

Using Strip Films To Record Pavement Distress in the Strategic Highway Research Program: Long-Term Pavement Performance Study

HERNÁN DE SOLMINIHAC AND HARVEY ROPER

The system recommended by the researchers to the Long-Term Pavement Performance (LTPP) studies of the Strategic Highway Research Program for the collection and storage of surface distress data is described. Specifically, the distress acquisition system, film interpretation system, quality assurance plan, certification procedure for Pavement Distress Analysis System operators, and, finally, how the system benefits the LTPP study are described. There are several advantages to using this system: it is semiautomatic and provides a permanent record of the pavement surface; in addition, work is performed exclusively at night, ensuring that there will be a minimum of traffic interference. Films provide additional information for the LTPP studies; that is, a complete picture of each site is available at the office. Such a capability allows the engineers not only to analyze pavement distress, but to perform quality control of the test sites as well (e.g., inspecting the locations of the weigh-in-motion and automatic vehicle counters sites). In addition, this information can be used later to interpret the data analysis output. Although the system is limited in some respects, these limitations can be overcome through operator experience and use of supplemental information available from the site.

The Strategic Highway Research Program (SHRP) was initiated in 1987 in an attempt to stem the rapid deterioration of pavements nationwide. The Long-Term Pavement Performance (LTPP) studies, in turn, evolved out of SHRP as its primary pavement research program. In establishing the LTPP, researchers hoped to develop the tools needed to increase pavement performance and service life. The specific objectives of LTPP included

- Evaluation of existing design methods;
- Development of improved strategies and design procedures for rehabilitation of existing pavements;
- Development of improved design equations for new and reconstructed pavements;
- Determination of the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance; and
- Establishment of an international long-term pavement database to support current and future needs.

Two sets of pavement are currently under investigation by the LTPP program. The first set consists of nearly 800 existing pavement sections to be evaluated for the General Pavement Studies (GPS); the second set, the Specific Pavement Studies (SPS), will provide comparisons that isolate the effects of certain factors.

Data will be collected from these experimental sites for 20 years. The data collected through these studies will make up the National Pavement Performance Database (NPPDB), to be located at TRB. The data for each section will be grouped within seven modules: (a) environmental; (b) inventory; (c) laboratory materials testing; (d) maintenance; (e) monitoring of deflection, surface distress, profile, rut depth, and skid resistance; (f) traffic; and (g) rehabilitation. Periodically, the data collected will be analyzed to ensure that the goals of the LTPP studies are realized. The first strategic analysis of the data contained in the NPPDB is the objective of the contract on data analysis (1).

Although almost all of the SHRP-LTPP research undertaken to date has been directed toward the creation of the NPPDB, this data base is only meant to satisfy the LTPP design-related objectives. The end products of the data analysis contract will be the first that are aimed specifically at the major objectives cited, and the first that will employ the NPPDB for its intended purpose. The main tasks of the research will include (a) sensitivity analysis of explanatory variables in the NPPDB, (b) calibration of the AASHTO design equations, (c) development of pavement rehabilitation strategies, and (d) development of future LTPP data analysis plans.

An important area within the NPPDB is the information relating to surface distress. To collect this information, SHRP uses a pavement distress data acquisition system developed by PASCO USA, Inc. This system had several advantages: it is highly automatic and is capable of producing a permanent record of the pavement surface (including rut depth information); in addition, because it is exclusively for night operation (working at a speed of 50 mph), traffic interference is kept to a minimum.

The main objective is to present the main components of the PASCO USA data acquisition system recommended by the researchers to SHRP for their collection and storage of distress data. Specifically, the distress acquisition system, film interpretation system, certification procedures for the interpretation system operators, and, finally, the important advantages—and limitations—of the system, are described.

H. de Solminihac, Center for Transportation Research, University of Texas at Austin, Austin, Tex. 78712. H. Roper, Texas Research and Development Foundation, 2602 Dellana Lane, Austin, Tex. 78746.

DESCRIPTION OF THE DISTRESS ACQUISITION SYSTEM (2)

Distress Acquisition System Vehicle

The distress acquisition system vehicle—properly termed the Roadrecon pavement photographing system vehicle—was developed by PASCO Corporation of Japan in 1970 (see Figure 1). While traveling at speeds of 5 to 55 mph, this van (weighing nearly 5 tons and running on diesel fuel) takes continuous photographs for distress information, and pulsed photographs for rut depth surveys. Two components of the system—the RR-70 and RR-75 subsystems—perform these photographic functions.

Roadrecon-70 (RR-70)

Designed exclusively for night operation, the RR-70 system consists of a 35-mm slit camera, lighting equipment, a power source, and a remote control device—all mounted on a bus-sized cargo van (see Figure 2). The camera is installed at a height of 10 ft perpendicularly facing the road surface. The lighting equipment is mounted in a position in geometric relation to the camera. The photographing scale is 1:200.

The RR-70 camera takes continuous photographs with constant exposures, synchronizing the film speed and light intensity to the traveling speed of the van by means of signals generated from sensors on the wheels of the van. The rated error of the synchronized film speed and light intensity is less than 1 percent.

The RR-70 is capable of photographing distresses at speeds ranging from 10 to 60 mph. The film magazine used for the camera has a capacity of 1,000 ft of film, yielding approximately 36 mi of road surface that can be continuously photographed before reloading of the film magazine is required. A two-person crew is required: one to operate the camera system, the other to drive the vehicle.

Roadrecon-75 (RR-75)

The RR-75 system is also designed for night operation. The system, again mounted on a bus-sized cargo van, consists of

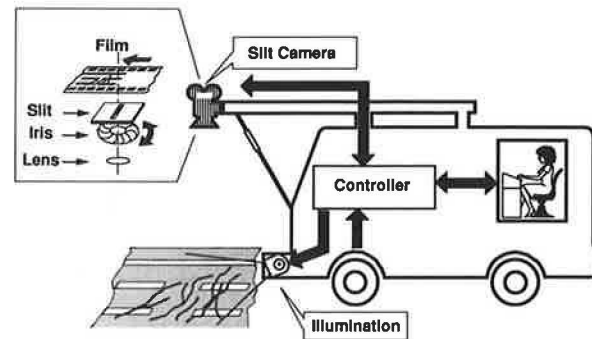


FIGURE 2 ROADRECON-70 for condition survey (3).

a 35-mm pulse camera, a hairline projector, lighting equipment, a power source, and a remote control device (Figure 3). The hairline projector is installed over the bumper of the vehicle at an angle of 26 degrees 33 min to the road surface; the camera is mounted at a height of 10 ft from the ground perpendicular to the road surface. The lighting equipment is mounted in a position in geometric relation to the camera. The photographic scale is 1:200.

The RR-75 camera automatically photographs at 50-ft intervals by synchronizing both the camera shutter and the flashing of the hairline projector with the speed of the vehicle. The film speed and flashing of the hairline projector are synchronized by signals generated from trip meters that receive signals from sensors mounted on the wheels of the van.

The RR-75 is capable of photographing distresses at speeds ranging from 10 to 60 mph. The film magazine used for the camera has a capacity of 400 ft of film, yielding approximately 60 mi of road surface that can be photographed at 50-ft intervals before reloading of the film magazine is required. Two persons are required to operate the camera system and drive the vehicle.

DESCRIPTION OF THE FILM INTERPRETATION SYSTEM

The film interpretation equipment developed by PASCO USA, Inc., makes up the Pavement Distress Analysis System

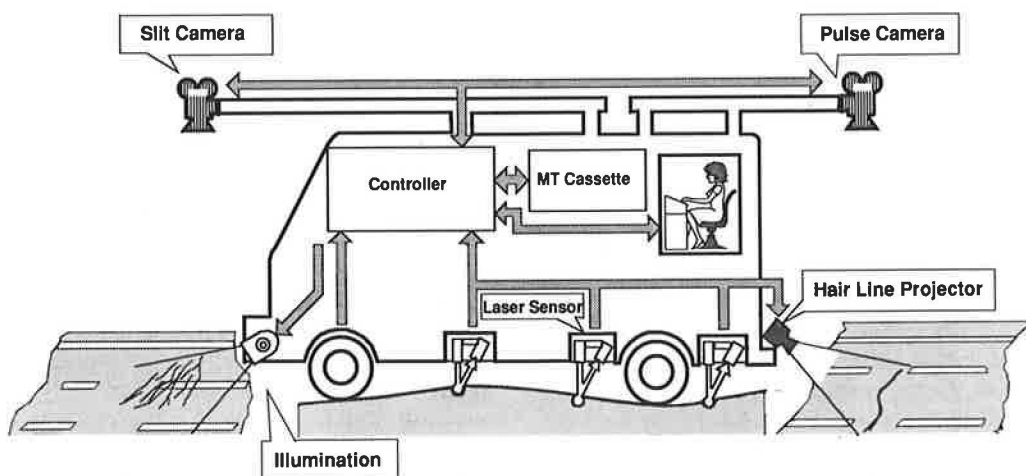


FIGURE 1 ROADRECON vehicle (3).

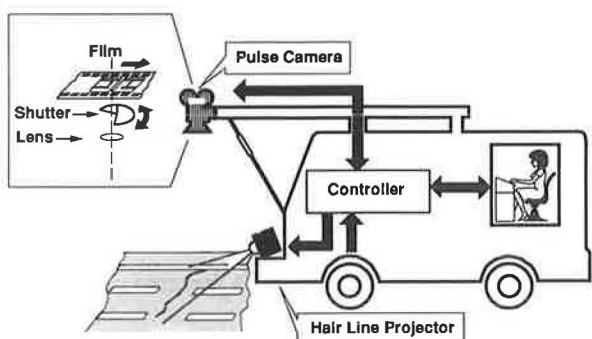


FIGURE 3 ROADRECON-75 for rutting survey (3).

(PADIAS). The PADIAS, shown in Figure 4, is a set of applications designed to control the interpretation of pavement distresses from a 35-mm strip of film. The hardware consists of an IBM-compatible 386 computer, a film motion analyzer (FMA) for interpretation of 35-mm films, and a printer for preparing the reports.

A flow diagram of the distress interpretation procedure is shown in Figure 5 (5). After receipt of the film from PASCO, the PASCO operator will complete a film quality review of the film to establish whether or not the film processing is satisfactory. During this acceptance review, the PADIAS operator will observe the general condition (severity of distress or rutting) of the section on the basis of the distress and rut depth films. After completion of the film review, the operator will then complete the corresponding film logs. Any irregularities in the pavement test sections noted during the review of the film will be brought to the attention of administrative personnel for resolution. The film logs are then forwarded to SHRP and the four SHRP regional engineers.

After the film acceptance review is completed, the distress interpretation process can begin. A nomination data base is queried for the section under active distress interpretation to provide pertinent information on pavement type, lane width, underlying layers, etc. The GPS section site verification videos and PASCO USA rut depth films are reviewed, as needed, to enhance the interpretive process. On completion of the interpretation process, the operator then generates reports summarizing the distresses found in the section. These reports are then forwarded to the initial PADIAS quality control review team for needed quality control checks of the interpretation. The selection procedure for these initial checks will be based on PADIAS operator comments concerning difficulty in interpretation, distress report complexity or anomalies, film condition, and clarity. Aside from those sections selected for initial checks, a minimum of 10 percent of the interpreted film (or 1 in 10) should be reviewed by the quality control (QC) review team using a random selection procedure. If any discrepancies are noted by the quality control team, the section shall be re-reviewed by the principal PADIAS operator to resolve such discrepancies in interpretation. If there are significant discrepancies observed in the random reviews or subsequent mandated review, then an increasingly higher percentage of the interpretation film (e.g., 20 or 30) should be reviewed by the initial PADIAS quality control review team.

After the quality control review has been completed, the processed data are then forwarded to the Regional Coordi-

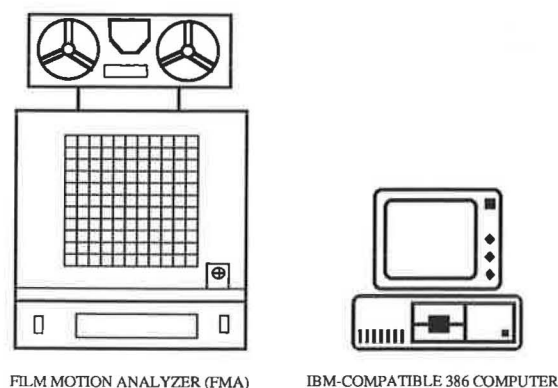


FIGURE 4 Main components of PADIAS (4).

nation Office Contractor (RCOC). The RCOCs will then implement their own quality control review of the film and distress reports. If any discrepancies are noted, the RCOC and PADIAS teams will review the section and mutually resolve any discrepancies. When this regional quality control review process is completed, the distress data can then be entered in the Regional Information Management System (RIMS).

Steps Before Film Interpretation (4)

The following four steps must be completed before the film interpretation can begin:

Step 1—Operator Certification. For reliable results, the PADIAS operator must be certified to interpret PASCO films, according to criteria provided by de Solminihac (6) and Gibson and Hadley (7).

Step 2—Film Acceptance. Once the film processing for each state is completed, PASCO forwards the film of all sites within that state. The PADIAS operator reviews the distress and rut depth film to establish the quality of the film as outlined by Roper and Hadley (5) and de Solminihac (8).

Step 3—Equipment Calibration. If the equipment has been moved or if 6 months have passed since the last calibration, then a new calibration should be performed. The equipment calibration includes two activities: mirror alignment and FMA calibration (9).

Step 4—Film Threading. The film should be threaded into the FMA projector (8).

Description of the Software Used for Film Interpretation (9)

The PADIAS distress interpretation program's main function is to interpret and record pavement distresses within a test section from the 35-mm RR-70 film using the FMA. This is accomplished by displaying the road surface one frame at a time, and using the FMA screen pointer (cursor) to designate and record distresses, and then to proceed to the next film frame. A frame is a 12- by 12-ft area, and normally a 500-ft section has 41 frames. Within the program there are three main menus to perform the needed functions. These include the entry menu (used for entering distresses), the edit menu (used for reviewing and changing existing distresses), and the

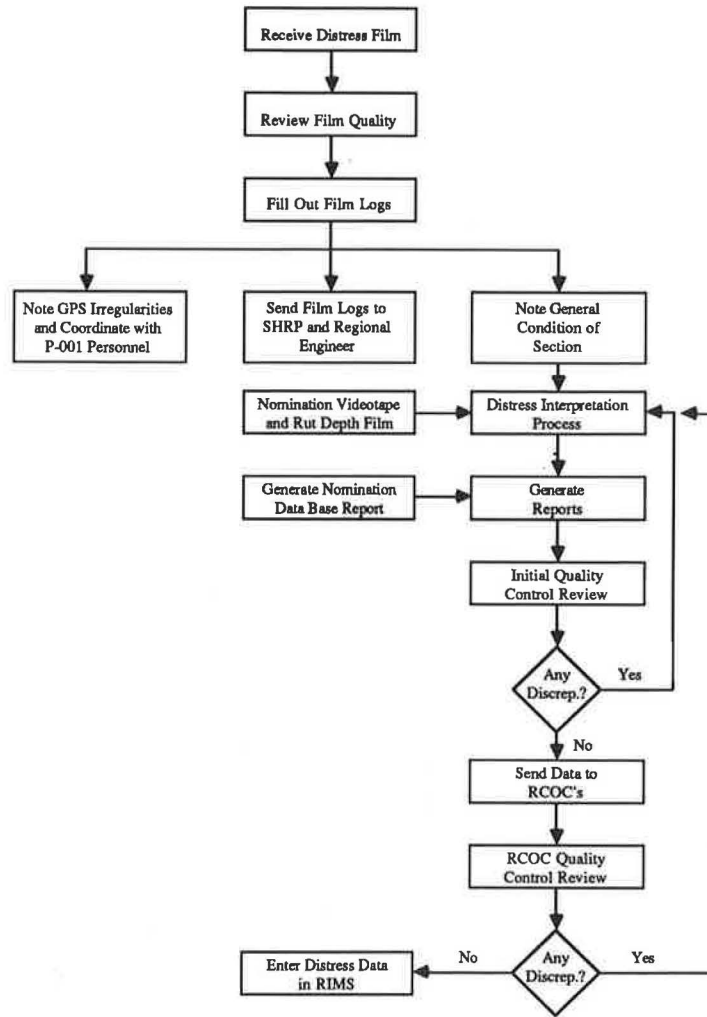


FIGURE 5 Distress interpretation procedure (5).

frame control menu (used for frame advancing, reversing, and other miscellaneous functions). The program will format the monitor into the following five areas (Figure 6):

1. Header information from the control section (top),
2. Grid cell area (middle left),
3. Work area (middle right),
4. Status line (second window from bottom), and
5. Bar menu line (bottom window).

Film Interpretation

Figure 7 shows a flow chart illustrating the film interpretation procedure. After the header file is completed, the DISTRESS INTERPRET function is selected from the system menu. However, before the actual interpretation is started, the road width must be defined by answering two program questions, indicating in the FMA (using the mouse) the lower left and the upper right portion of the displayed road surface. After this alignment is defined, the starting point must be indicated. This starting point corresponds to the starting mark of the LTPP section (9).

Then the actual film interpretation can begin. For this activity, the operator may use the Distress Identification Manual

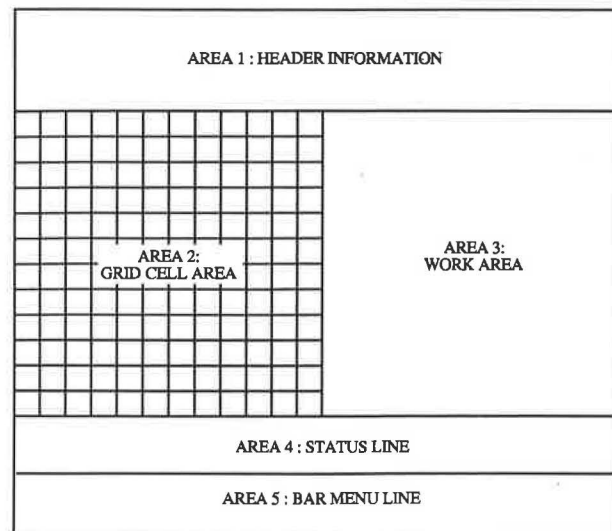


FIGURE 6 The five main working areas of the monitor displayed when the distress interpret option is selected (4).

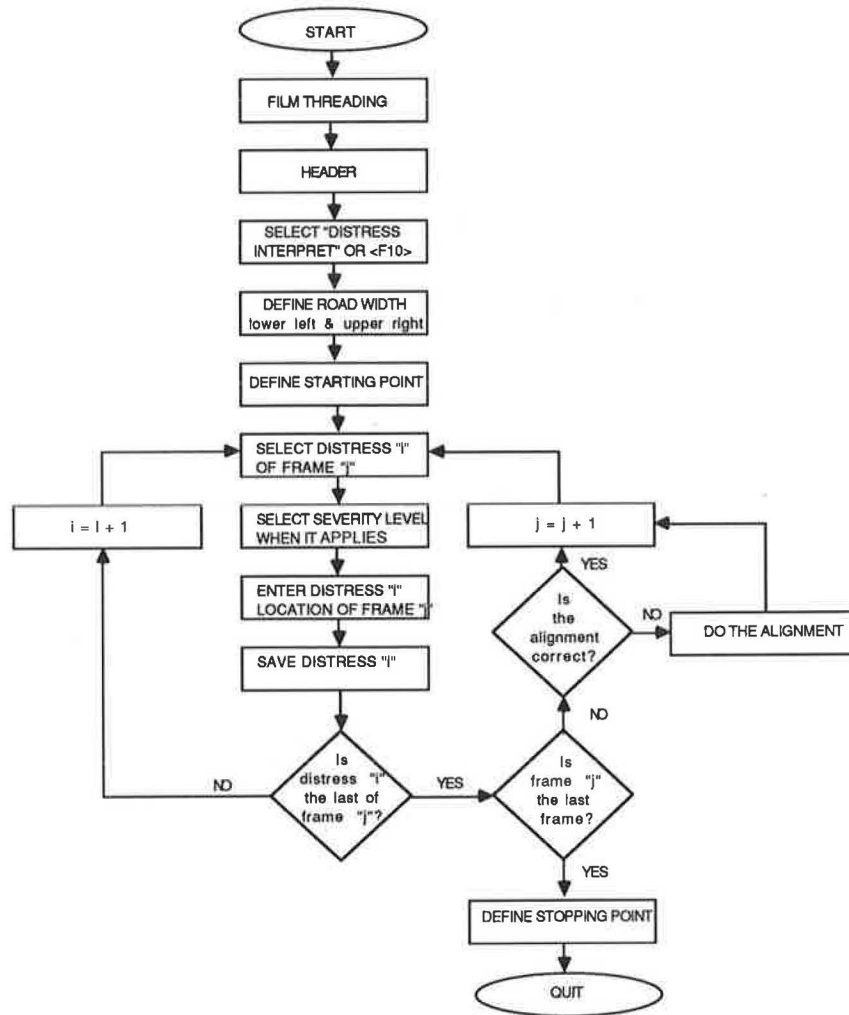


FIGURE 7 Flow chart for the film interpretation process (4).

(10). A screen, such as the one shown in Figure 8, will appear. Starting with the first frame, the first distress identified in that frame is selected and assigned a severity level (if applicable). The location of that distress is also recorded using the mouse and the grid; finally, the distress is saved using the SAVE command on the bar menu line. Then, using the same procedure described earlier, the next distress within the same frame is recorded.

When the first frame is completed, the second frame is selected; the process continues until all frames are completed. The distress data consist of three basic parts: (a) the distress type; (b) the severity level; and (c) the area location. The distress type identifies the distress on the basis of the pavement type and film interpretation. The distress menu for each pavement type appears in the work area when the cursor is moved to the right side of the screen when in the entry mode. The severity level is set by a message window in the work area after the distress is identified. A check box indicating either low, moderate, or high levels must be selected. If no severity level is necessary, the program will inform the user and request the pressing of a cursor button to continue. After that, the program will record the grid cell location of the

SHRP Control Sec N°		LTPP Sec N°		PADIAS DISTRESS INTERPRETATION HEADER DATA		PADIAS2 1.1		PASCO USA Inc. Frames															
Operator Name		Weather Cond.		Date		Time		Speed															
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				<table border="1"> <tr> <th colspan="2">PAVEMENT TYPE I</th> </tr> <tr> <td>Distress 1 for pav type I</td> <td></td> </tr> <tr> <td>Distress 2 for pav type I</td> <td></td> </tr> <tr> <td>Distress 3 for pav type I</td> <td></td> </tr> <tr> <td>.</td> <td></td> </tr> <tr> <td>.</td> <td></td> </tr> <tr> <td>Distress n for pav type I</td> <td></td> </tr> </table>						PAVEMENT TYPE I		Distress 1 for pav type I		Distress 2 for pav type I		Distress 3 for pav type I		.		.		Distress n for pav type I	
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ENTRY MENU CONTROL: Erase, Reset, Save, Review, Next frm, Frm cfl, Quit EDIT MENU CONTROL: Erase, Reset, Add, Change, Delete, Next, Next Frame, FrmCtl, Quit FRAME CONTROL MENU: Align, Advance, Reverse, Reset, Restart, Start pt, Stop pt, Escape																							

FIGURE 8 Screen sketch of the PADIAS distress interpretation program (4).

distress by positioning the cursor over the film where the distress occurs. The distress is represented on the grid area on the monitor by the blackened grid cells (9).

Before quitting the program, the stopping point should be defined in the frame control menu using the STOP PT command. This point is used to define the end of the LTPP sections being studied. To finish the interpretation process, the QUIT command in the entry menu control is used.

Checking Consistency (5,11,12)

Immediately after completing a distress interpretation for a test section, the operator will run a consistency check using the PADIAS consistency checking program from the main PADIAS menu to ensure that each 1- by 1-ft grid square presents only those distresses that could, in practice, coexist for the type of pavement structure being analyzed. If the PADIAS operator encounters a condition that appears to be an exception to a coexistence matrix, such as the one shown in Figure 9, it should be noted on the interpretation log form for possible review by the QC team and brought to the attention of a pavement engineer.

Output of the PADIAS (5)

The output of the PADIAS consists of a series of (a) printouts that summarize and graphically display the section condition, and (b) software files that subsequently are used to transfer the section distress interpretation information to the information management system (IMS). The control section report program from the main menu produces this output.

The reporting output for a section is available in the following four distinct formats:

1. The section map report option produces a graphic representation of each frame of film for an entire test section in

which a distress was recorded. The location of each distress is indicated using a letter or number code. Because one page per frame is required, a complete section frame map printout can include as many as 42 pages and require as much as 30 min of printing time for the existing equipment and set-up defaults.

2. The grid summary report is a one-page summary of the distresses in a section and indicates the total number of grid cells affected by a particular distress at each severity level.

3. The section summary report (Figure 10) is a one-page summary of the distresses in a section listed by type and severity level in units appropriate to the type of distress. This report corresponds to the input for the LTPP-IMS.

4. The frame map report provides the operator with the option of calling up and generating a printout of a particular frame within a section.

These four reports can be provided in two types of output: a visual copy (on the screen) or a hard copy (printout). To output to the screen, the View Report function is selected, whereas the Print Report function is selected to provide a hard-copy output print.

After the distress interpretation of a test section is completed, the PADIAS operator should print out a grid cell summary report and a section summary report. These reports should be compiled with the nomination data base information and the interpretation log form for the section and submitted to the senior pavement engineer for review. This packet should provide sufficient information about both the condition of a pavement section and the film interpretation on which to base acceptance or QC review decisions.

A printout of the section map report for a section should only be made (a) when the data are going to be compared with existing manual survey results, or (b) when needed in the field for an on-site comparison. Printing out a section map for each section would be time consuming and would require large amounts of paper.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15A
1. Alligator (Fatigue) Cracking		N	N	C	N	C	C	N	*	N	N	*	C	*	*	*
2. Block Cracking			C	C	C	C	N	N	*	N	N	*	C	*	*	*
3. Edge Cracking				N	N	C	C	N	*	C	N	*	C	*	*	*
4. Longitudinal Cracking					C	C	C	N	*	N	N	*	C	*	*	*
5. Reflection Cracking at Joints						C	C	N	*	C	C	*	C	*	*	*
6. Transverse Cracking							C	N	*	C	C	*	C	*	*	*
7. Patch/Patch Deterioration								N	*	C	C	*	C	*	*	*
8. Potholes									*	N	N	*	N	*	*	*
9. Rutting										C	C	*	C	*	*	*
10. Shoving											C	*	N	*	*	*
11. Bleeding												*	N	*	*	*
12. Polished Aggregate													*	*	*	*
13. Raveling and Weathering														*	*	*
14. Lane-to-Shoulder Dropoff															*	*
15. Water Bleeding & Pumping																*
15A. Lane-to-Shoulder Separation																

Legend
 N = Cannot coexist
 C = Can coexist
 * = Not applicable

FIGURE 9 Consistency checking matrix for asphalt concrete pavements (11,12).

Control Section ID : 287012
 LTPP GPS Section ID : 287012
 Date of Filming : 5/27/89
 Time of Filming : 10:42
 Filming Operator : unit # 1
 Weather Condition : unknown
 Measuring Speed : 20 m.p.h.
 Pavement Width : 500 feet
 Date of Analysis : 7/18/90
 Time of Analysis : 10:30
 Analysis Operator : sdg

Existing AC Overlay of JCP

Distress Type	Number of Marked Grid Meshes		
	High	Medium	Low
Alligator (Fatigue) Cracking			
Block Cracking			
Edge Cracking			
Longitudinal Cracking			
Long. Reflect. Cracking at Jts	0	64	20
Trans. Reflect. Cracking at Jts	38	145	23
Transverse Cracking			
Patch/Patch Deterioration	0	0	20
Potholes			
Shoving			
Bleeding			
Raveling and Weathering			
Lane-to-Shoulder Separation			
Water Bleeding and Pumping			

FIGURE 10 Section summary report.

Quality Control Review (5)

After interpretation, the section summary reports are printed and attached to the nomination data base project information sheet and the film reviewer's interpretation log. The reports are then presented to the distress quality control review team. The quality control team reviews the reports and selects those requiring review on the basis of PADIAS operator comments, film condition and clarity, pavement type, and requirements for random quality control checks. In this QC review, the slide projector adapter is used to view the PASCO distress and rut depth films (7). The section's nomination videotape may be reviewed to confirm the PADIAS operator's interpretation of the section. If discrepancies exist, the differences are listed, the PADIAS operator will reinterpret the section, and a mutual resolution of the discrepancies will be made final.

RCOC Quality Control Review (5)

Upon satisfactory completion of the PADIAS distress quality control team review, the distress data are forwarded to the appropriate RCOC. The RCOC distress quality control (QC) team reviews the reports and uses a combination of the slide projector view of the PASCO film (8), the nomination verification videotape, and spot checking of the actual section conditions in the field to confirm the PADIAS operator's interpretation of the section. If discrepancies exist, the differences are listed and communicated to the PADIAS con-

tractor so that the PADIAS operator can review the section and conduct a reinterpretation to resolve the discrepancies.

The RCOCs will likely develop review criteria on the basis of information available in the PADIAS output packet (which includes a grid cell summary report, section summary report, nomination data base information, and interpretation log) correlated with results of an early concentrated QC and quality assurance effort in review of the PADIAS FMA distress interpretation.

As an aid in the early QC effort, it is recommended that the RCOCs undertake a full (Level I) review of all frames of at least 10 of the first 20 FMA interpreted films and a partial review (i.e., 5 to 10 frames) of the remaining 10 designated interpreted films. The films for full review should be based on a random selection method, whereas the frames to be investigated in the partial review group should also be randomly selected.

If discrepancies are encountered in the partial reviews of the second set of 10 LTPP sections, then a full review of all 10 of these sections should be undertaken. In addition, any significant discrepancies in the full review of the first set of 10 LTPP sections or the mandated subsequent full review of the second set of LTPP sections should result in the continuation of the initial review procedure of the PASCO film for the next (randomly selected) 20 LTPP sections. This process should be continued until results from distress interpretation by PADIAS FMA and RCOCs are consistent and free of discrepancies.

On the other hand, if no significant discrepancies in interpretation are encountered in either the full or partial Level I review, then the RCOCs could opt to undertake subsequent reviews at a reduced rate (Level II). For example, the subsequent review process could consist of one out of four randomly selected sites scheduled for full-frame review, whereas the remaining sites (three out of four) could be partially reviewed.

If, at any subsequent time in the Level II review process, a new PADIAS FMA operator is introduced or significant discrepancies are encountered, then the initial review format could be reinstated and maintained until a desirable level of consistency is obtained between PADIAS FMA and RCOC distress interpretations. In this instance, those sets of interpretations involving partial reviews of three out of four sites should be rescheduled for review under the initial review format (i.e., Level I).

The RCOC QC interpretation team should document the discrepancies encountered and notify the PADIAS FMA of a need for re-review of a particular section. The films for LTPP sections that have been reviewed a second time by a PADIAS FMA operator should subsequently be fully reviewed by the RCOCs.

Randomization in the selection of the highway sections is essential; however, the review process may require adjustments to ensure a minimum number of full reviews for all pavement types (i.e., asphalt concrete, joint reinforced pavement, continuous reinforced concrete pavement, and jointed pavement).

Entry of Data into RIMS

On satisfactory completion of the RCOC distress QC team review, the distress data are entered in the RIMS data base.

CERTIFICATION PROCEDURE FOR THE PADIAS OPERATOR (7)

Official certification of a PASCO film distress interpretation technician represents a recognition that the technician has demonstrated competency in the operation of the FMA and related equipment, and has attained a high degree of competency in

- Identifying types of pavement distresses,
- Determining the extent of the identified distresses, and
- Determining the level of severity of the identified distresses.

The criteria for certification as a PASCO film distress interpretation technician shall include minimum experience, education and training requirements, and a demonstrated knowledge and competency in distress interpretation. A certified technician must have completed satisfactorily the following:

1. A minimum of 2 years conducting pavement evaluation and condition surveys,
2. An educational or training course on distress types and distress surveys,
3. An examination of the Distress Identification Manual for PASCO Films, and
4. An actual distress interpretation of PASCO films in substantial compliance with refereed interpretations.

Further descriptions of these procedures are provided by de Solminihac (6) and Gibson and Hadley (7).

SUMMARY

The use of photographic film in analyzing pavement distress in SHRP-LTPP study has many benefits. The film provides a permanent record of the condition of the pavement at a specific point in time; such photographs taken over time can yield useful information regarding the development of distress, which in turn can be used to update distress prediction models. In addition, digitizing the film provides for analysts an easier method for studying the many SHRP sections.

The film also provides test site QC, allowing inspection of instrumentation sites (containing weigh-in-motion equipment, automatic vehicle counters, etc.), including verification of the sites against any core sampling that might have taken place in the test section that could affect the roughness measurements and the deflection testing to be completed during the SHRP-LTPP program. Thus, the filming process has proven beneficial in detecting site movement and relocation.

On the other hand, there are limitations that must be taken into account to ensure that truly accurate pavement distress information is obtained (13). One such limitation is the difficulty in perceiving low-severity cracking; in addition, such surface distresses as bleeding, raveling, and weathering require extensive viewing experience to make valid comparative evaluations.

However, these limitations can be overcome through operator experience, the use of a slide projector adaptor to enhance film resolution, and supplemental information gained from videotapes and manual distress surveys when possible.

The distress data collected using the described procedure (among other information available in the NPPDB) will be used to satisfy the main LTPP design-related objectives, such as (a) evaluation of existing design methods, (b) development of improved strategies and design procedures for rehabilitation of existing pavements, and (c) development of improved design equations.

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