	3.75	3.81	3.79	3.75	3.90
41	3.77	4.05	3.96	3.93	4.13	4.14	4.14	4.11
44	1.44	1.30	1.28	1.34	1.33	1.29	1.36	1.35
55	3.34	3.40	3.32	3.35	3.23	3.24	3.24	3.22

Regression Output:		
Constant		0.11
Std Err of Y Est		0.15
R Squared		0.98
No. of Observations		26.00
Degrees of Freedom		24.00
X Coefficient(s)	0.91	
X Coefficient(s)	0.96	
Std Err of Coef.	0.03	

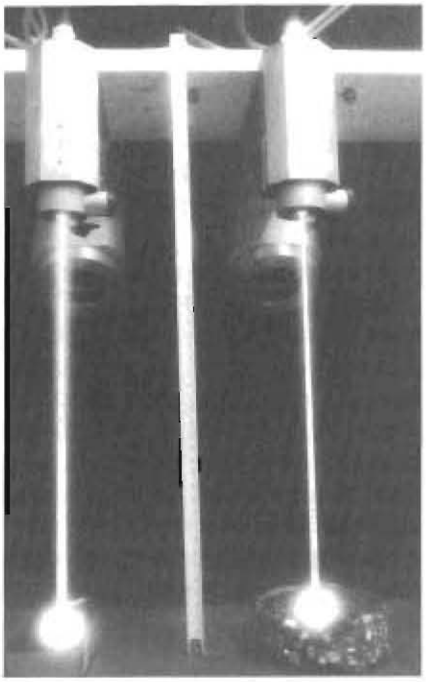

FIG. 2: Selcom laser probe.

in the design. Two of the major improvements were a digital (as opposed to analog) computer and software with "spatial" filtering that compensates for speed variations (originally profile measurements had to be taken at a constant speed). In 1980 after several years of research, the Department decided to purchase an improved Surface Dynamics 690D Profilometer from K.J. Law, Inc. The cost was approximately $216,000. This new unit was also assigned to U.T. for highway surface analysis research until 1983 when the Highway Design Division (D-8) requested its use within the Department. In September 1984, the unit was transferred to the Technical Services subsection of Research in the Transportation Planning Division (D-10) where other surface measurement devices and adequate facilities were available [*3*]. In May 1987, a new section devoted to pavement evaluation, D-10E, was created. Part of this section is the profilometer support team from D-10R. D-10E's efforts are directed at automating and increasing the precision of pavement condition data.

Until 1986 the SD profilometer sampled road surface conditions only through two road-following wheels. The wheels are held to the surface via a torsion bar system which loads the wheels to about 300 psi [*4*]. A linear potentiometer is mounted between each sensing wheel and the vehicle body to provide a voltage proportional to the difference between the vehicle frame and the road. Two accelerometers, mounted above their respective potentiometers, provide vertical vehicle acceleration. This acceleration is digitized by a profile computer and summed with the digitized potentiometer signal resulting in a road profile. A high pass filter is used to remove low frequency or very long wavelength profiles, such as hills, which are normally excluded from profile analysis.

The on-board computer used in the pre-1986 profilometer was a DEC PDP 11 with a Gould strip chart for recording in real time, as well as a digital magnetic tape recording system for profile data storage and later data processing. Although once a very popular and up-to-date system, the PDP 11 is now outdated. Before useful information such as present serviceability index numbers could be obtained, the data first had to be dumped from the 9-track tape to the mainframe. After the data was on the mainframe, it joined the line of jobs waiting to be processed. Often there was a wait of several days before the data was processed.

Advances in computer technology have now resulted in systems which are more reliable, smaller, have more memory, require less power, are less expensive and are much faster. The newer systems permit much more on-board processing. Thus turnaround time on information such as road profile and pavement roughness can be provided the same day without going to a mainframe. Upgrading to one of these faster, newer systems was considered essential along with the upgrade to noncontact probes, in order to make the profilometer as accurate and fast a piece of testing equipment as possible.

THE REFIT (STUDY 494)

Optical light, infrared light, laser, and ultrasonic pulse are all possible bases for noncontact measurements. The Swedish Selcom Optocator (laser transducer) and the Infrared-Light Linear Transducer, developed at Southwest Research Institute in cooperation with the FHWA, were tested and compared with each other and with the mechanical system. The results are published in report 251-3F. Both systems appeared capable of replacing the profiling wheels and correlating well with the old system. The Selcom laser transducer was chosen because it was commercially available and could be easily mounted on the profilometer van (Fig. 3). For testing and comparison, the mechanical wheels were left operable. The laser probes (with separate accelerometers) are mounted forward of the mechanical

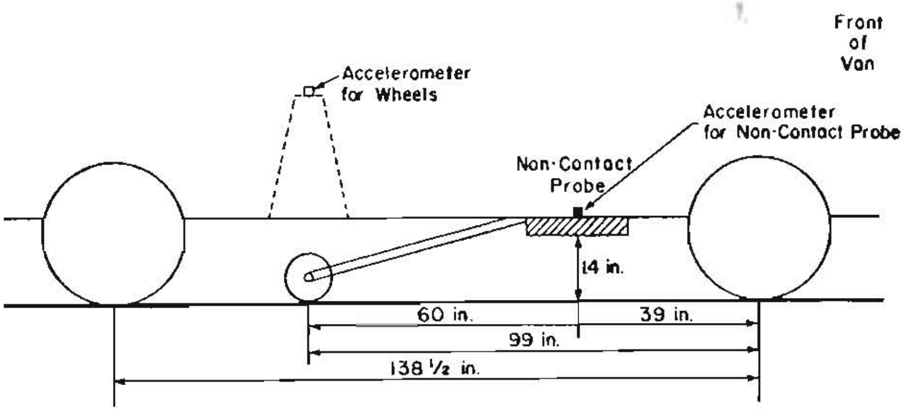

FIGURE 3: Laser probe installation in relation to following wheels.

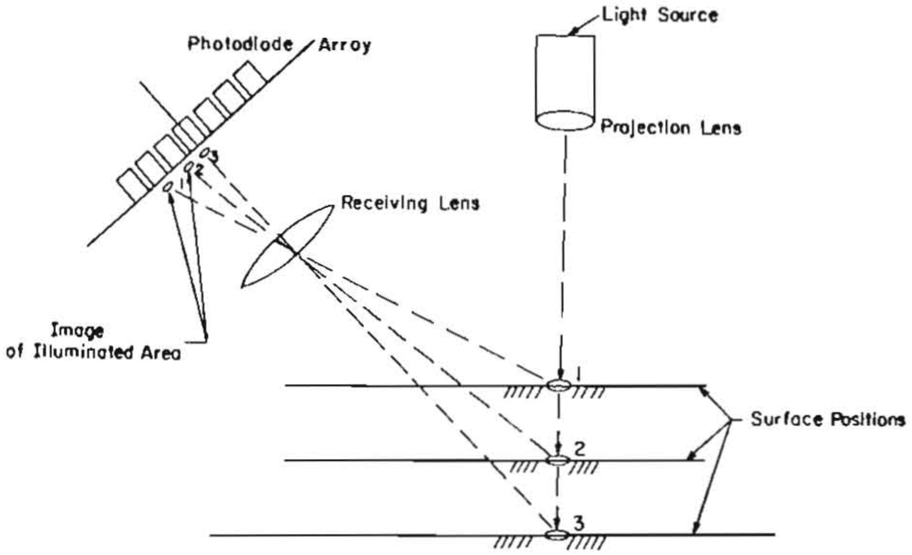

FIGURE 4: Selcom, the basic operating principle.

trailing arm, one for each of the left and right wheel paths of the van. Provisions were made for the systems to be run alternately if desired.

The laser transducer comes in two main parts: the probe unit consisting of the laser light source, the camera with lens and detector, and the signal processing electronics; and the central processing unit (CPU) which receives and processes the reading from the probe unit and makes it available to the profile computer. The CPU also contains power supplies for itself and probe. The laser probe works by triangulation (Fig. 4), calculating height from the apparent position on the detector of a dot-image projected by the laser reflected by the road surface through the receiving lens. The laser light source is regulated to maintain a constant reflected intensity on the detector surface so that variations in the texture, color and reflectivity of the surface will not affect the accuracy of the profile reading. The laser is pulsed 32,000 times a second in order for the detector to be able to distinguish it from other unwanted sources. The probe unit updates the distance reading to the CPU every 62.5 microseconds. The CPU averages a selectable number of readings from the probe to prevent cracks or irregularities in the road surface from distorting the data. The processor makes a new reading available to the profilometer computer as soon as the required number of readings from the probe have been averaged. No handshaking is needed between the Optocator and the profilometer computer.

In order to take advantage of the noncontact probe's measurement ability at higher velocities, a higher computational speed and more computer memory was needed. Greater processing speed allows more real-time analysis of the collected data. Real-time analysis detects measurement errors at once so that a section can be remeasured immediately instead of losing that data due to equipment malfunction. The computer system built around the Motorola VME-131 processor board which Dr. Roger Walker of U.T. Arlington is developing for the laser probe crack study was to slowly phase out the PDP 11 system and operate as the on-board profilometer computer. However, in January 1986 before the Motorola system was anywhere near completion, a severe thunder storm struck Austin. During the storm, the profilometer was connected by its external power connection to a power line. The line was struck causing a number of the computer and profilometer interface boards to be damaged beyond repair. The boards damaged were not all made by the same manufacturer. Some of the boards were obsolete and no longer manufactured at all. Digital Equipment Corporation estimated $15,000 to repair the boards of its manufacture. Most of the other boards would have had to have been sent back to K.J. Law to be completely rebuilt.

An "in-house" upgrade of the system seemed the most attractive alternative for three reasons: 1) computer upgrade was an objective of Study 494; 2) repair would be as (or more) costly than new equipment; and 3) personnel changes at the University and the private software design companies hampered successful rebuilding. An intermediate system was devised using a COMPAQ 286 computer and an off-the-shelf Data Translation analog-to-digital board. The COMPAQ performs both the data acquisition and the road profile computations. It greatly simplifies the data collection routine, as can be seen by comparing Figure 5 with Figure 6. The programs were written for the COMPAQ so that it could output either profiles or present serviceability index data the same day as the measurement run was made (Fig. 7).

Work began on creating digital, high frequency noise filters for the probe accelerometers as soon as the COMPAQ software was far enough along. Trial runs on the Austin Test Sections began. Shortly thereafter, the left accelerometer failed. (Its signal would drop out completely at a certain threshold.) The VERTAC program interpreted the signal deviation as a sudden difference of several hundred feet between the left and right wheel path. New accelerometers, expected to be more robust, were purchased. These new accelerometers had to have digital filters designed for them. Trial runs started over. One of the accelerometers failed. "It was a nightmare," said the electronics technician. The researchers and Departmental technicians tried again. This time they modified the Walker Roughness Device (SI-ometer) accelerometers, modified the digital filters and were up and running by August 1986.

Although the computer and accelerometer problems did not allow extensive usage of the laser and new computer system to be completed during the study, such usage is now under way. This usage is needed to correct any problems overlooked in the upgrade process. One such problem is the current need to limit section length greater than .2 miles. In its present configuration, the COMPAQ system cannot process data for more than a mile. Soon to be purchased are some powerful boards which will allow the profilometer to run long sections at 50 mph.

SUMMARY OF ACCOMPLISHMENTS

1. The Selcom noncontact laser probes have been installed, tested and validated.

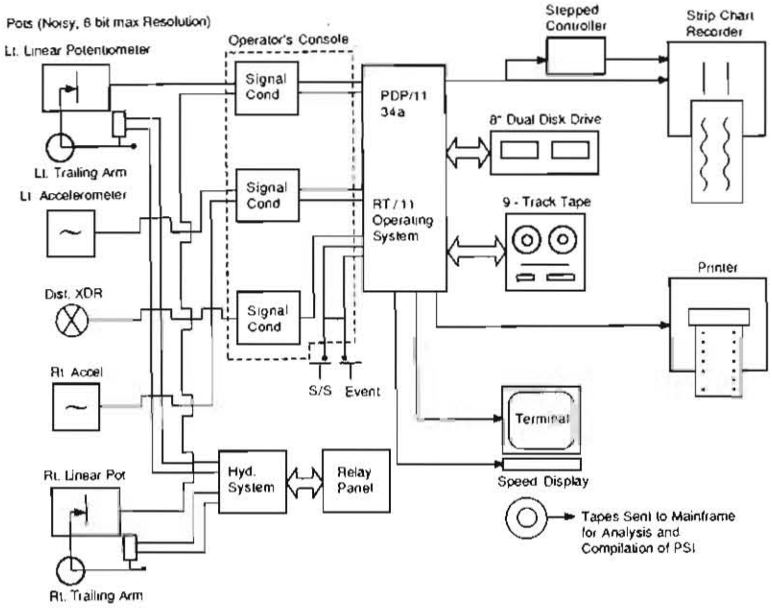

FIGURE 5: Simplified schematic of K.J. Law system.

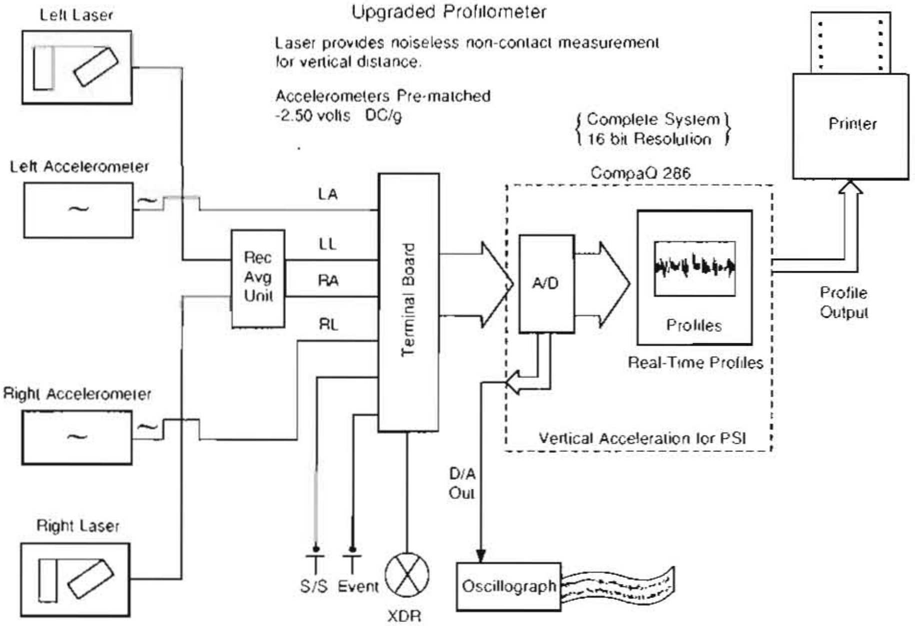

FIGURE 6: Simplified schematic of COMPAQ system.

2. The profilometer computer has been upgraded to a COMPAQ 286 based system. This system has adequate processing and storage for on-board data processing, reducing dependence on main frame systems and thus reducing data reduction costs and turn-around time. Now field engineers can ask the profilometer operator to process the data and show them the results prior to the unit leaving the site.

3. The upgraded SD profilometer has been used successfully in several research projects including its correlation with the Walker Self Calibrating Roughness Device and the Rainhart and California profilographs.

4. Department personnel have been trained in the theory and techniques of the SD profilometer so that delays and errors in data collection and equipment repair can be avoided.

5. The profilometer can now be run at near highway speeds, rather than 20 mph. At highway speeds the profilometer is less of a hazard to the traveling public and is less dangerous for the crew to operate.

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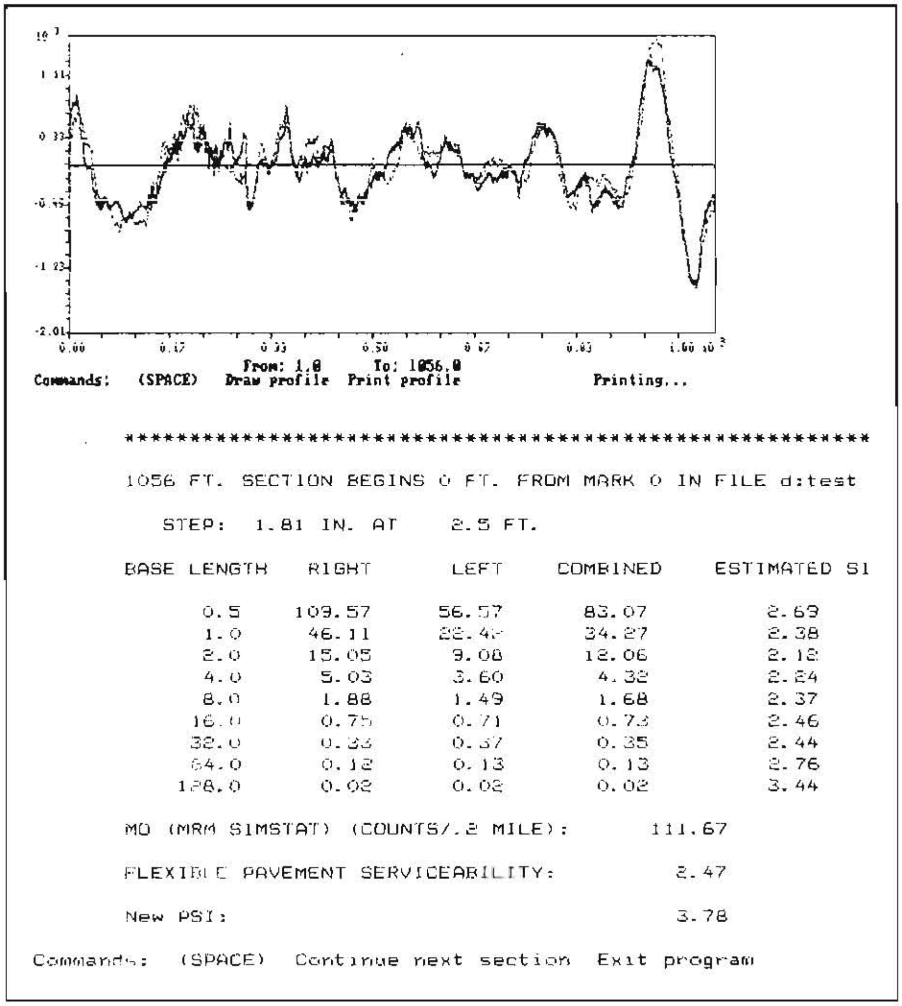

```
                    From: 1.0      To: 1056.0
Commands:   (SPACE)   Draw profile  Print profile                 Printing...

      ***********************************************************

      1056 FT. SECTION BEGINS 0 FT. FROM MARK 0 IN FILE d:test

         STEP:  1.81 IN. AT     2.5 FT.

      BASE LENGTH   RIGHT       LEFT     COMBINED     ESTIMATED SI

             0.5    109.57      56.57      83.07           2.69
             1.0     46.11      22.4[illegible]      34.27           2.38
             2.0     15.05       9.08      12.06           2.12
             4.0      5.03       3.60       4.32           2.24
             8.0      1.88       1.49       1.68           2.37
            16.0      0.75       0.71       0.73           2.46
            32.0      0.33       0.37       0.35           2.44
            64.0      0.12       0.13       0.13           2.76
           128.0      0.02       0.02       0.02           3.44

      MO (MRM SIMSTAT) (COUNTS/.2 MILE):          111.67

      FLEXIBLE PAVEMENT SERVICEABILITY:              2.47

      New PSI:                                       3.78

Commands:   (SPACE)   Continue next section  Exit program
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FIGURE 7: Sample of output.

ARAN® AUTOMATES URBAN PAVEMENT DATA COLLECTION

ARAN®, or the Automatic Road Analyzer, is a multiple function vehicle, designed to collect and record numerous roadway data in one pass at highway speeds between 30 to 50 mph (Fig. 1). Still in the advanced stages of development, it is replacing labor-intensive rating methods in urban areas where slow speed data collection is a danger both to the rating team and to the traveling public. The ARAN® can perform rut depth analysis, videologging for pavement distress analysis and for sign and bridge condition rating, determine crossfall, grade and curve radius and perform a roughness rating. Its distance measuring instrument has 0.001 mile resolution, is transmission-driven and is capable of providing recalibration for tire wear. Highway Products International, Inc., has been developing this machine since 1977. The vehicle's chassis is of a standard Detroit van type. Its special features include

FIG. 1: The ARAN®.

FIG. 2: Built-in arrow board.

speed control, heavy duty suspension, a separate gas generator to run on-board electrical equipment, power steering and brakes, wide profile radial tires, a separate air-conditioning unit for the computer components and an arrow board built into the rear panel (Fig. 2). The ARAN® is already a major tool for Pavement Evaluation System (PES) data collection in urban areas, and research is being done for its use in the Highway Performance Management System (HPMS).

A modified "Ruggedized Industrial" IBM PC-AT serves as a central computer for various subsystems. The computer stood up well during the recent collection of 1000 miles of roadway data in Houston. It showed no sign of problems caused by vehicle vibration or by dust contamination. This computer stores data on battery-backed RAM discs, which permits continuous data collection. The operator uses a 9 inch color CRT, mounted between driver and passenger seat, for continuous data monitoring. The operator enters header data such as road number, section, lane, date and interval of sampling (from .01 to 1 mile) on a small, lap-type main control keyboard (Fig. 3). The header data is transferred to the video screen as well as to the RAM discs so that video information can be correlated exactly to other computer data. On-board software subsystems are comprised of speed compensating software which allows the driver to vary speed with traffic and not invalidate data; diagnostic software to detect the source of many types of malfunctions; calibration software to check the data; and data acquisition routines for roughness, rut depth, grade and crossfall, curve radius, surface condition and videologging.

For roughness, accelerometers, on the rear axle and on the body, measure vertical accelerations and provide data as an average of the two wheel paths. The roughness numbers displayed are the root mean square of vertical accelerations (RMSVA) and mean rectified slope (MRS). At present, only pavement serviceability index (PSI) can be determined when the van is in roughness mode. PSI as derived by the ARAN® correlates well to the SD Profilometer PSI. The software is not yet available to enable profile to be determined by the ARAN®.

FIG. 3: Main control keyboard.

Ultrasonic transducers are used to measure distance to the pavement surface for rut depth calculations. They are installed on the front bumper-mounted rut bar (Fig. 4). The sensors on the rut bar can measure the pavement surface profile for a 6- to 12-foot lane width. The extra width is provided by folding, detachable wing extensions. One minor difficulty with the ultrasonic transducers is that they cannot be used to measure rut depth during or after a heavy rain when a pavement has standing water on it. The ultrasonic transducers are unable to distinguish the signal sent back by a rut full of water from the signal sent back by a level piece of road.

Ultrasonic transducers, in conjunction with gyroscopes, make up the attitude sensing subsystem. The gyroscopes are of two types: a pitch and roll type and a precision directional type. Crossfall is determined by the computer using ultrasonics and the gyro roll measurement. Grade is determined by ultrasonics and the gyro pitch measurement. The directional heading gyroscope measures 0° to 360° actual heading while traveling at highway speeds. Curves with radii from 50 feet to 6 miles can be calculated from the data. This gyro is unaffected by lateral forces. As a whole, this subsystem can make a measured inventory of grade and crossfall parameters, map the longitudinal profile of any feature that affects sight distance and provide information on curve severity which can be used in setting safe and reasonable maximum speeds. Crossfall and rut depth data can be used together to help estimate how much level-up material will be needed in a rehabilitation job.

ARAN®'s videologging subsystem enables it to obtain a permanent visual record of roadways and pavement surfaces. The cameras and recorders are high resolution and computer aided. The computer digitally ties in the video data to the other data being acquired by the ARAN®. This interfacing allows for high-speed video search analysis,

FIG. 4: Bumper-mounted rut bar.

interactive processing with data from other subsystems and in-office condition rating of pavement surfaces. One high-speed, shuttered, solid-state camera, with a wide angle lens, is mounted in the rear of the ARAN® and is focused on the pavement. Under optimum conditions, the camera can detect fine pavement cracks as small as 1 mm while traveling at 50 mph. Often, lighting conditions prevent this level of detail. However, further developments in video technology appear to be solving the light level problem. Plans are being made to replace the present cameras with more advanced ones in the next year. Eventually, ARAN® will also be fitted with noncontact laser probes to detect cracks in the road surface. The front camera is a medium-speed, nonshuttered, solid-state camera. This camera is used to record the right-of-way (ROW) view. Records of the ROW can be used to monitor the condition of roadside appurtenances like signs, shoulders, bridge abutments and edge markings.

While pavement distress type and severity can be recorded during ARAN® data runs by a team of raters watching the pavement camera monitor and using a pair of condition rating keyboards, speed makes it difficult. It is far easier to rate pavement in-office (Fig. 5) from the videologging data. Once the data is downloaded from the RAM to a floppy disc, translated, and edited according to any notes made about the run, distress rating can begin. The computer finds the requested section on the video tape. The rating keyboard (Fig. 6) provides capacity for 20 user-chosen distress categories, 3 degrees of severity, 10 degrees of extent of affected area and 8 special event keys. The 8 special event keys register bridge decks, railway crossings and overpasses for editing and data analysis. The video tape speed can be slowed, stopped or fast forwarded.

Right now, the translation of the data from its compressed state is rather slow. An upgrade in computer memory will take care of that. Decisions about storing the large data base of information created by the ARAN® need to be made. Storage on optical discs is being considered currently, as well as the more usual methods of storing on the mainframe. When the software, storage and lighting condition problems are solved, ARAN® will be an extremely efficient, safe way to collect virtually all the data needed for highway pavement management.

FIGURE 5: In-office computer for ARAN® pavement rating and data analysis.

TEXAS MODEL FOR INTERSECTION TRAFFIC

by Dr. Clyde Lee
Center for Transportation Research
University of Texas

Street and highway intersections are critical areas. They represent potential hazard, congestion, and capacity constraint in road networks. Intersection design process generally involves developing several practicable alternative plans, each of which will satisfy the specific needs of the situation, and then selecting the best, or most desirable, one. Because of the large number and range of variables involved, this is a complex task. In the past, traffic engineers have had to rely heavily upon observation of traffic operations at existing intersections and subsequent application of a few physical and psychological principles as the basis for developing alternative intersection designs. Likewise, selection of the one design to be implemented has been based mostly on experience with situations similar to those under consideration. Sometimes comparable situations have not been available to traffic engineers when a specific intersection design was being developed.

Computer simulation for intersection design and evaluation has been developing over the last ten years. The advent of the microcomputer, with its interactive screen display capabilities, made it desirable to develop a user-friendly version of the TEXAS Model for convenient, routine use by traffic engineers. (The original mainframe version of the model, which became available in 1977, was cumbersome to use. Data entry was accomplished via several

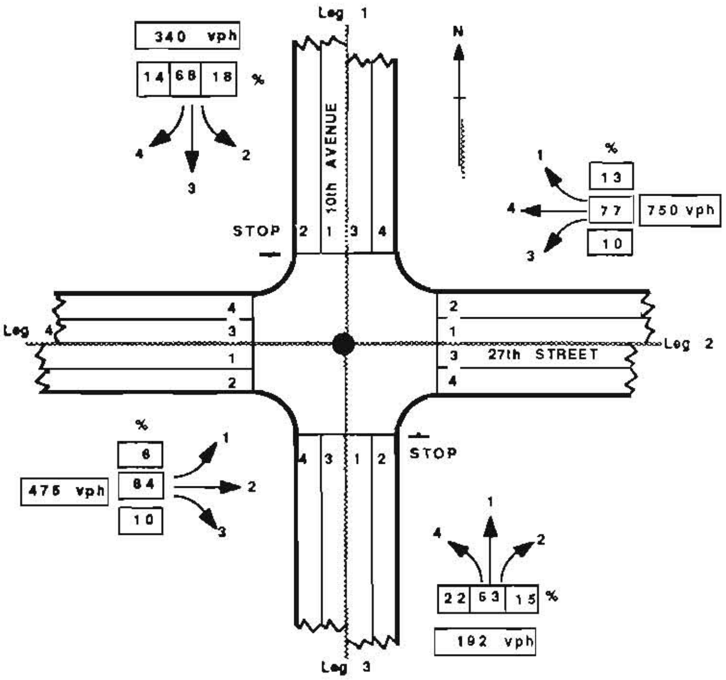

FIGURE 1: A screen from the new animated graphics display.

sheets of hand-written coding forms and punched cards. Remote access to the mainframe computers was very limited.) The TEXAS Model for intersection traffic is a powerful microcomputer simulation package which allows the user to study, in great detail, the complex interaction among individual/vehicle units as they operate in a defined, single intersection environment under a specified type of traffic control.

With the TEXAS Model loaded into a desk-top microcomputer, a traffic engineer can get quick answers to questions such as, "What if I install stop signs; what if traffic increases; if the percentage of trucks increases; if a traffic-actuated signal is put in; if a left-turn bay is added; etc.?" The answers appear as printed summary statistics or as a real-time, animated-graphics display of vehicles moving through the intersection on the microcomputer screen. A number of intersection types are available by menu selection. After an intersection and traffic parameters are specified, the computer model will then provide various summary performance statistics such as delay, speed, number of stops, length of queues, actuated-signal behavior, vehicle emissions, and fuel consumption. These statistics give the traffic engineer quantitative measures of effectiveness for the specified design. A proposed plan can be evaluated without having to try it under actual field conditions. With a few runs of the model, capacity and level-of-service determinations can be made, and near-optimum geometry and traffic control can be defined.

Animated graphics show drawn-to-scale, color-coded vehicle types moving through the geometry of the intersection in either real-time or stop-action mode in response to their static and dynamic surroundings and in obedience to official traffic controls. These graphics allow the engineer to analyze the overall performance of a particular design, as well as study the behavior of individual vehicles and geometric features of the intersection environment. It also provides a convincing means of communicating complex intersection performance patterns to public bodies and to other traffic experts.

The current version of the TEXAS Model for Intersection Traffic exemplifies the evolutionary development of practical engineering tools and techniques through the Department's cooperative research program. Development of the model began in 1974, using the mainframe computers of that era, as a research study done for the Texas Department of Highways and Public Transportation under the Federal Highway Administration's Cooperative Highway Research Program by the Center for Transportation Research at the University of Texas at Austin. Although the mainframe model was cumbersome by today's standards, it was validated rather convincingly with field studies of several intersections and proved to be a valuable research tool. It has been used for a number of research studies throughout the decade.

The TEXAS Model is written in FORTRAN-77 and can be run on mainframe computers as well as IBM PC's and compatibles. To run the model, the PC should be configured with DOS 3.1, Math Coprocessor, 512K RAM, Fixed Disk, and Printer. Research Study No. 3-18-87-1133, *Animated Graphics for Intersection Traffic Analysis*, has added the animated-graphics feature described above. The graphics package is displayed only on the PC and requires either a color graphics adapter and color graphics display or an enhanced graphics adapter and mono, color, or enhanced graphics display. The microcomputer version of the TEXAS Model for intersection traffic (including the animated graphics feature) is public-domain software and will be available soon to Department personnel from the D-10 Research Library, (512) 465-7644 or STS 241-7644. Other interested individuals may obtain the package for the cost of distribution through McTrans, the Center for Microcomputers in Transportation, University of Florida, 512 Weil Hall, Gainesville, FL 32611, (904) 392-0378.

THIRD-POINT LOADING RECOMMENDED FOR QUALITY CONTROL

by P. M. Carrasquillo
and R. L. Carrasquillo
Center for Transportation Research
University of Texas at Austin

INTRODUCTION

Quality control tests must be repeatable, accurate, sensitive to relevant characteristics and properties of the material tested and as insensitive as possible to external factors such as type of testing equipment used, handling and difference in operators. Center-point loading (CPL) is the quality control test currently used by the Texas State Department of Highways and Public Transportation (SDHPT) to monitor concrete strength for highway construction. The CPL flexural beam test is Texas Test Method Tex-420-A [1]. When beams are tested in CPL, the point of maximum moment (and therefore maximum stress) occurs at midspan (Fig. 1). It is this maximum value that is reported at failure. However, very often beams tested in center-point fail at a location other than at midspan—in other words, at a point subjected to a lower moment and thus lower stress. A beam that has broken at an angle to the midpoint, by standard procedure, must still be recorded at the maximum value, even though this value may overestimate the actual strength of that beam in flexure. In addition, the variability in test results obtained using CPL is often high because the maximum moment occurs at one point only. For these reasons, a research project was conducted to determine the adequacy of CPL procedure and to investigate an alternate test procedure, namely the flexural beam test using third-point loading (TPL). This research project, No. 3-9-87-1119, *Improved Concrete Quality Control Procedures Including Third-Point Loading*, was sponsored jointly by the SDHPT and the Federal Highway Administration (FHWA).

Third-point loading is ASTM Standard Test Method C78 [2]. When beams are tested TPL, there is a region of the beam equal to one-third of its span length which is subjected to constant maximum moment (Fig. 2). Failure occurring at any cross section within that region will not cause an overestimation of flexural strength because the whole region is subjected to maximum stress. Having a region of constant maximum moment reduces the variability.

RESEARCH PROGRAM

The research program included a two-phase study which compared TPL and CPL and, in the interest of ease of handling and storage, investigated the use of 4.5-inch × 4.5-inch × 15.5-inch beams (approximately 25 lbs) in place of the standard 6-inch × 6-inch × 20-inch ones (approximately 65 lbs). A total of over 700 specimens were cast and tested. Concrete mixtures were designed to give strengths representative of all classes of concrete currently used by the SDHPT. Both crushed limestone and silicious river gravel coarse aggregates were used in nominal maximum sizes ranging from 3/8-inch to 1-1/2-inch. Both sizes of beam specimens were cast from each type of mix. Specimens were tested in either CPL or TPL at seven days in the laboratory, and at 75 to 90 days in the field.

Rainhart Series 416 recording beam testers were used in testing all specimens. In order to test the 6-inch × 6-inch × 20-inch beams in TPL, it was necessary to replace the CPL loading head (Fig. 3) with a TPL loading head (Fig. 4) and to use a loading chart made specifically

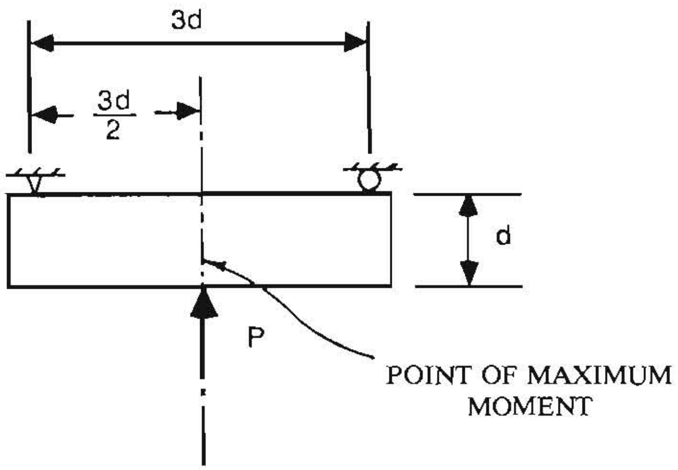

FIGURE 1: Center-point loading schematic.

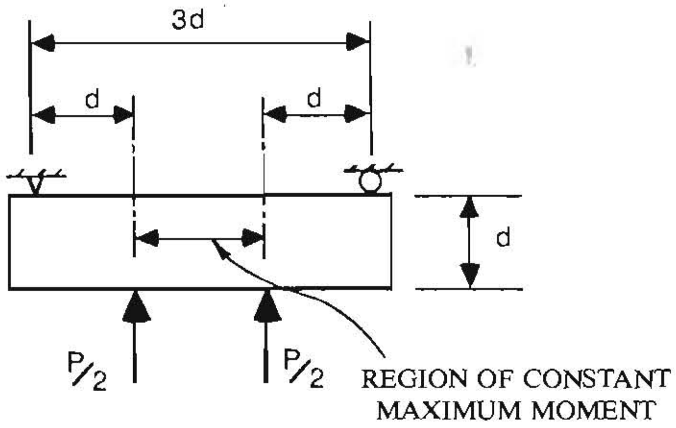

FIGURE 2: Third-point loading schematic.

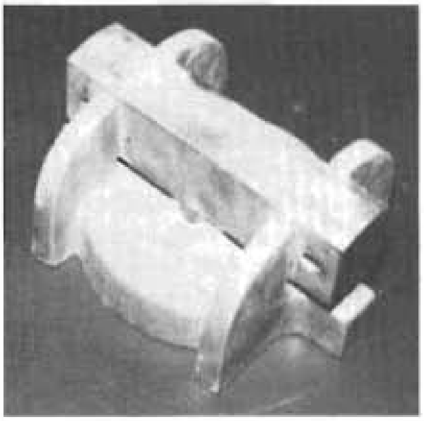

FIGURE 3: CPL head.

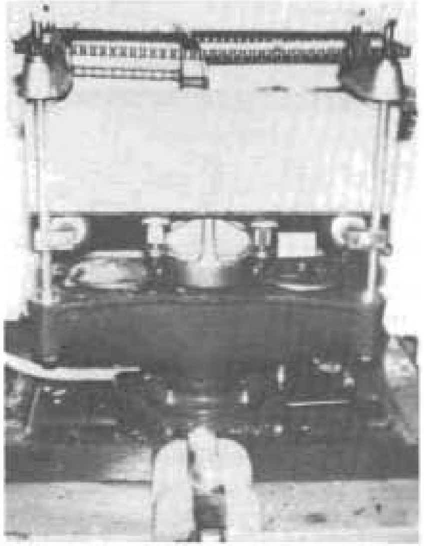

FIG. 4: TPL head in place.

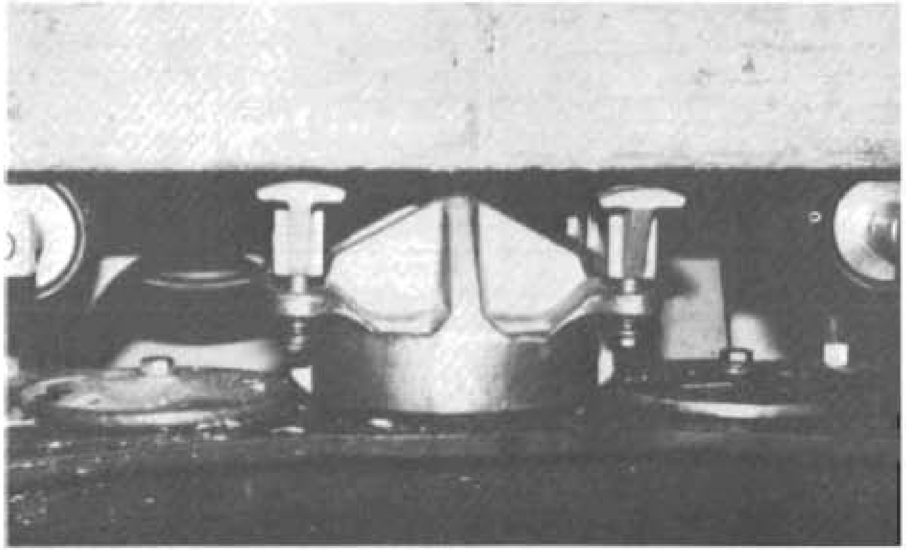

FIGURE 5: TPL close-up.

for TPL. Both the loading head and chart for TPL (Fig. 5) are available from the manufacturer of the testing machine. The TPL head costs about $200 and takes very little time to change. A modified TPL head had to be fabricated to test the 4.5-inch × 4.5-inch × 15.5-inch beams in TPL on the beam testers. However, since the 4.5-inch beams gave more variable test results than the 6-inch beams in both CPL and TPL, it is not necessary to discuss the modification.

Tests were conducted both in the Ferguson Structural Engineering Laboratory at the University of Texas at Austin, and in the field offices and main office of District 14. In the tests conducted throughout District 14, the specimens were tested by SDHPT personnel.

RESEARCH RESULTS

Based on the laboratory tests, 6-inch × 6-inch × 20-inch beams tested in TPL showed more uniform test results than the CPL standard test method (Fig. 6). The uniformity of test results obtained from tests conducted by SDHPT field personnel, however, showed no clear trend with respect to test method used. For example, in the field trial, 6-inch × 6-inch × 20-inch concrete beam groups having CPL specimens with an average strength of about 740 psi, showed more uniformity of test results in the TPL companion specimens, whereas beam groups having CPL specimens with an average strength of about 950 psi, showed less uniformity of test results in the TPL companion specimens.

With the exception of Classes C-C and F, current SDHPT strength specifications for both structural and pavement concretes call for minimum flexural strengths of, at most, 650 psi depending on class. In the 700 psi range, both laboratory and field test results indicate that the third-point loading test using standard concrete beams yields more reliable, uniform test results than CPL. These results mean more confidence can be placed in the TPL value, particularly that flexural strength has not been overestimated. Since TPL tests yielded average test results which were approximately 86% of CPL test results (Fig. 7), new flexural strength specifications reflecting this percentage will be made once TPL is officially adopted. Changing to TPL should not affect design thickness of concrete pavements.

IMPLEMENTATION

Materials and Tests Division (D-9) and Highway Design Division (D-8) personnel plan to include the use of the third-point loading test in several concrete paving jobs on a

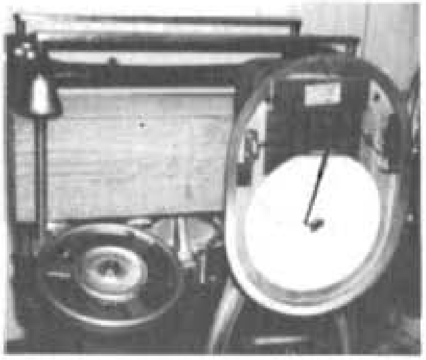

FIG. 6: TPL chart in place.

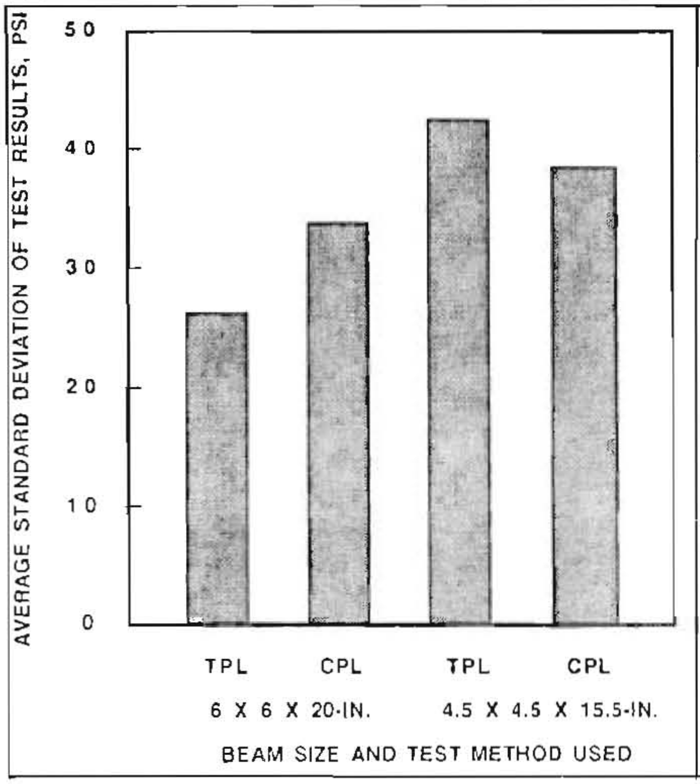

FIG. 7: Uniformity of test results obtained from each test method and beam size.

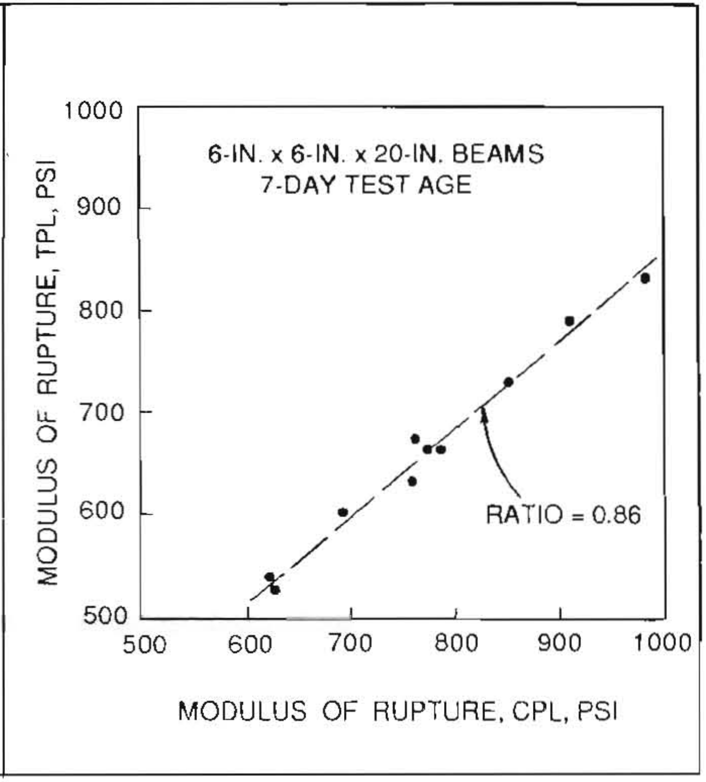

FIG. 8: Modulus of rupture of beams tested in CPL versus TPL, for 6 × 6 × 20-inch beams.

trial basis in the upcoming year. Beams will be cast and tested in both CPL and TPL so that the average strength and uniformity of results obtained from each method can be compared further. In order to obtain the best data possible from the trial, random factors which affect the tests need to be controlled. Experienced lab technicians will already be familiar with these factors from D-9's *Manual of Testing Procedures*.

A quick review of factors known to affect the validity of flexural strength test results includes the following:

1. Consolidation: rod or vibrate depending on slump of concrete.
2. Curing: surfaces must not be allowed to lose moisture prior to testing, since drying shrinkage of the specimen surface could result in up to 100 psi decrease in apparent flexural strength.
3. Specimen surface: all surfaces should be blemish free with no scars, indentations, holes or inscribed identifications. Beam identifications should be made with a permanent marker when a specimen is removed from its mold.
4. Placement of specimen in testing apparatus: the specimen must be placed on its side, with respect to casting position, for testing. There should be no gaps greater than 0.004 inch between the specimen and either the loading surface(s) or reaction surfaces.
5. Chart placement: the pen should be at zero load when no load is on the loading head. Charts are not interchangeable between the two methods. Center-point recording charts must be used only with center-point loading heads. Third-point loading charts must be used only with third-point loading heads.
6. Measurements: after testing, both the beam width and depth at the point of fracture must be measured to the nearest 0.05 inch. Beam width and depth are taken in the testing position, not the casting position.
7. Observations: the location of the failure plane along the beam length should be noted.

SUMMARY

Beams having the dimensions of 6-inch × 6-inch × 20-inch and 4.5-inch × 4.5-inch × 15.5-inch were tested using both CPL and TPL. It was found that 4.5-inch × 4.5-inch × 15.5-inch beams tested in either CPL or TPL gave less uniform results than those tested according to the current standard method (6-inch × 6-inch × 20-inch beams tested in CPL). However, results obtained from 6-inch × 6-inch × 20-inch beams loaded in TPL were generally more uniform than those from the standard method. Therefore, various concrete pavement jobs throughout the state will be chosen for including the TPL test method on a trial basis.

REFERENCES

1. "Flexural Strength of Concrete (Using Simple Beam with Center Point Loading)," Test Method Tex-420-A. Vol. 2, *Manual of Testing Procedures.* Austin: Texas State Department of Highways and Public Transportation.
2. "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)," ASTM Designation C78-84. Vol. 04.02, *Concrete and Mineral Aggregates, 1986 Annual Book of ASTM Standards.* Philadelphia: American Society for Testing and Materials, 1986.

TAINTED WINE USED TO MELT ROAD ICE

The [Austrian] government may have come up with a safe use for millions of gallons of wine withdrawn from the market . . . [in 1985] after it was found spiked with an antifreeze additive. Mixed with salt, the wine seems to melt hazardous highway ice much better than road salt alone. If laboratory tests are any indication, the discovery should please government officials wanting to get rid of the wine, environmentalists who want it disposed of safely, and Austrian motorists facing another icy winter. The Ministry of Public Works began examining uses of the mixture in September and is optimistic about initial results. Road tests are scheduled to begin soon. Ministry spokesman Hannes Drossler now is convinced that "it is an extremely interesting development." (*Austin American-Statesman,* 25 December 1986)

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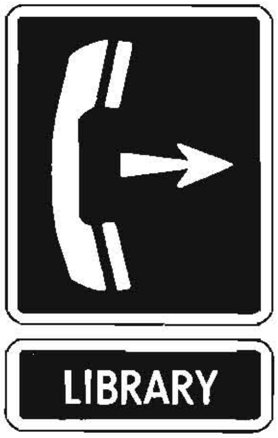

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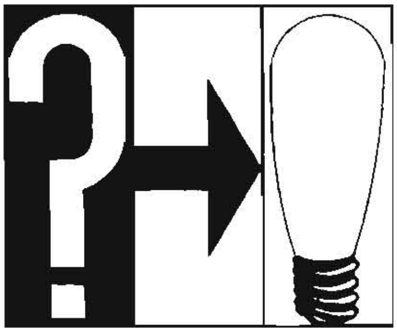
The D-10 Research Library can send you copies of articles and publications summarized in *The Research Digest, Technical Quarterly* and *The Annual Listing*, as well as perform information and literature searches. Call Librarian Kevin Marsh with your requests.

ATTENTION SDHPT INNOVATORS



Articles, techniques or ideas about any facet of highways or public transportation are welcomed. If you have a new way to handle an old problem, a helpful hint for making better use of a standard procedure or product or new application of a common item, send it to us. It doesn't have to be an earthshaker to be useful and appreciated.

If you have an idea to share, a comment to make or materials to request, use the tear sheet in this issue or call Kathleen Jones at (512) 465-7947 or STS 241-7947.

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A FIRST

The first highway divider was created by a woman driver in California. Dr. June A. Carroll, of Indio, painted a line along a one-mile section of dangerous highway in 1912 to help uncertain travelers find their way. Shortly afterward, the California Highway Commission adopted the idea which has become standard throughout the world.

Failure Analysis on General Electrodynamics Corporation M 700/1100 Scale Platform

GEC has experienced an occasional platform failure in the field. Failure has been narrowed down to two different conditions: 1) excessive shock load, and 2) weighing surfaces that do not adequately support truck loads. These conditions may not be intentional, but operators of this equipment are the only persons who can control and insure the product is not being mistreated in the field. The following steps should be taken to avoid possible damage to scale platform:

(a) The weighing site should be one that adequately supports the entire length and width of each side of the scale and be capable of supporting a maximum truck load.

(b) It is important that the operator understand that a moving truck, even carrying a legal load, is capable of generating 20 times its actual weight by either stopping or starting sharply on the scale platform. To prevent this, the operator must make the truck come to a complete stop prior to driving onto the scale.

The driver should be cautioned to proceed at a rate of speed less than 2 m.p.h. and avoid jamming his brakes. Once readings have been taken to verify the weight, the driver should again be cautioned to proceed slowly while exiting the scale.

The above procedures should apply to all portable axle load scales regardless of brand. For more information, please contact Mr. Bryan Whitten (D-4), (512) 463-8893, STS 255-8893.

The information contained herein is experimental in nature and is published for the development of new ideas and technology only. Any discrepancies with official views or policies of the TSDHPT should be discussed with the appropriate Austin Division prior to implementation of the procedures.

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