Automated Distress REcording System (ADRES)

JEROME F. DALEIDEN AND BRIAN M. KILLINGSWORTH

As Pavement Management Systems become the primary tool by which agencies allocate the funds for pavement rehabilitation, the accuracy of data collected for these systems becomes paramount. Distress data play a significant role in such pavement evaluations and there are many different methods available for collecting this data, one of these being manual distress surveys. However, manual (visual) distress surveys have their limitations. Inaccuracies that arise in the manual accumulation and summarization of the distress data can limit or impair its use significantly. In this study the latest "electronic clipboard" technology was employed to create a computerized system that will store and summarize distress data automatically. Software was developed so that as a distress and its associated location are identified and drawn "electronically," pertinent information about the distress is stored in a data base that is used to automatically summarize the results. Using this system greatly reduces the potential for errors that occur when distress surveyors process and relay information from one set of forms to another. The system has been developed so that a surveyor can conduct a distress survey on a computer without the need for a keyboard. The pen computer technology takes the concept of "user-friendly" technology to another level. Not only can this system be adapted to any distress survey procedure, but this technology appears to have significant potential for an almost unlimited array of comparable applications.

Pavement Management Systems (PMS) continue to grow in popularity as a means of justifying or allocating the distribution of limited resources for maintaining an agency's pavement network. These systems, however, can only be as accurate as the data that are collected for them. Similarly, studies on the performance of pavements, such as the Long Term Pavement Performance Studies (LTPP) initiated by the Strategic Highway Research Program (SHRP) and currently continuing under the FHWA, will be restricted by the quality of the data collected for each test section under observation.

Distress data play a significant role in such pavement evaluations. Automated photographic equipment can be utilized to collect parts of this distress data. However, use of such equipment can be cost-prohibitive, and, as found in the SHRP and FHWA LTPP program, can have limited reliability for those distresses in which depth perception or fine resolution is required (*1*). Hairline cracking, fault measurements, lane-to-shoulder drop-off, and similar distresses are currently still presenting problems for this type of equipment.

Manual distress surveys serve as an alternative to the collection of this data, but they have their limitations as well. Distress identification manuals, like SHRP's "Distress Identification Manual for Long Term Pavement Performance (LTPP) Studies" and other similar documents (*2–4*) provide a uniform basis for collection of this type of distress data. Although such manuals normally provide sufficient descriptions of the distresses themselves and their associated severity levels and instructions on how to measure each distress, inaccuracies arise in the processing of this data as they are transferred from the field to the distress maps, to the summary sheets, and then to an electronic storage medium (i.e., a data base). To minimize these inaccuracies, considerable work time is expended in quality assurance exercises, which include reviewing the data at various phases of its processing to catch and eliminate as many of the errors as possible.

With the creation of the Automated Distress REcording System (ADRES) for the storage and summarization of this information, considerable hours of quality assurance time can now be saved, and the potential for inaccuracies in the distress data can be reduced considerably. Not only is the collection process expedited, but all summarization is done automatically.

Brent Rauhut Engineering Inc., 8240 Mopac, Suite No. 220, Austin, Tex. 78759.

RESEARCH WORK PERFORMED

In general, the work performed under this Phase 1 research was the development of an operating prototype of the computer-based pavement distress identification system. Included in the development of this prototype was the programming of all associated software and the procurement and development of all the hardware necessary to complete a working system. This includes hardware that provides the system with the position of the distresses within the test section so that operator entry of this data may be bypassed as well.

With the ADRES, the distress surveyor has a decreased amount of data to process and transcribe from one set of forms to another. Therefore, the number of potential errors will be reduced and, ultimately, survey production will be increased. The reduction of errors and increases in productivity will enhance the validity of the data and their use in predicting pavement performance. Ultimately, such improvements will optimize the use of the available resources for managing our nation's infrastructure.

Work on this project was divided into three tasks: (a) hardware procurement and configuration; (b) software development; and (c) testing and validation.

Hardware Procurement and Configuration

Evaluations of available hardware were conducted to identify the most suitable and cost-efficient system available for the proposed field application. The "electronic clipboard," or pen computer technology, was selected to allow input into the system so that a keyboard would not be exposed to the elements in the field. Dust, mist, and other types of contaminants are of particular concern when conducting field work on the side of a highway. Using the pen interface should also prove particularly advantageous in that distress surveyors need not touch a keyboard at all. This aspect will enhance the user-friendliness of the system and inevitably lead to much more accurate surveys.

Operators interface with the system through a "touch screen" by pointing the magnetic pen at the desired screen symbols (buttons) to initiate the survey activities required. This technology is fairly similar to the "mouse" technology currently employed by most personal computer (PC) users (both in the expense of the hardware and the costs associated with software development), but it eliminates the awkwardness of utilizing a mouse in the field and the problems associated with track balls (inverted mouses for portable PCs) when exposed to the elements. This pen technology was developed specifically for gathering field data and is now commonly used for bridge inspection, survey work, and other similar field applications.

After choosing the pen computer technology as the means of gathering the data, a search was begun to find the most field-worthy and economical system. Power management, durability, and screen visibility in direct sunlight were evaluated to establish field worthiness.

The pen system selected was a GRiD 486 notebook Convertible. This system has a keyboard that was used in conjunction with the pen interface to facilitate the development of the ADRES software; however, the keyboard is not required to operate the ADRES software. The GRiD system comes with a 4-h battery, automatic standby for improved power management, and a feature to allow batteries to be switched in the middle of an operation without losing any data. This feature was particularly appealing due to the fact that with the addition of a spare battery the system could be run for a full 8 h without down time or data loss. Also, the system has a backlit screen for ease of use under direct sunlight, and was sold for less than the other pen systems available at the time. At the time the GRiD system was purchased, there were several other hardware manufacturers that were in the process of developing pen-based notebook computers. The available pen-based machines varied, but the ADRES software should run on any hardware system with the proper operating system present. The ADRES may even be run without the benefit of a pen-based system by utilizing the mouse of a standard computer; however, this defeats many of the previously noted advantages of the pen system.

Initial efforts were also made to explore the feasibility of developing hardware and software that would obtain the *x* and *y* coordinates of distresses contained within the limits of the test section lane and provide the locations to the ADRES software during runtime. Two feasible alternatives were identified. The first was to mount a distance-measuring instrument (DMI) in a light collapsible frame on wheels, much like a golfclub cart (for portability). Two wires connected to the electronic clipboard would lead to "electronic hubs" on the DMI frame, one to measure distance longitudinally (*x*) and one to measure distance transversely (*y*). The second system utilized the DMI concept as before for the *x* coordinate and a laser system to locate the *y* coordinate from a fixed height.

Software Development

Before generating any computer code, a user's manual was prepared to ensure that the generated software followed a logical progression and was easy to use. The user's manual then became both the design document and the function test document.

Once the hardware was acquired and configured, and the first draft of the user's manual was completed, development of the software began. The primary challenge of this particular project was developing the software to be as user-friendly as possible, which will facilitate its acceptance by field technicians and minimize the potential for error.

The software was written to provide data entry through two basic screens. The first is the main screen (see Figure 1), which serves three primary purposes. In this screen, the user is asked to provide header information for labeling and storing the distress data to be collected, such as section identification and date, as well as information regarding the conditions under which the survey was conducted.

Once all header information has been entered, the surveyor can initiate the survey by tapping the appropriate button for the type of pavement surface to be surveyed. These buttons store all header information and take the surveyor to the surveyor's screen to initiate the distress mapping and recording. The surveyor's screen will be discussed in greater detail in the following paragraphs.

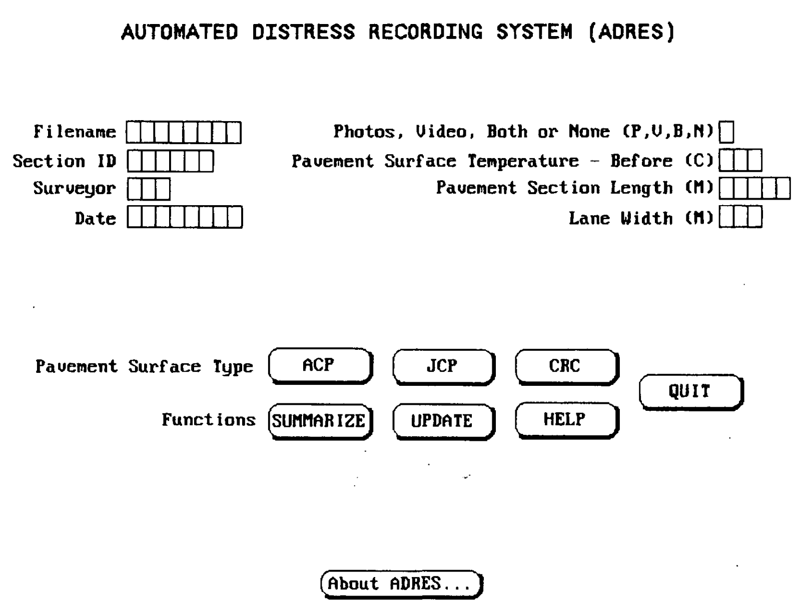

FIGURE 1 Main screen.

The final set of buttons on the main screen provides support functions such as summarizing and printing the maps generated or the summary quantities calculated, bringing up help screens, and exiting the system.

With the electronic clipboard, the header data can be written on the screen with the magnetic pen (which will convert the data written into ASCII format, which is then stored in a data file), or a visual image of a keypad can be brought up on the screen with the operator touching the pen to the "screen keypad" for the keystrokes desired.

After the header information has been entered, selecting one of the pavement type buttons on the main screen will bring up the second screen, which is the surveyor's screen. The top half of this screen provides a scaled grid comparable to that provided for distress mapping as part of the SHRP LTPP Guidelines for distress surveying. The bottom half of the screen has buttons for specifying the type of distress noted and auxiliary functions as necessary. An example of this type of screen for asphalt concrete surface pavements with some associated subscreens is shown in Figure 2. Only those distress types applicable to the chosen pavement surface type will be shown on the surveyor's screen. More than 100 support screens have been generated, which will be used as needed while the operator conducts the survey. As an example, on entry into the jointed concrete pavement or continuously reinforced concrete surveyors screens, support screens come up asking for the number of longitudinal joints sealed and the presence of joint sealant for transverse joints in jointed concrete pavements.

When a distress is noted on the pavement being surveyed, the surveyor simply notes the type of distress by touching the appropriate distress category button. This opens up another screen for the surveyor to note additional details regarding the distress (see Figure 3). When the details for the distress being recorded have been entered, and the surveyor touches the "OK" button with the pen, a dialogue box will open (see Figure 4) requesting the current x and y position. At this point the surveyor may accept the current coordinates or input new ones by editing the fields. No editing of the coordinates will be required if the surveyor utilizes the total system (cart and computer) and locates the cart at the proper locations along the boundaries of the distress. With the establishment of the preferred coordinates, the surveyor can then touch the "OK" button and the surveyor's screen will reappear. Once a given distress has been initiated, the surveyor just touches the pen to the map as necessary to outline either the perimeter of an areal distress or the path of a linear distress.

After the first point of a given distress is positioned, the surveyor may either continue mapping the distress initiated or begin another distress. To continue with the mapping of the current distress, the surveyor must touch the map with the pen. This brings up the location screen again. Three options are then available to proceed. By selecting the "draw" button on the location screen, the system will incorporate the coordinates of the last point that the surveyor touched on the map in the distress being diagrammed. As a second option, the surveyor may use the coordinates provided by the positioning system and just touch the "OK" button (assuming the location cart is being utilized). As a third and final option the surveyor may change the coordinates by inputting his or her own. This option is particularly helpful if a distress is noted to exist throughout the length of the section, but the surveyor has not yet reached the end of the section.

If an attempt is made to begin diagramming the distress before a type has been specified, the surveyor will be redirected to the distress type buttons so that the distress may be defined first.

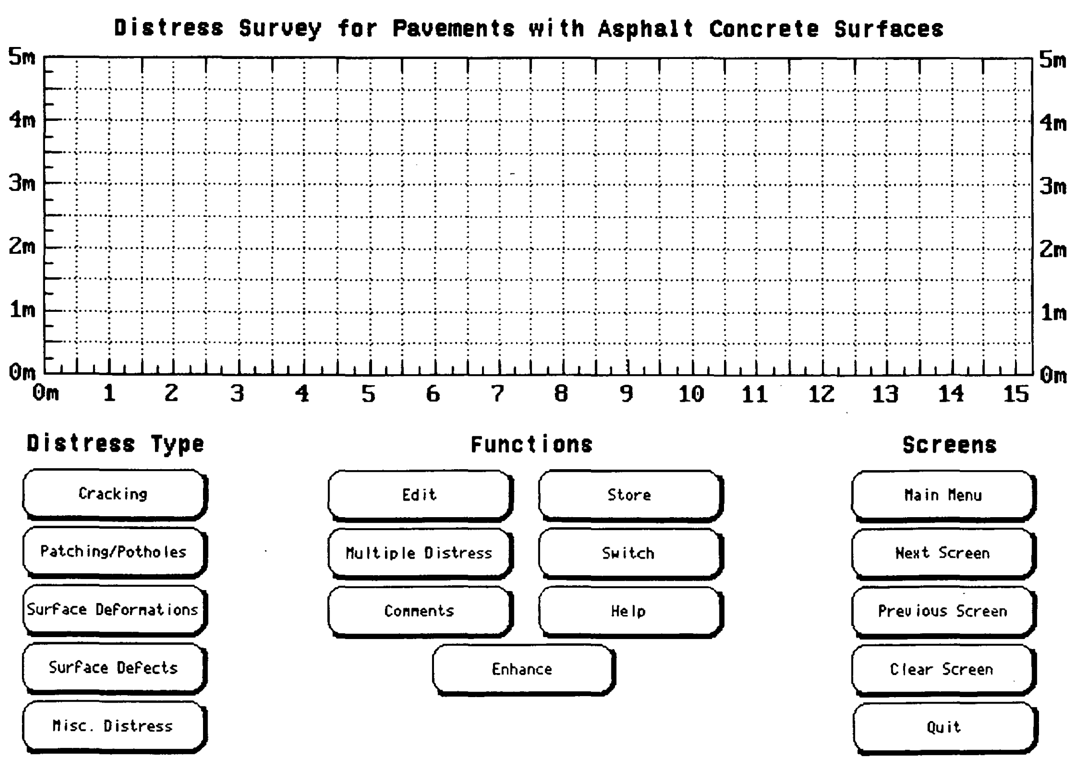

FIGURE 2 Example surveyors screen for 15.24 m of asphalt concrete pavement.

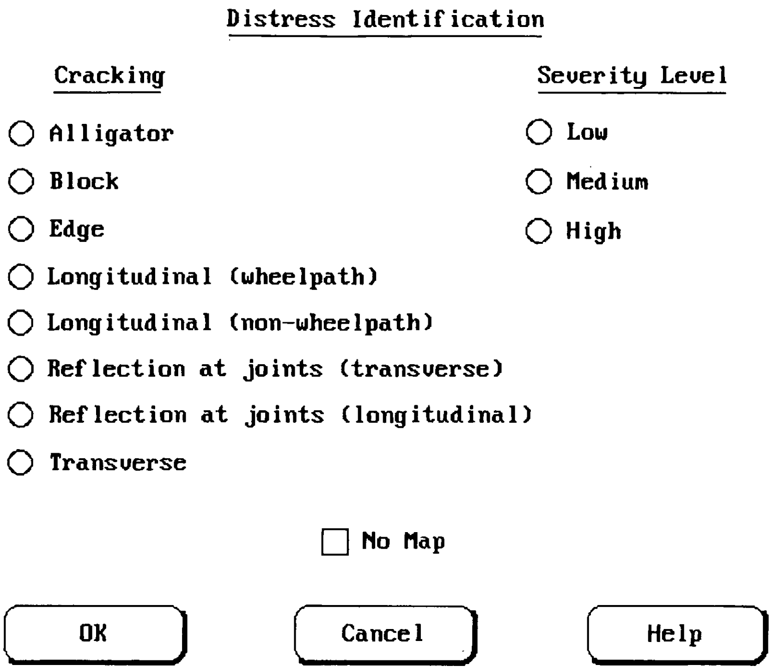

FIGURE 3 Distress identification screen for cracking in asphalt concrete pavements.

The distress types and their associated subtypes are shown in Tables 1 to 3.

If the surveyor does not wish to include a distress on the map (to avoid clutter), he or she can select the "no-map" button when specifying the other features of the distress in question (severity, type, etc).

Selection of several of the distresses (rutting, faulting in jointed concrete, lane-to-shoulder drop-off, and lane-to-shoulder separation) brings up support screens for the entry of the actual values measured. No mapping is performed or necessary for these distresses. The surveyor can collect and enter all or portions of these measurements at any point during the survey process. Some surveyors prefer to collect this data after all other mapping is completed, whereas other surveyors collect this data as they progress through the site. Any of these surveying styles may be accommodated by the ADRES.

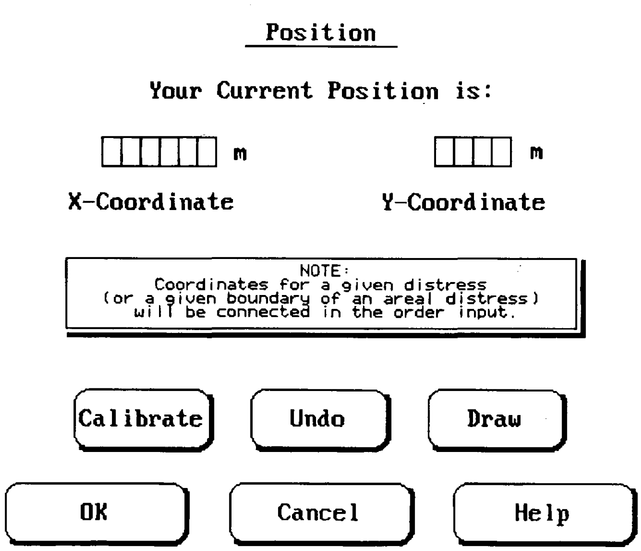

FIGURE 4 Distress location screen.

The function buttons provided on the surveyor's screen were programmed to provide the surveyor with flexibility and to improve efficiency in collecting the distress data. Included in the function buttons are features that allow for entry of more than one distress at a time, editing of errant points, entry of comments into the data base, storing of distress entries completed, and enhancement of the map to provide additional notes or markings on the map as necessary.

Buttons are also provided so that users may return to the main menu, proceed to the next screen for the next 15.24 m of a test section, return to the previous screen, clear the screen should they wish to start over, or quit. There are currently a total of 10 surveyor's screens for each pavement type (to accommodate a section of 15.24 m in length). The surveyor simply progresses through each of the screens as one would progress through the section to conduct the survey. The flexibility is provided by the system to backup or skip screens should the need arise while conducting the survey.

ADRES will continue seeking coordinates for a given distress until that distress is stored or another distress is initiated with the multiple distress button.

When the survey is completed, the surveyor can print out the results of the survey conducted, start another survey, or exit the system altogether. When a print request is initiated through the "Summarize" button on this main menu, a dialog box is provided to collect additional details regarding what information is to be printed (see Figure 5). Options include writing the distress quantities to a file in a format compatible with the LTPP Information Management System, or printing paper copies of the maps, summaries, or both. The software will calculate the quantities of each distress and summarize them in the same format as currently prescribed for SHRP-LTPP. Automated summarizing is conducted with the use of an external Fortran program that is run by the ADRES system when

TABLE 1 Asphalt Concrete-Surfaced Pavement Distress Types

DISTRESS TYPE	UNIT OF MEASURE	DEFINED SEVERITY LEVELS?
Cracking		
1. Fatigue Cracking	Square Meters	Yes
2. Block Cracking	Square Meters	Yes
3. Edge Cracking	Meters	Yes
4a. Wheel Path Longitudinal Cracking	Meters	Yes
4b. Non-Wheel Path Longitudinal Cracking	Meters	Yes
5. Reflection Cracking at Joints		
Transverse Reflection Cracking	Number, Meters	Yes
Longitudinal Reflection Cracking	Meters	Yes
6. Transverse Cracking	Number, Meters	Yes
Patching and Potholes		
7. Patch/Patch Deterioration	Number, Square Meters	Yes
8. Potholes	Number, Square Meters	Yes
Surface Deformation		
9. Rutting	Millimeters	No
10. Shoving	Number, Square Meters	No
Surface Defects		
11. Bleeding	Square Meters	Yes
12. Polished Aggregate	Square Meters	No
13. Raveling	Square Meters	Yes
Miscellaneous Distresses		
14. Lane-to-Shoulder Dropoff	Millimeters	No
15. Water Bleeding and Pumping	Number, Meters	No

the summarizing option is chosen. This program reads the data bases generated throughout the survey process and calculates the lineal or areal quantities for each distress type by utilizing the coordinates stored for each distress. Lineal quantities are simply calculated using the Pythagorean theorem, and areal quantities are calculated by using a numerical approximation procedure called the trapezoidal rule. Error associated with this procedure is quite small because of some internal error-reducing techniques utilized by the program developers.

Testing and Validation

Continued testing and refinement of the system were conducted throughout the programming phase. Every effort was made to ensure that this prototype was as complete and bugfree as possible. The prototype system was taken out in the field and used by persons other than the developers to conduct distress surveys and seek "bugs" in the system. Any flaws identified were corrected.

RESULTS OBTAINED

An operational, computer-based, pavement distress identification prototype system has been created. As noted above, although there are only two primary types of screens required for data entry, more than 100 screens were developed to support or facilitate the systems operation and make it easier to use.

With the exception of the "Help" buttons and the positioning system, all other aspects of this prototype are fully operational. Completion of the "Help" buttons requires development of the appropriate text support screens to be displayed at the appropriate points in the system. The only reason this has not yet been accomplished is that it is anticipated that the text provided in the help screens may be dictated by the types of problems users encounter as they implement the system to some extent. Full testing and validation is not yet completed and hence further development of these "Help" screens is still pending. Initially, however, these support screens will contain portions of the user's manual or the LTPP DIM.

The positioning system has been tested and proofed and the software to support its operation is incorporated into the working prototype, although the actual hardware has not yet been field tested in conjunction with the prototype software. The system has been constructed so that it can function independently of the positioning hardware, or simply stated, the surveyor can specify the appropriate coordinates when the system asks for them. However, it is still anticipated that the system can and will function more efficiently in conjunction with the positioning hardware.

A second phase of this project is planned and is currently awaiting funding. Included in Phase 2 are enhancements to the system to

TABLE 2 Jointed Concrete-Surfaced Pavement Distress Types

DISTRESS TYPE	UNIT OF MEASURE	DEFINED SEVERITY LEVELS?
Cracking		
1. Corner Breaks	Number	Yes
2. Durability Cracking ("D" Cracking)	Number of Slabs, Square Meters	Yes
3. Longitudinal Cracking	Meters	Yes
4. Transverse Cracking	Number, Meters	Yes
Joint Deficiencies		
5a. Transverse Joint Seal Damage	Number	Yes
5b. Longitudinal Joint Seal Damage	Number, Meters	No
6. Spalling of Longitudinal Joints	Meters	Yes
7. Spalling of Transverse Joints	Number, Meters	Yes
Surface Defects		
8a. Map Cracking	Number, Square Meters	No
8b. Scaling	Number, Square Meters	No
9. Polished Aggregate	Square Meters	No
10. Popouts	Number/Square Meter	No
Miscellaneous Distress		
11. Blowups	Number	No
12. Faulting of Transverse Joints and Cracks	Millimeters	No
13. Lane-to-Shoulder Dropoff	Millimeters	No
14. Lane-to-Shoulder Separation	Millimeters	No
15. Patch/Patch Deterioration	Number, Square Meters	Yes
16. Water Bleeding and Pumping	Number, Meters	No

TABLE 3 Continuously Reinforced Concrete-Surfaced Pavement Distress Types

DISTRESS TYPE	UNIT OF MEASURE	DEFINED SEVERITY LEVELS?
Cracking		
1. Durability Cracking	Number, Square Meters	Yes
("D" Cracking)	Meters	Yes
2. Longitudinal Cracking	Number, Meters	Yes
3. Transverse Cracking		
Surface Defects		
4a. Map Cracking	Number, Square Meters	No
4b. Scaling	Number, Square Meters	No
5. Polished Aggregate	Square Meters	No
6. Popouts	Number/Square Meters	No
Miscellaneous Distress		
7. Blowups	Number	No
8. Transverse Construction Joint Deterioration	Number	Yes
9. Lane-to-Shoulder Dropoff	Millimeters	No
10. Lane-to-Shoulder Separation	Millimeters	No
11. Patch/Patch Deterioration	Number, Square Meters	Yes
12. Punchouts	Number	Yes
13. Spalling of Longitudinal Joints	Meters	Yes
14. Water Bleeding and Pumping	Number, Meters	No
15. Longitudinal Joint Seal Damage	Number, Meters	No

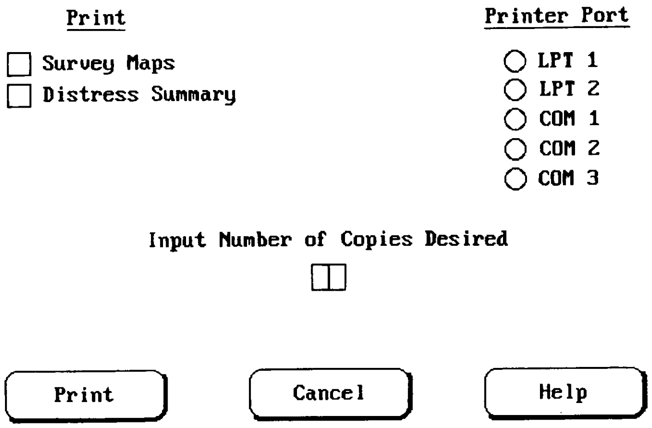

FIGURE 5 Printing screen.

complete the "Help" features, upgrade the graphical capabilities for even greater system efficiency, refine the hardware, and conduct a full scale beta test of the revised software and hardware.

CONCLUSIONS

A working prototype of the ADRS has been developed to collect and summarize pavement distress data. This particular system was developed to be consistent with the LTPP format. However, it is anticipated that with some software modifications, the prototype system would be readily adaptable to whatever format might be of interest. Typically, fewer distress types are monitored for pavement management systems implemented by cities, counties, and state highway agencies. However, such modifications would not be difficult to accomplish.

Similarly, the software on this particular prototype is set up to summarize the data in the LTPP format. Most agencies have their own unique format for summarizing distress data (typically providing a composite index value for comparison with other test sections). Modifications of this type would ultimately need to be made in the software to suitably adapt the prototype system for use by other agencies, but again such modifications would not be difficult.

The majority of this research effort is directly adaptable to any other agency (federal, state, or local) that may wish to use it. The primary thrust of this work is in the application of the pen computer hardware to field applications such as pavement distress surveying. Most of the software development was focused on maximizing the use of this "electronic clipboard" technology and the "*x* and *y* positioning" capabilities. Both of these features should be directly applicable to any agency currently involved in manual collection of field data or data in which positioning is involved.

Phase 2 research is currently underway to refine this existing system and conduct extensive beta testing.

REFERENCES

1. Daleiden, J. F., and A. L. Simpson. Evaluation of SHRP LTPP Distress Data Collection Procedures. Presented at 1994 Annual Transportation Research Board Meeting, Washington, D.C., 1994.
2. *Distress Identification Manual for the Long-Term Pavement Performance Studies.* Strategic Highway Research Program, SHRP-LTPP/FR-90-001, TRB, National Research Council, Washington, D.C., 1990.
3. "Pavement Condition Index Field Manual," APWA, July 1984.
4. Smith, R. E., S. M. Herrin, and M. I. Darter. *Highway Pavement Distress Identification Manual.* FHWA, National Cooperative Highway Research Project 1-19, U.S. Department of Transportation, March 1979.

Publication of this report sponsored by Committee on Pavement Monitoring, Evaluation, and Data Storage.