

# Obtaining Rut Depth Information for Strategic Highway Research Program Long-Term Pavement Performance Sites

WADE L. GRAMLING, GEORGE S. SUZUKI, JOHN E. HUNT, AND KAZUHIKO MURAOKA

The use of automated pavement condition survey systems has been a goal of highway managers for many years. With the advent of the Strategic Highway Research Program's (SHRP's) Long-Term Pavement Performance study the need for permanent, high-resolution pavement distress records arose. To meet this need through the use of state-of-the-art technology, SHRP chose to use automated RoadRecon survey systems to obtain permanent high-resolution records of pavement surface distress and transverse profile. The survey system and procedures used in the field to record the transverse profiles on 35-mm film, the procedures used in the office to process the films, the methods used to analyze the transverse profiles to report the rut depth data, and the quality-control procedures employed are all discussed. The data for the first three rounds of measurement on many of the sites are available. The results of some preliminary analysis of these data are also described.

The Strategic Highway Research Program (SHRP) announced the initial request for proposals for the Long-Term Pavement Performance (LTPP) program in 1987. Included in the request was a project to collect pavement surface distress as a major component of the monitoring of selected sections of pavement on in-service highways. The data were required to be obtained in a rigorously consistent fashion and were to be of an accuracy and precision required by the needs of the LTPP studies.

The objective of the pavement distress data collection work was to provide high-resolution visual records of the pavement condition and high-quality measurements of the rut depth of each wheel track in the outside lane of each LTPP test section.

A contract was awarded in the fall of 1987 to PASCO USA for the collection of pavement distress data. New RoadRecon survey units, equipped with RR-70 and RR-75 survey systems, were designed and constructed to perform the data collection. The RR-70 and RR-75 survey systems are used to collect surface distress and rut depth data, respectively. On completion of construction, the performance of the units was thoroughly evaluated and SHRP LTPP operational guidelines were established. This effort is described in another paper (Gramling et al., unpublished data, July 1992).

On completion of the construction and evaluation of the RoadRecon units, routine survey operations began on March 8, 1989, near Sedalia, Missouri.

This paper describes the survey methods used in the field to obtain transverse profiles and the procedures used in the office to process, analyze, and report the rut depth data. The initial three rounds of data for most of the SHRP LTPP sites are available and the contents are described.

## RR-75 SURVEY SYSTEM

The RoadRecon-75 (RR-75) survey system consists of a 35-mm pulse camera synchronized with a strobe projector. The pulse camera is mounted on a boom that extends from the rear of the survey vehicle with its lens pointed directly down and perpendicular to the pavement and focused on the surface. The projector is mounted on the center of the rear bumper at a set distance above the roadway. A glass plate with a hairline etched in its surface is positioned in front of the projector lens so that when the strobe is triggered a shadow of the hairline is projected onto the pavement directly under the center of the camera. The position of the camera and the angle of the projector are carefully maintained. The projected hairline shadow provides a thin, sharp-edged image on the film caused by the intensity of the projector flash.

In operation, the RR-75 pulse camera is triggered at selected intervals to photograph the projected hairline. The 35-mm film frame exposure then contains the hairline image across the pavement lane for a width of 4.7 m (15.5 ft) accurately reflecting the profile of the pavement.

## Nightly Survey Setup Procedures

To obtain high-quality film exposure and resolution, which are controlled by artificial illumination and the angle of lighting, survey operations are performed only during nighttime hours. Before beginning operations each night, quality control procedures are followed by the survey crew to ensure the safe operation of the vehicle and to verify the condition of the survey system setup. Detailed checklists are completed by the crew to ensure that all required items are inspected. An illumination check is run on the front lighting arrangement, which is part of the RR-70 system, and a set of calibration blocks is used to verify that the RR-75 system is in proper position. The tests are run with the vehicle static at a convenient level parking area before starting the night's production survey.

## Survey Operations

The SHRP LTPP program includes a large number of carefully marked and documented "in-service" pavement sections across the United States and Canada. There are General Pavement Study (GPS) sections that represent the most common typical pavement types found and the Special Pavement Study (SPS) sections that are fewer in number and are selected to investigate specific pavement questions. All of the GPS and SPS sections have been selected to fit into a preplanned experimental matrix.

SHRP LTPP GPS sections are 150 m (500 ft) in length with a lead-in of 150 m (500 ft) and ending marks at 76 m (250 ft). The sections are marked with white paint on the roadway surface. Blue reflectors and signs denoting the upcoming section have been placed along the right shoulder. Figure 1 shows a typical GPS test section layout (1).

Other SHRP functions have been directed at formally establishing, documenting, and marking SHRP sites for inclusion in the research. The current list of approved sites is used to develop a survey routing that requires the least amount of travel time to systematically move from site to site and cover logical geographic parts of the United States and Canada. Surveys are done usually in the northern areas during the summer, in the middle states during the autumn and spring, and in the southern and west coast states during the winter.

In survey operations the crew goes through the setup procedure before approaching the site to be surveyed. When the survey crew approaches the site the systems are in operating

position and are ready to be activated to begin filming. Each 150-m (500-ft) test section has a 150-m (500-ft) lead-in, which is the first mark encountered; the test section is also marked at each 30.5-m (100-ft) station. When the crew sights the first mark the systems are activated and filming begins. When the vehicle reaches a point in advance of the section start mark, the operator resets the systems to take the first transverse profile shot at the begin mark. After the reset, the RR-75 system automatically records a frame at the beginning and at each subsequent 15.25-m (50-ft) interval. The survey continues through the 76-m (250-ft) runout marked with a paint stripe following the test section. This results in a continuous RR-70 film record of the 376-m (1,250-ft) length marked and a series of RR-75 transverse profiles, which include the 11 profiles at 15.25-m (50-ft) intervals required through the actual test section.

The crew makes visual observations of the RR-75 filming operation during the survey run by watching for, and counting, projector flashes to verify that the profile shots are on the targets and that there are 11 sequential shots taken within the test section during the survey run.

Because the test section survey costs are relatively minor compared with the travel costs to get to the section, each test section is filmed at least twice to provide a backup record. If one of the two runs is questionable, additional runs are made until the crew is satisfied that they have observed two good runs. On completing a section survey the crew proceeds to the next section on the schedule and the survey process is repeated.

SHRP LTPP SPS sites are much fewer in number than the GPS sites. However, each site may contain 10 or more 150-m (500-ft) test sections. Occasionally some of the SPS sections are longer than the 150-m (500-ft) GPS standard. Usually there is a GPS section associated with each SPS site, and there may be a number of supplemental sections that have been added by the state or province.

The distress survey procedures used at the SPS sites are the same as those used for GPS sites as far as possible. At some SPS sites the spacing between the various sections does not permit resetting the RR-75 system. For those particular sections involved, the 15.25-m (50-ft) interval for profiles is maintained, but the quality-control requirement for locating the transverse profile within a few meters of the 30.5-m station marks is waived.

When an SPS site that includes an associated GPS section is surveyed, separate surveys are performed. The GPS section is surveyed using normal GPS procedures and then another survey is performed to record the SPS sections, including the GPS section. Any agency supplemental SPS sections are surveyed and processed in the same manner as that for LTPP sections.

## Periodic Checks

At the end of each week's survey operations, or after 20 sites have been surveyed, the crew performs a quality-control check. The quality-control check is done by the crew placing a standard resolution board on the pavement and making an additional survey run. The unit is also stopped at a level parking area and the calibration blocks are filmed by manually acti-

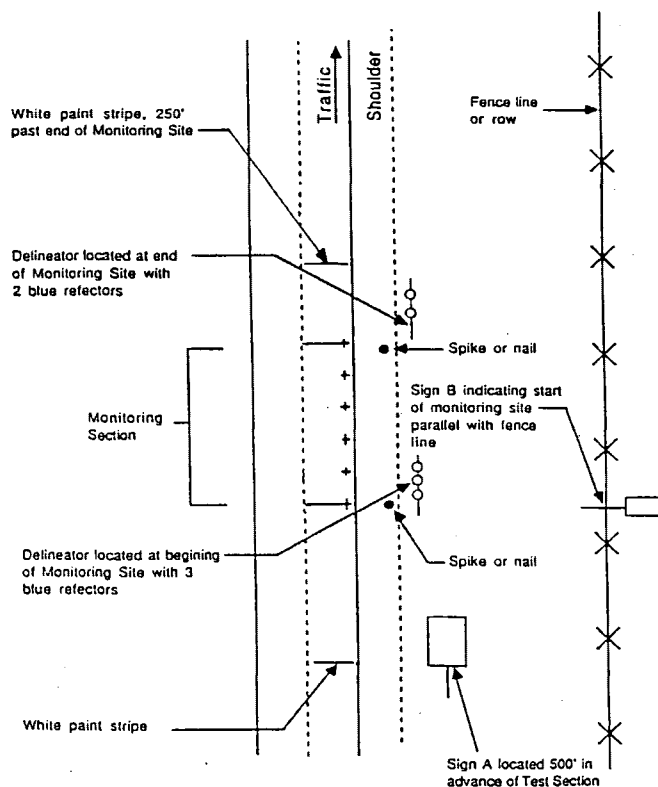


FIGURE 1 General layout of test section showing sign locations.

vating the strobe projector. The exposed film containing the routine survey runs, the resolution board, and the calibration blocks is then shipped to headquarters for processing and analysis.

## Office Operations

### Film Processing

On receipt of the exposed film at headquarters the film is developed using an automatic film developer and then viewed by a technician at a film processing work station. The work stations consist of a 1.2-m (48-in.) light table and film winders. The negative RR-70 film is reviewed for quality by checking longitudinal distortion, lateral lane placement, and exposure. The RR-75 film is checked to locate longitudinal profile locations and to ensure that 11 frames were recorded within the test section without skips. The profile location is identified using conventional stationing, with the first station coinciding with the begin mark of the 150-m (500-ft) test section. The paint marks are usually visible in the RR-75 frames, enabling an accurate offset station to be assigned to each profile hairline. If the offsets are more than +1.2 m (4 ft) to -0.6 m (-2 ft) the profile hairline placement is identified by using event marks found on the RR-70 film that are automatically placed when the RR-75 system shots are triggered. The event marks are related to the section paint marks to determine the offset of the profiles and to establish the stationing.

After the RR-75 film has been checked for quality and completeness, and profile stations have been assigned, the film is edited by trimming and splicing, labeled, and moved to an RR-75 work station for digitizing.

### Digitizing

The digitizing work station combines a film motion analyzer (FMA), a personal computer, and custom software to record transverse profile information and compute rut depth values from the RR-75 films. The RR-75 film is mounted on the FMA film transport, which back-projects the profile hairline image on a digitizing screen. The operator enters the section identification (ID) information and proceeds to digitize each film frame profile into the computer data base using a cursor to input coordinates.

The operator begins the digitizing operation by identifying the first point to be digitized. This point is located along the shoulder edge of the pavement and is identified by following a set hierarchy of criteria.

For concrete pavements, the operator identifies the lane-shoulder joint and then digitizes the first point on the pavement lane's surface adjacent to the joint. If this is not visible, the first point is digitized on the pavement's surface adjacent to the outside edge of the pavement's edgeline.

For bituminous surfaced pavements, the operator first checks to see whether a lane-shoulder joint is present. If so, then the first point is digitized on the pavement lane's surface adjacent to the joint. If a joint is not readily apparent, then the operator's second check is for an obvious difference in the surface texture between the pavement lane and the shoul-

der. If this difference exists, then the operator digitizes the first point on the lane's surface adjacent to the location of the texture change. If a texture difference cannot be found, then the operator's third check is the pavement's edge line, and the first point is digitized on the pavement's surface adjacent to the outside edge of the edge line.

Once the first digitizing point has been identified and digitized, the operator digitizes between 24 and 29 additional points along the hairline image at approximately 15-cm (6-in.) intervals across the pavement's lane.

After the required profile points are entered, the computer calculates the rut depths and displays the profile for the operator's review and acceptance. After the section's last profile is entered the operator can view all 11 profiles overlaid to judge if any anomalies might be obvious. If the operator is satisfied, the file is accepted and moved to quality assurance.

### Quality-Assurance Procedures

The quality-assurance procedures for the profile data involve checking the identifying header information against the log information used to track individual data records for each section scheduled and surveyed in the field. An historical check is also made after the first survey is recorded for a section. Each subsequent round of survey information for a section is checked to verify that the latest rut depth values are logical and reasonable when compared with prior sets of survey data. If anomalies are found, the prior RR-75 film records are available if needed to verify data.

After the sections pass quality-assurance reviews, an ASCII data file, a section summary report, and a set of transverse profile plots are generated for each test section. These records are forwarded for SHRP entry into the TRB IMS data base.

### Data Format

The data output from digitizing the profiles from the RR-75 frames is provided in a set of 11 profile plots that contain the section ID, the date surveyed, and the station of the profile. The profile plot graphically shows a standard reference plane established by the lane edges, the profile, and the high points of the profile determined by the wire method of analysis (2). The maximum values for rut depths are given for the center and shoulder half of the lane, and the locations of the values are plotted. Figure 2 shows a standard profile plot with the center of the lane higher than the baseline, and Figure 3 shows a standard profile with the center lower than the baseline.

A summary data sheet that contains a tabulation of the stations for each profile and the maximum rut depths for each half lane is also supplied. The 11 sets of data are summarized with an average rut depth for each half lane, the maximum and minimum values are shown, and the standard deviation for the rut depths through the section is given. Figure 4 shows a typical summary sheet.

An ASCII data file is also supplied containing the data along with positive copies of the edited RR-75 film. The original negative film is packaged for placement in the TRB LTPP archives and could be used in the future to perform any additional analysis desired.

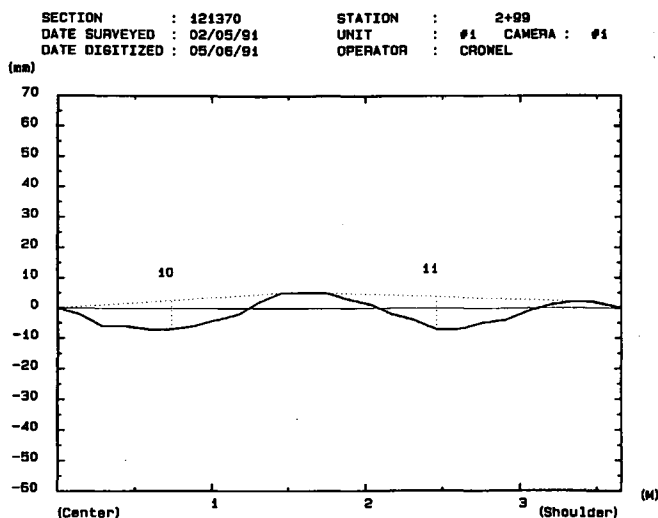


FIGURE 2 Standard profile in which center of lane is higher than baseline.

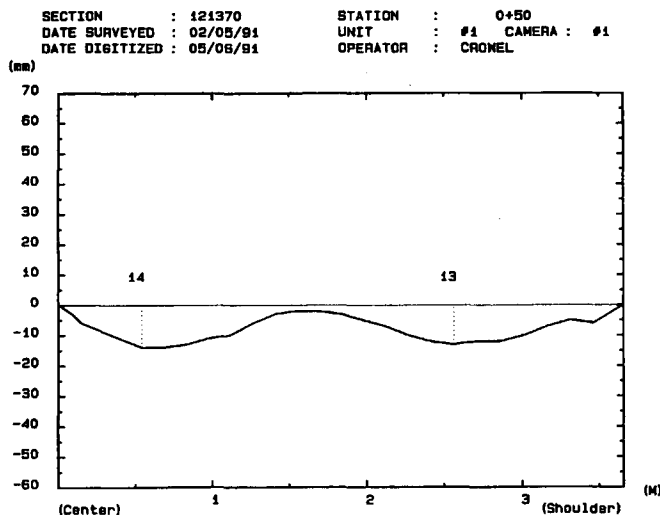


FIGURE 3 Standard profile in which center of lane is lower than baseline.

### Results to Date

The initial SHRP LTPP efforts to collect distress information, including rut depths, have been completed with three rounds of survey data collected for a large majority of the GPS sections. The following table gives the distribution by region of the 763 GPS sections surveyed:

Region	Number of Sites
North Atlantic	134
Southern	258
North Central	199
Western	172

The same procedures were used on both portland cement concrete and asphaltic concrete sections filming both RR-70

### \*\*\* LTPP Section ID : 121370 \*\*\*

Date Surveyed : 02/05/91  
 Unit : #1  
 Camera : #1  
 Operator : CROWEL  
 Date Digitized : 05/06/91

Rut Depth(mm)			
No.	Station	Leftside	Rightside
01	0+00	11	13
02	0+50	14	13
03	1+00	10	11
04	1+50	10	9
05	1+99	9	8
06	2+49	16	8
07	2+99	10	11
08	3+49	8	10
09	3+98	8	9
10	4+48	9	10
11	4+98	7	8
Summary			
Maximum		16	13
Minimum		7	8
Average		10.2	10.0
SD		2.7	1.8

FIGURE 4 Sample summary report.

for continuous distress records and RR-75 for rut depths. Table 1 shows the pavement types included in the total GPS experiment. Table 2 contains the average rut depths by region for each of the GPS pavement types. Table 3 contains the average of the standard deviations for each of the GPS pavement types by region.

### SUMMARY

The initial 5 years of the SHRP LTPP program has resulted in the development of equipment, survey methods, data analysis procedures, and standards of quality for the automated collection of pavement distress and rut depth determination. The survey procedure produces a permanent 35-mm film record.

Three rounds of rut depth survey data have been collected for most of the GPS sections, and the data have been processed and supplied to the TRB IMS data base. Similarly, two rounds of rut depth data are available on most of the SPS sites.

A review of the average rut depth data would lead to several observations about the SHRP GPS sites. There is not much difference in average rut depths between the center half lane and the shoulder half lane. The average rut depths for all pavement types and regions are well below  $\frac{1}{2}$  in. and would be considered acceptable by most pavement condition criteria. There are differences between pavement types and between regions. There are also GPS sections with rut depths well above  $\frac{1}{2}$  in., but they are found throughout the pavement types and across the regions. Some agencies have a greater number of GPS sites with larger rut depths than many of the other agencies. The significance of this observation is beyond the scope of this paper.

These data also indicate that the average rutting on concrete pavements was found to be less than 4 mm for the GPS pavement types including jointed plain, jointed reinforced, con-

**TABLE 1 GPS Experiment Pavement Types**

Pavement Type	Description
1	Asphalt on Granular Base
2	Asphalt on Bound Base
3	Jointed Plain Concrete
4	Jointed Reinforced Concrete
5	Continuously Reinforced Concrete
6A	Existing Asphalt Overlay of Asphalt
6B	Planned Asphalt Overlay of Asphalt
7A	Existing Asphalt Overlay of Concrete
7B	Planned Asphalt Overlay of Concrete
9	Unbonded Concrete Overlay of Concrete

**TABLE 2 Average Rut Depths by Region**

Regions	North Atlantic		Southern		North Central		Western	
Pavt. Types	C-AVG	S-AVG	C-AVG	S-AVG	C-AVG	S-AVG	S-AVG	C-AVG
1	9.0	8.7	6.0	8.3	6.1	6.9	7.0	8.9
2	5.3	5.7	4.5	6.4	9.7	9.9	5.3	5.5
3	2.6	3.4	2.1	3.2	2.5	3.0	3.6	4.0
4	3.2	3.4	1.7	2.6	2.3	2.6	---	---
5	2.8	3.4	2.1	3.2	2.8	3.5	3.8	4.0
6A	12.5	13.3	5.1	6.5	6.9	7.2	6.9	6.9
6B	6.6	5.3	5.7	6.4	3.7	2.8	4.9	5.7
7A	7.2	6.0	8.3	9.0	4.3	5.7	11.1	10.7
7B	3.9	3.6	1.3	2.5	2.7	2.9	---	---
9	2.1	2.3	1.9	2.3	2.5	3.2	3.5	4.6

Note: Depths given in millimeters

C-AVG = The average rut depths of the center side.

S-AVG = The average rut depths of the shoulder side.

**TABLE 3 Average GPS Standard Deviation of RUT Depths by Region**

Regions	North Atlantic		Southern		North Central		Western	
Pavt. Types	C-STD	S-STD	C-STD	S-STD	C-STD	S-STD	S-STD	C-STD
1	1.8	2.1	1.6	2.2	1.8	1.9	1.8	1.9
2	1.2	1.2	1.6	1.8	1.7	1.9	1.5	1.7
3	1.0	1.4	1.1	1.4	0.8	1.0	1.1	1.0
4	1.1	1.2	0.7	1.1	0.8	0.9	---	---
5	0.9	1.4	0.8	1.2	0.8	1.0	1.1	1.0
6A	2.6	2.3	1.6	1.6	1.3	1.3	1.4	1.6
6B	1.7	1.7	1.5	1.7	1.3	0.9	1.4	1.5
7A	1.4	1.0	1.7	1.9	1.5	1.9	2.3	1.9
7B	1.4	1.0	0.5	1.0	1.5	1.9	---	---
9	0.8	1.1	0.7	0.8	1.0	1.1	1.1	1.4

Note: Depths given in millimeters.

C-STD = The average standard deviation of the rut depths of the center side.

S-STD = The average standard deviation of the rut depths of the shoulder side.

tinuously reinforced, and concrete overlays. Isolated GPS sections were surveyed that had greater rut depths, but these were scattered.

The averages of the standard deviations by region and pavement type generally are less than 2 mm. This would indicate that the rutting is found to be fairly uniform through each of the 500 GPS sections. When the generally lower average rut depths of concrete pavements are considered with the standard deviation values it appears that most of the rut depths might be associated with construction procedures producing the transverse cross-section variables observed as rutting. A closer inspection and analysis of the data within the GPS sections, including the transverse location of maximum rut depth in each half lane and the transverse profiles, will provide insight into these data.

The quality-assurance procedures and consistency of data would indicate that the intended accuracy and precision required in obtaining the rut depth data have been achieved.

## ACKNOWLEDGMENT

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