NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 161

TECHNIQUES FOR REDUCING ROADWAY OCCUPANCY DURING ROUTINE MAINTENANCE ACTIVITIES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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TECHNIQUES FOR REDUCING ROADWAY OCCUPANCY DURING ROUTINE MAINTENANCE ACTIVITIES

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST

- PHOTOGRAMMETRY
- MAINTENANCE, GENERAL
- CONSTRUCTION AND MAINTENANCE EQUIPMENT
- HIGHWAY SAFETY
- TRAFFIC OPERATIONS AND CONTROL

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1975

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices The Board is uniquely suited for this purpose as. it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs

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FOREWORD

By Staff
Transportation
Research Board

The procedures described in this report will be of particular interest and value to highway maintenance personnel and others desirous of reducing roadway occupancy time during maintenance activities in the traveled way. The report organizes the specific activities of bridge deck repairs, pavement patching, crack and joint sealing, and mudjacking into tasks and identifies a number of techniques suitable for accomplishment of each. Standard time data have been compiled for several maintenance techniques. Procedures have been developed for analyzing and managing maintenance activities. Based on actual field studies and observations in 14 states, it has been demonstrated that application of the procedures can result in substantial reduction in roadway occupancy time by maintenance crews using current technology.

Occupancy of the traveled way by maintenance crews and equipment is often extremely hazardous to both maintenance personnel and the traveling public. Where traffic speeds and density are such that interruptions create major tie-ups, severe limitations may be placed on timing and duration of maintenance work. In many instances, the need for extensive traffic control systems is the most expensive part of the maintenance activity. The objective of this research project was to develop procedures for improving the safety and efficiency of maintenance operations by identifying methods of reducing the time of occupancy of the roadway by maintenance crews during bridge deck repairs, pavement patching, crack and joint sealing, and mudjacking

The investigation, undertaken by the consulting engineering firm of Byrd, Tallamy, MacDonald & Lewis, was conducted in two phases. The first was discovery—an attempt to identify unique and innovative procedures that appeared to have promise for reducing roadway occupancy time. This was followed by an analysis phase that included extensive observations of maintenance activities in many parts of the U.S. to determine the impact of various equipment, materials, and organizational procedures on occupancy time. The search for new equipment, materials, or other techniques for accomplishment of the specific activities being studied was not as fruitful as was initially anticipated, although some promising techniques were identified. There appears to be a growing interest in prefabricated repair units and fast-curing materials The extremely heavy traffic volumes carried on many parts of the highway system have resulted in minimizing of routine maintenance activities, such as patching, in favor of early resurfacing and major rehabilitation of larger roadway sections.

The data collection and analysis procedure for evaluating various current maintenance techniques utilized time-lapse photography. Several considerations led to use of this technique, including: relatively inexpensive equipment; continuous observation of an activity; hours of observation can be reviewed in a few minutes, data take-off can be selective; and observations can be stored for future reference. From the field data files accumulated with time-lapse photography, several analyses were made. Total observed occupancy time was divided into traffic control time, delay time, work time, and curing time Opportunities for reducing crew size and improving task sequences often were apparent. Analysis of the activities studied indicated that reduction in work time requirements would not likely result in major reductions in total occupancy time Instead, major occupancy time reduction most often is dependent on elimination of delay time and minimizing of traffic control and curing time.

Although this report does not identify major technological breakthroughs for the maintenance activities studied, it does describe time-lapse photography data collection and analysis procedures involving the categorization of roadway occupancy time that can be used in the management process in many instances to improve dramatically safety and the efficient movement of traffic during routine maintenance activities. Consequently, maintenance and safety personnel should give serious consideration to the procedures, particularly in areas of high traffic speeds and volumes.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 14-2 by Byrd, Tallamy, MacDonald & Lewis, now a division of Wilbur Smith and Associates L G Byrd served as the Principal Investigator throughout the conduct of the research, with Bertell C Butler as the key staff researcher.

Appreciation is expressed to the individuals and the organizations, agencies, associations, and state highway departments participating in the interviews and conferences or otherwise contributing the valuable information and suggestions by which this project benefited

Also appreciated is the cooperation and assistance provided by individuals during the field observations

TECHNIQUES FOR REDUCING ROADWAY OCCUPANCY DURING ROUTINE MAINTENANCE ACTIVITIES

SUMMARY

This comprehensive study of maintenance activities on the traveled way revealed that major reductions in roadway occupancy time—up to 48 percent in some instances—can be achieved using present technology. The major findings leading to this conclusion are as follows:

1. Although major occupancy time reductions were not achieved directly by the use of new and innovative materials and equipment, effective techniques were identified in this study for the efficient accomplishment of each required task. Several techniques using new or modified materials and equipment are sufficiently promising to merit consideration by agencies performing maintenance activities on the road under heavy or fast traffic. Promising materials and equipment include:
   - (a) Rapid-curing epoxies and regulated set cements
   - (b) Precast concrete slabs for partial-depth and full-depth pavement repairs.
   - (c) Prefabricated surface patches for asphalt pavements.
   - (d) Large-diameter cutting wheels for concrete cutting
   - (e) Percussive cutting heads for partial-depth, predimensioned concrete cutting.
   - (f) Large-diameter cylindrical saws for cutting concrete.
   - (g) Horizontal pressure-grouting equipment for under-slab base restoration and slab leveling.

2. Several planning and management tools, developed in the study, offer significant potential for reducing roadway occupancy time. These include:
   - (a) Structuring maintenance procedures by activities, tasks, and techniques.
   - (b) Using time-lapse photography for data collection and analysis.
   - (c) Developing standard time data for maintenance tasks.
   - (d) Preplanning activities for minimum occupancy time using crew balance charts with standard time data to optimize the selection and sequencing of alternative techniques.

3. Improvements in managing the entire maintenance activity showed the greatest potential for significant reduction of roadway occupancy time by maintenance crews. Major opportunities for improvements were in the following areas:
   - (a) Selection of maintenance techniques best suited to carrying out the activity.
   - (b) Organization of the activity by task with manpower assignments and scheduling preplanned and designated.
   - (c) Job-site supervision and control.
   - (d) Equipment selection, readiness, and reliability.

Approach

Highway maintenance activities often require occupancy of traffic lanes. Conflicts between these activities and the traveling public endanger both workmen and motorists. There is a need to minimize the problem and to provide a higher level of safety, economy, and convenience for the highway user during required maintenance activities.

The project encompassed maintenance activities for.

1. Bridge deck repairing
2. Travelway patching
3. Crack and joint sealing.
4. Mudjacking and subsealing.

The need to work with the individual elements of various activities was recognized and accommodated by the structuring of maintenance procedures into: *activities, tasks*, and *techniques*.

Tasks were defined as the principal elements or subdivisions of an activity. For this project a specific list of tasks were identified and given code numbers.

Techniques were defined as unique ways of performing given tasks. In the first phase of the study, new and innovative techniques were sought to perform tasks. To evaluate new techniques, existing standard techniques also had to be analyzed.

Time-lapse photography was used to collect and develop data for the various maintenance techniques being studied. Where new techniques were found, they most often involved the minor modification or fabrication of equipment and tools within maintenance shops

The few major changes in techniques identified in the study usually were associated with the use of new equipment and/or materials developed by manufacturers or contractors.

Time reduction was achieved by:

1. Use of mechanization.
2. Use of rapid-curing and/or prefabricated materials
3. Use of optimum equipment and crew size
4. Strategic scheduling of tasks.
5. Techniques that combined or eliminated tasks

Techniques

Several innovative techniques showing promise for reducing roadway occupancy time were identified in this study

- A percussive cutter is used to mill away concrete to create a predimensioned opening for partial-depth repairs.
- A cylindrical saw, similar to a coring saw but of large (2 ft or greater) diameter is used to make full-depth, one-piece circular cuts in concrete pavement.
- A large (7-ft diameter) power-driven wheel, fixed with carbide-tipped cutting teeth along its rim, is used as a massive concrete saw to cut full-depth, 3½-in wide through concrete pavements.
- Precast concrete slabs have been used to replace full-depth or partial-depth sections of concrete pavement.
- "Band-aid" prefabricated bituminous surface patches have been used for shallow surface repairs on flexible pavements.

- Compartmented, truck-mounted concrete batch plants have been used to permit on-site mixing of concrete in batch sizes to fit the repairs.
- One-inch-thick steel plates have been used to bridge concrete pavement repair sites while concrete patches are curing
- Tractor-mounted multiple-head drills set at a standard spacing have been used to drill more than one hole concurrently for mudjacking.

Occupancy Time

Roadway occupancy time was divided into four categories. Traffic-control time; delay time, work time; and cure time. Traffic-control time was observed to be the least variable of all occupancy time categories. Elimination of delay time would have resulted in major reductions in occupancy times observed during the study. Cure time frequently represented a major percentage of total occupancy time. Work time was analyzed to determine the man-hours that were being invested in productive work. Nonproductive man-hours were divided into avoidable and unavoidable nonproductive man-hours.

Standard time data can be used to predict the length of time required to perform a given amount of work using a specific technique The majority of the standard times established during the study were for techniques that are routinely used by most highway maintenance agencies. Although not complete, the standard time values that were developed represent an important step toward a data file on maintenance techniques useful for a variety of management and planning applications.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

Highway maintenance activities often require occupancy of traffic lanes, structures, and shoulders of the roadway by men, materials, and equipment. Conflicts between these activities and the traveling public thus endanger both workmen and motorists and restrict the flow of traffic. Hazardous situations and interference with the orderly flow of traffic are pronounced where high-speed and/or high-density traffic conditions exist. There is a need to minimize the problem and to provide a higher level of safety, economy, and convenience for the highway user during required maintenance activities. Utilization of techniques designed to reduce roadway occupancy time by maintenance activities appears to offer potential for alleviation of the problem

OBJECTIVES

The objectives of this project were to identify and evaluate superior existing techniques that significantly reduce the occupancy time of the highway travelway and shoulders by maintenance forces. Development of new materials or new equipment was not within the scope of the study

In its original stage, the project encompassed maintenance activities for

1. Travelway patching.
2. Shoulder patching
3. Travelway resurfacing and resealing
4. Shoulder resurfacing and reconditioning
5. Crack and joint sealing
6. Mudjacking and subsealing.
7. Bridge deck repairing.

After the initial work was completed and an interim report reviewed by the project Advisory Panel, the scope of the work was modified to permit a more complete evaluation of a lesser number of activities for

1. Bridge deck repairing
2. Travelway patching
3. Crack and joint sealing
4. Mudjacking and subsealing.

The effort on the four activity areas also was assigned a priority rating in the same sequence as the foregoing listing.

RESEARCH APPROACH

Literature Search

As a part of the literature search, the Highway Research Information Service (HRIS) was engaged to make a search of their abstract files. The HRIS search produced 50 abstracts dealing with maintenance techniques in the United States, Italy, the Netherlands, Poland, Canada, England, and Germany. Approximately 717 publications were searched by the project team and from these 152 abstracts were prepared to record information of importance to the project.

To keep abreast of maintenance developments during the course of the project as chronicled in the literature, HRIS supplied a monthly set of abstracts of research in progress and available worldwide literature.

Staff Input

An initial conference was held by the members of the project team in November 1970. With the principal investigator and five field representatives bringing an aggregate of 160 years of experience as operating maintenance engineers to the project, staff input was useful in developing initial concepts for some maintenance techniques and in evaluating techniques employed or proposed by others.

Personal knowledge of the project team members and leads furnished by the literature search provided the basis for developing lists of agencies to be contacted through a questionnaire and agencies to be visited in the initial field interviews

Staff members and field representatives reconvened for a 3-day workshop on May 11-13, 1971, following completion of the initial field visits and receipt of responses to the questionnaires At the workshop, a review was made of all techniques identified to date and each technique was evaluated. Lists and descriptions were drafted to include all current knowledge about each accepted technique, and follow-up assignments were made where additional data were needed Plans also were made for the in-depth study of selected techniques through the cooperation of maintenance agencies known by the staff to have the program, equipment, and willingness to participate in the research effort

Questionnaires

Two mailing questionnaires were developed to solicit information for the project. (See Appendix B.) One questionnaire was designed to elicit information from agencies performing street or highway maintenance It was accompanied by a packet of illustrative maintenance techniques designed to arouse the recipients' interest and encourage response One hundred twenty-seven questionnaires were mailed. All 50 state highway maintenance organizations, 31 toll road and toll bridge authorities in the United States and Canada, 12 major cities and urban counties with responsibility for high-traffic-density highways and expressways, and a small number of foreign organizations, private firms, research agencies and individuals were queried Seventy-seven agencies responded, of which about one-third received a personal follow-up to explore promising techniques, equipment, materials, or organizations in greater depth.

It was evident as a result of the initial search that many opportunities for improved maintenance techniques lay in innovative development and use of equipment and materials. Consequently, a list of manufacturers and suppliers of highway maintenance equipment and materials was compiled and another questionnaire was dispatched to 185 agencies. Responses were received from 73. Most evidenced a keen interest in the project and offered to cooperate by loaning equipment for testing and by supplying sample materials, data, or other pertinent information and suggestions

Inquiries also were dispatched to embassies of countries with traffic and maintenance problems similar to those of the United States Leads were followed up with direct questionnaires to foreign maintenance and research organizations.

Interviews

As a result of information gathered from the foregoing sources, maintenance organizations were selected for in-depth interviews because of the promising techniques they were using Project staff members made field visits to agencies in 31 states, Canada, and England (Fig. 1). All agencies evidenced a strong interest in the research project and offered to help in testing equipment, in gathering data, or in restructuring and testing maintenance tasks.

Field Studies

Field observations of maintenance activities were conducted over a 12-month period by a two-man crew The field study covered 14 states (Fig 1). Observations ranged from 2 to 5 hours at each site, and resulted in recording more than 10,000 ft of time-lapse film for evaluation

Panel Review

A project review conference was held by the project Advisory Panel in September 1971 At that conference, the research team reported on the project status and accomplishments Also, concepts and procedures for carrying out the remainder of the project were presented, with emphasis on the development of field data and analysis of techniques.

Following the conference, the Advisory Panel reduced the number of activities being studied so that a greater effort could be made in the remaining activity areas. The Advisory Panel requested prompt implementation of the field phase so that maximum data could be developed for the activities remaining to be studied

Interim Reports

Two interim reports were published during the conduct of the study The first was developed at the end of 5 months to provide updated information on a refined work plan and a summary of findings evolving from an extensive literature search. In addition, the report included samples of a letter of transmittal and a questionnaire proposed for mailing to selected maintenance agencies

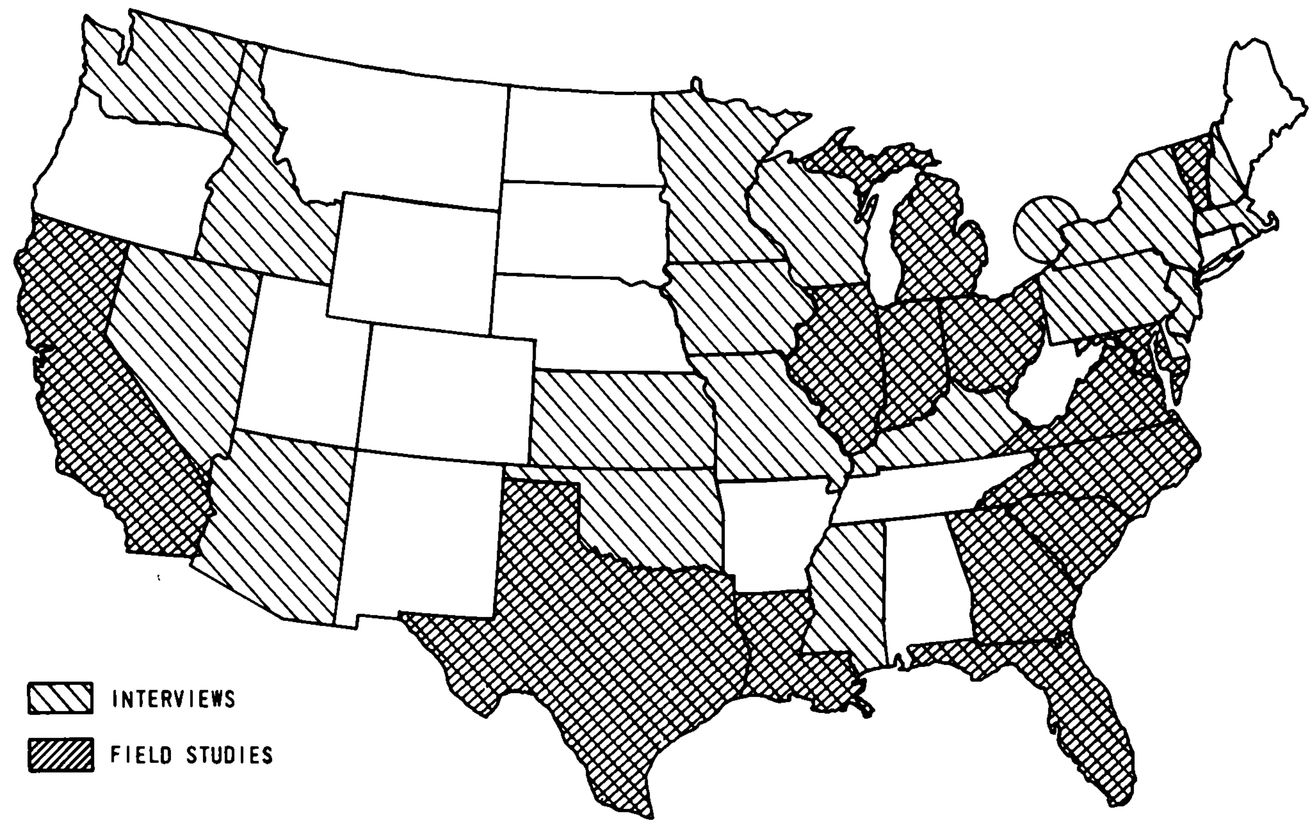


Figure 1. States where interviews were conducted

The second interim report, prepared after 8 months of research, summarized the results of the search phase of the project The techniques uncovered in the literature search, highway maintenance agency and manufacturer surveys, and personal interviews were identified and discussed and innovative or unique ones were illustrated in detailed technique descriptions An abbreviated version of the second interim report was prepared for distribution by the Transportation Research Board to state agencies This dissemination made the early project findings available for use by maintenance organizations.

ORGANIZATION AND ANALYSIS OF MAINTENANCE ACTIVITIES

As a result of the initial phases of the study, the need to work with the individual elements of various activities was recognized and accommodated by the structuring of maintenance procedures into *activities, tasks,* and *techniques*

Activities were defined as work procedures producing a completed end-product or result in the maintenance program For ease of reference, the activities under study were coded by.

Component.	I	Pavement
	II	Shoulder
	III	Bridge deck
Material.	A	Concrete
	B	Bituminous
	C.	Composite
	D	Other
Action	1	Patch or repair
	2	Resurface
	3.	Surface treat
	4	Seal
	5.	Mudjack
Location.	a.	Surface
	b	Partial-depth
	c.	Full-depth
	d.	Joint or crack

Thus, an activity coded as I A 1 b was "pavement, concrete, patch or repair, partial-depth."

Tasks were defined as the principal elements or subdivisions of an activity. Obviously, without a very detailed definition, a variety of interpretations of what comprises a task could result. For this project, the definition was applied to a specific list of tasks that were identified and given code numbers The list was intended to include all tasks required to accomplish any of the activities under study. These tasks were

1. Set up or remove work zone materials and traffic controls

2 Identify, locate, detect, or delineate areas of deteriorated material to be removed.

3. Cut, grind, mill, plane, or break deck or pavement materials

4. Remove broken or disintegrated deck, pavement, or base material.

5. Clean, dry, and prepare patch area or surface area.

6 Prepare and place forms, screeds, or other material-controlling devices.
7. Apply tack coats or bonding material
8. Mix and place patching, surfacing, or sealing materials.
9. Compact, vibrate, screed, or finish patching or surfacing material.
10. Apply curing or blotting material.
11. Construct temporary travel surface over repaired area.
12. Clean out joint or crack
13. Fill joint or crack
14 Locate, layout, drill, and prepare mudjack holes
15. Prepare slurry and perform mudjacking
16 Apply liquid coating to surface.
17. Spread aggregate on surface
18. Miscellaneous

Techniques were defined as unique ways of performing given tasks For example, the installation of a precast concrete slab was a technique for accomplishing Task 8, "Mix and place patching, surfacing, or sealing materials." Obviously, some tasks could be achieved by a variety of techniques, others did not offer many alternatives.

Roadway Occupancy Time

For purposes of the study, roadway occupancy time was subdivided into four categories

1 *Traffic control time* —Time spent on work zone set-up and removal when only traffic control work was being performed

2 *Delay time* —Time when the roadway was occupied by the work zone but no work was being performed and no material-curing was taking place.

3 *Work time* —Time during roadway occupancy when maintenance work was being performed at the occupancy site.

4 *Cure time.*—Time requiring roadway occupancy only to permit materials to cure.

If a work task was initiated before the completion of the traffic control set-up, this was considered to be the end of the traffic control time interval As long as one or more tasks continued, the work time interval continued. Any break in which no task was being performed was classified as delay time. At the completion of the last maintenance task, either traffic-control removal was in progress, cure time had commenced, or the interval observed was classified as delay time until traffic-control removal was initiated These categories of roadway occupancy are shown in Figure 2

The Informational Requirements of the Study

In the first phase of the study, new and innovative techniques to perform tasks were sought. Although general information on new techniques was developed, complete evaluation required that observations be made of the techniques being performed in the field.

Information was needed relating to field procedures under a variety of roadway and workload conditions. The labor, equipment, and material requirements and production rate associated with the technique needed to be established. Also, the techniques required field evaluation in the

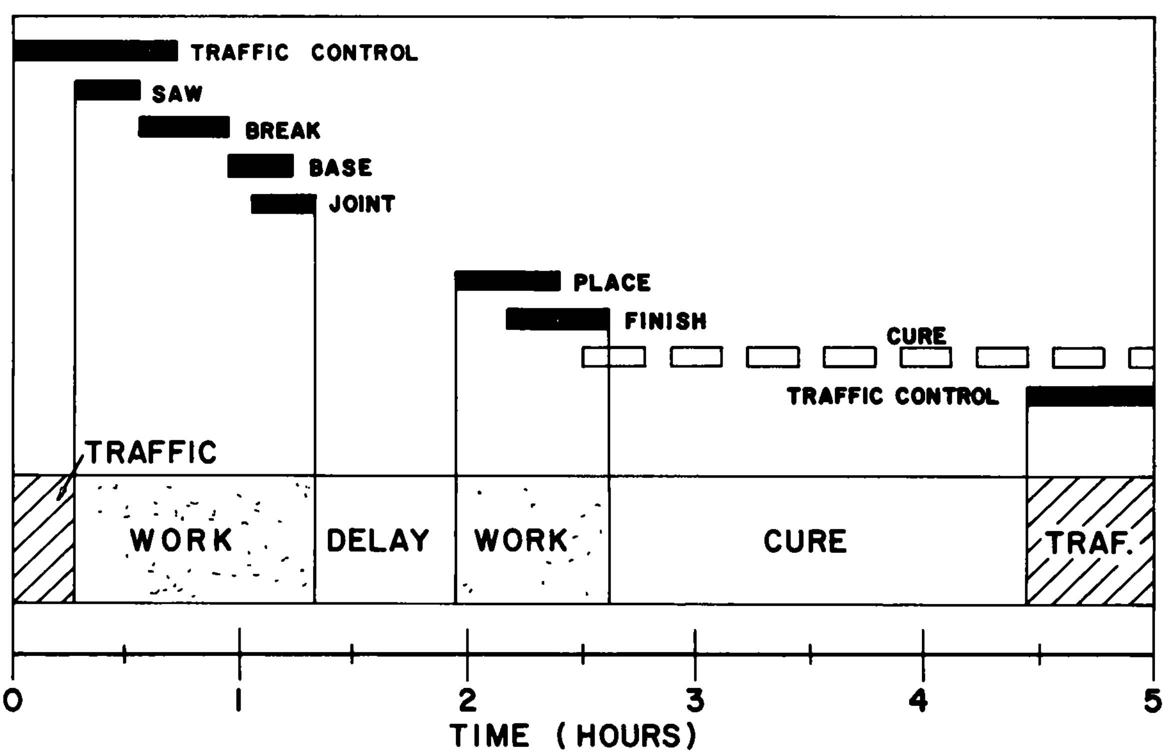


Figure 2 A schematic representation of roadway occupancy time for a concrete repair project

context of the total activity. This required information on occupancy time and maintenance activity procedures also.

To evaluate new techniques, existing or standard techniques also had to be analyzed. To do this effectively, the same level of documentation was needed on existing techniques as on the new techniques. Adequate information was not available from the literature or from agency records so it also had to be developed in the field phase of the study.

Standard Data Development

In evaluating and reorganizing an activity so that it becomes more efficient, one approach that permits considerable flexibility involves the development of standard data for the various components of the activity. The standard data can include time required per unit of work accomplished for given crew sizes. With these data, many component variations and combinations can be explored to find the minimum time for the activity.

This procedure for predicting work time offers some other distinct advantages. The approach is objective. The same time will always be predicted for like procedures. The activity time estimate can be made rapidly. The approach is applicable over a wide range of workloads. Consequently, the standard data approach was selected as a mechanism to be used in evaluating techniques for performing a maintenance task.

Use of Time-Lapse Photography for Data Collection

Since the required standard data were not available from maintenance organizations or literature, time-lapse photography was used to collect and develop data for the various maintenance techniques being studied.

The selection of time-lapse photography as the data collection technique was based on several considerations:

1. The time-lapse filming could be performed by technicians with little or no training in time and motion study procedures.
2. Maximum information on maintenance tasks and activities could be collected with a minimum investment in labor and travel expense.
3. Film could provide a complete and retainable record of the observed maintenance activity as it occurred.
4. The time constriction created by the time-lapse film permitted repeated reviews within short time intervals.
5. The film could be reviewed in an office environment by experienced professionals and their expertise used for project input with a minimum investment.
6. The film could have potential as a training aid.
7. Supplemental data, not envisioned at the time of field observations, could be captured from the film.
8. Relatively inexpensive super-8 commercial equipment could be obtained on the market.

The equipment used included a super-8 camera with zoom lens and automatic exposure meter, an 8-speed solid-state intervalometer, and a built-in rechargeable battery with battery charger, all enclosed in a weatherproof housing. A heavy-duty tripod; a modified projector with flickerless 8 speeds forward and reverse, lighted control panel, and a frame counter; and heavy-duty carrying cases for both the camera and projector were used.

Photographic Procedures

The time interval between frame exposures required for the time-lapse record was one that would put a maximum time period on one film without loss of pertinent detail. A 2-sec interval proved best for the study. Super-8 color film was used to permit easier identification of individual workmen by clothing colors.

The monitoring position for the camera needed to be high enough above the work being photographed to reduce the frequency of the camera view being blocked by men or equipment. To ensure the best possible coverage, a number of camera support arrangements were developed. Two were built into a panel truck that served as field team transportation. For one mount, two 16-ft ladders were fastened in an A-frame around the truck, which served as ballast (Fig. 3). For the other, a collapsible vertical tripod was fastened to the top of the truck. Also used was a tripod equipped with vacuum-assisted suction cups that permitted mounting on the top of any available equipment in the vicinity of the work site (Fig. 4).

A header was used for each 50-ft reel of film to ensure the correct identification of the location, date, and time of the film record (Fig. 5).

Support information was recorded on a field data log (Appendix C) and a field narrative that provided a written description of the activity plan as established by the maintenance agency. The procedures filmed did not always represent the normal procedures used by the agency. The field narrative documented the general procedure used by the agency with comments on the good and poor aspects of the observed and planned procedure.

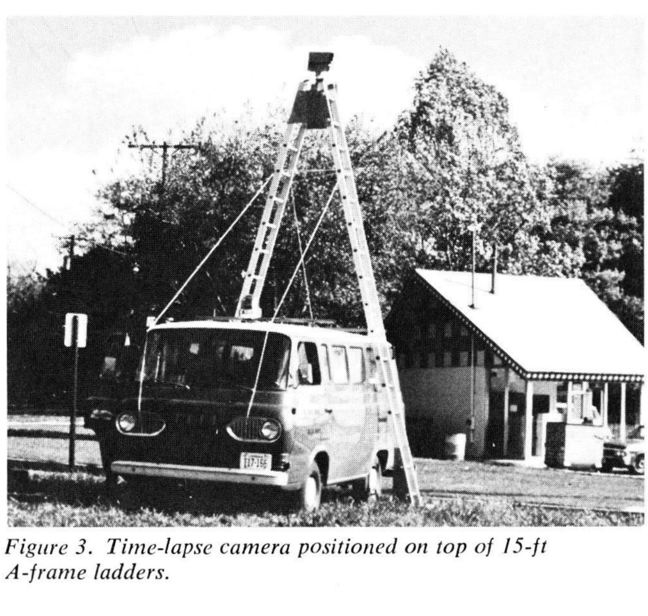


Figure 3. Time-lapse camera positioned on top of 15-ft A-frame ladders.

Figure 4. Positioning camera tripod with special suction pads on top of truck cab.

Film Review

In the review process, the film was screened first for general content. All film of the same activity and site was consolidated, time-sequenced, and spliced together on one or more 200-ft reels. The initial analysis procedures consisted of identifying all maintenance tasks on the film that could be used to develop standard time data.

For development of the standard time data, two takeoff forms were used (see Appendix D). "Cyclic" operations involved work of short duration repeated regularly during an activity, such as the sealing of joints or the drilling of holes for a mudjack operation.

"Noncyclic" operations were of longer duration with men varying in numbers during the course of the task. Examples of a noncyclic task would be breaking pavement with air hammers, installing a pavement contraction joint, or placing concrete.

To evaluate standard time data for each task, it was necessary to develop uniform measurements. Widely varying crew sizes with differences in efficiency made it difficult to make a comparison of work between work sites. Therefore, work time was analyzed and divided into "productive" time and "nonproductive" time for each crew member. The nonproductive time was defined as the sum of those increments of time during which a crew member was not working.

To accommodate varying crew sizes, the minutes or hours of productive time for each crew member were recorded and then totaled to produce productive man-hours for the crew. This total of productive man-hours was divided by the total elapsed task time to give the equivalent crew size if each member were working productively for the entire task time. Thus, the standard time data developed were comparable for different observations and different crews.

Once detailed data were available on each crew member it was possible to develop crew balance charts for the observed activity. The crew balance chart shown in Figure 6 is representative of the charts developed in the study. It shows how each crew member's time was divided between productive and nonproductive time. The chart shows that man No. 1 has 24 min of productive time and 6 min of nonproductive time. There are four men working and the total productive time is 90 man-minutes (24 + 23 + 20 + 23). The standard time of 30 min would be applicable for a three-man equivalent crew (90/30). Thus, the standard time reflects only pure work time. In plotting the crew

ROADWAY OCCUPANCY STUDY

BTML 107.07 **NCHRP 14-2**

DATE_____,1972 TIME START______ STOP______

REEL NO.______ TIMELAPSE INTERVAL______

ACTIVITY CODE ________ TASKS________

DESCRIPTION________________

LOCATION________________

MATERIAL____________ UNITS________

Figure 5. Header form used to describe filming location.

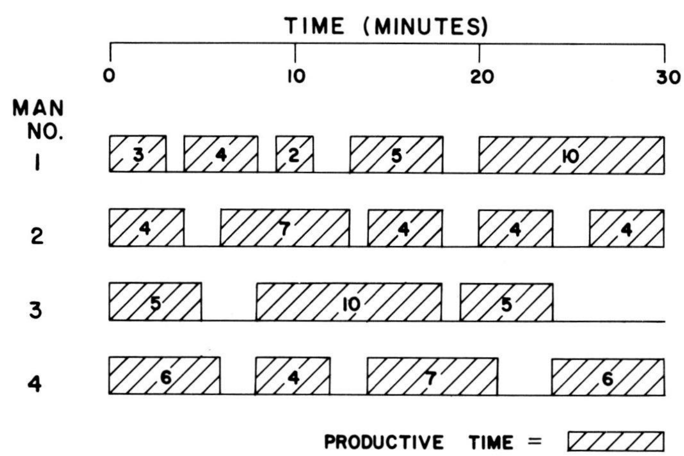


Figure 6. Crew balance chart showing the division of productive and nonproductive work for four men placing concrete over a 30-min worktime interval.

balance charts for observed operations, it was possible to recognize places where procedures could be improved through better use of crew members. These improvements were built into revised crew balance charts and the potential occupancy times compared with those observed.

With a potential procedure for an activity developed, alternative techniques also could be substituted in the procedure and the impact on occupancy time evaluated. Also, the potential procedure permitted the ready identification of the task or tasks that could effect a significant reduction in occupancy time if they were improved—hence, the candidates for further research.

CHAPTER TWO

FINDINGS

TECHNIQUES IDENTIFIED

Although major occupancy time reductions were not achieved directly by the use of new and innovative materials and equipment, effective techniques were identified in this study for the efficient accomplishment of each required task.

Based on information developed in the study, Table 1 gives the present status of the maintenance techniques identified during the study.

The table classifies the present availability of equipment and material into three categories: (1) experimental, (2) local fabrication, and (3) commercially available. It indicates the applicability of the technique for present use based on how widely the technique has been tested and the availability of either the equipment or the materials needed to perform the technique. The categories are "experimental," "limited," and "immediately applicable."

The techniques listed as "experimental" in Column 5 of the table appear to have merit but will require additional development beyond the scope of this project. These techniques have been so categorized because either the required equipment is still experimental and has not been proved or the application or adaptation of commercial equipment to the technique has not been proved or is unsatisfactory.

The techniques listed as "immediately applicable" in Column 7 have been employed successfully in actual field operations by one or more maintenance agencies. The equipment and material necessary to use the techniques are either commercially available or can be fabricated easily in local shops or yards.

Innovative techniques showing promise for reducing occupancy time about which information was obtained in this study are listed by tasks, as follows:

Task 1. Set up and remove work zone materials and controls.

(a) A "diminishing zone" arrangement has been used for an operation like joint sealing. The work zone is set up in one lane at a size to permit several hours of work. The work then progresses against the flow of traffic, within the work zone, and the "downstream" end of the zone is removed by the work crew as it progresses "upstream."

(b) Special pickup or panel trucks have been outfitted with sign racks, cone chutes, and platforms to permit quick set-up and removal of work zones with minimum manual work (Fig. 7).

(c) A series of trailer-mounted signs have been towed in a train behind a towing truck and disengaged to provide stationary signs at appropriate points along the work zone approach (Fig. 8).

Task 2. Identify, locate, detect or delineate areas of deteriorated material to be removed.

(a) An instrument measures the electrical potential that exists between corroding steel reinforcing bars in the presence of chlorides and surrounding concrete. Since the presence of chlorides sets up a local galvanic cell, by attaching one lead of a circuit through a voltmeter to the reinforcing steel and the other lead to a saturated copper sulfate half cell set down elsewhere on the deck, the potential at that point can be measured. A high potential reading indicates areas of damaged or vulnerable concrete.

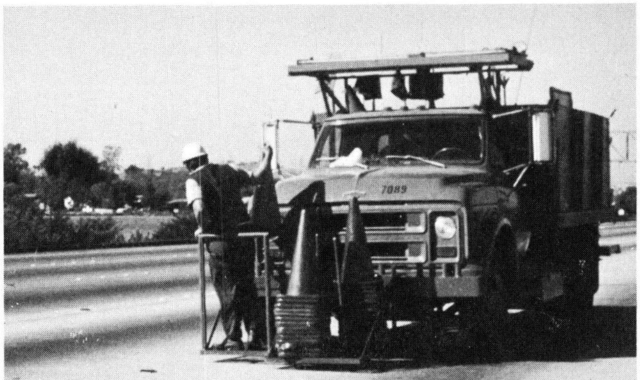


Figure 7. Truck-mounted safety platform used in manual placement of traffic control cones.

TABLE 1

SUMMARY OF IDENTIFIED MAINTENANCE TECHNIQUES

1	Equipment and Material Availability			Current Applicability		
	2	3	4	5	6	7
Technique	Experi-mental	Local Fabri-cation	Commer-cially Avail-able	Experi-mental	Limited	Immedi-ately Appli-cable
Task 1. SET UP AND REMOVE WORK ZONE MATERIALS AND CONTROLS.						
a. Diminishing zone						X
b. Automated zoning			X			X
c. Motorized signs			X			X
Task 2. IDENTIFY, LOCATE DETECT OR DELINEATE AREAS OF DETERIORATED MATERIAL TO BE REMOVED.						
a. Electrical potential			X	X		
b. Acoustic reflection	X			X		
c. Infrared photography			X	X		
d. Concrete sounding		X				X
Task 3. CUT, GRIND, MILL, PLANE OR BREAK OLD DECK OR PAVEMENT MATERIALS.						
a. Rocket Burner			X		X	
b. Conical bit			X			X
c. Mechanical grinding			X			X
d. Concrete saws			X			X
e. Rams and hammers			X			X
f. Klarcrete cutter			X		X	X
g. Coring saw			X		X	
h. Vermeer cutter			X		X	
i. Heater-planer			X			X
j Disc cutter		X				X
k. Toothed cutting edges			X			X
Task 4 REMOVE OLD DECK, PAVEMENT OR BASE MATERIAL						
a. Saw and lift			X			X
b. Vacuum suction			X		X	
c. Mechanized removal			X			X
Task 5. CLEAN, DRY OR PREPARE PATCH AREA OR SURFACE AREA						
a. Rocket Burner			X		X	
b. Heating torch			X			X
c. Water jets			X	X		
d. Airjets			X			X
e. Vacuum suction units			X	X		
f Sand blasting			X		X	
g. Acid etching			X			X
Task 6. PREPARE OR PLACE FORMS SCREEDS OR OTHER MATERIAL CONTROLING DEVICES						
a. Pull in place forms		X				X
b. Leave in place forms		X				X
c. Elevating platform			X			X
Task 7. APPLY TACK COAT OR BONDING MATERIAL.						
a. Pressure sprayer			X			X
b Brushed on			X			X
Task 8. MIX AND PLACE PATCHING SURFACING OR SEALING MATERIAL						
a. Pre-cast concrete slabs		X			X	
b. Band-aid		X			X	
c Portable batch plants			X			X
d. Repaver			X		X	
e Insulated transport boxes			X			X
f. Spreader boxes		X				X

Table 1 (Cont.)

1	Equipment and Material Availability			Current Applicability		
	2	3	4	5	6	7
Technique	Experi-mental	Local Fabri-cation	Commer-cially Avail-able	Experi-mental	Limited	Immedi-ately Appli-cable
Task 9. COMPACT, VIBRATE, SCREED, ROLL OR FINISH PATCHING OR SURFACING MATERIAL.						
a. Vibratory compactor			X			X
b. Portable rollers			X			X
c Drag boxes		X				X
Task 10. APPLY CURING OR BLOTTING MATERIAL.						
a. Paper roller		X				X
b. Sprayed curing compounds			X			X
c. Sprayed sand			X		X	
d. Other agents			X			X
Task 11. CONSTRUCT TEMPORARY TRAVEL SURFACE OVER REPAIRED AREA.						
a Steel plates		X	X			X
Task 12. CLEAN OUT JOINT OR CRACK.						
a. Rocket Burner			X		X	
b. Plow bit			X			X
c. Rotary drill			X			X
d. Disc cutter		X				X
e. Tennant router			X			X
f. High-pressure jets	X			X		
g. Vermeer cutter			X	X		
Task 13. FILL JOINT OR CRACK.						
a. Poured-in-place			X			X
b. Extruded neoprene			X			X
c. Pressure applied			X			X
d. Foamed in place			X			X
e. Pre-formed fillers			X			X
Task 14. LOCATE, LAYOUT, DRILL OR PREPARE MUDJACK HOLES.						
a. Template		X		X		
b. Multiple head drills			X			X
c. Ultrasonic drills	X			X		
d. Horizontal drilling		X			X	
e. Hand-held drills			X			X
Task 15. PREPARE SLURRY AND PERFORM MUDJACKING.						
a. Concrete mixers			X			X
b. Combination mixer & jack			X			X
c. Horizontal jacking		X			X	
Task 16. APPLY LIQUID COATING TO SURFACES.						
a. Pressure spray bar			X			X
b. Slurry boxes			X			X
c. Hand spray nozzles			X			X
Task 17. SPREAD AGGREGATE ON SURFACE.						
a. Tailgate spreaders			X			X
b. Wheel-mounted spreaders			X			X
c. Self-propelled spreaders			X			X
d. Pressure spray			X		X	
Task 18. MISCELLANEOUS TASKS.						
a. Wooden plugs for mudjack holes		X				X
b. Bridge membranes			X			X

Figure 8. Sign train used to expedite placing traffic controls.

(b) An electronic device has been used to detect horizontal cracking or delamination in concrete bridge decks. The device is a mobile cart with two rolling acoustic receivers spaced 12 in. apart, two tapping wheels 6 in. apart, and a 2-pen recorder by which variations from a straight line are scribed on a roll tape to indicate delamination.

(c) Infrared photography reveals differences in temperature between solid and delaminated areas of concrete bridge decks and may prove useful in locating defective sections of concrete.

Task 3. Cut, grind, mill, plane or break old deck or pavement materials.

(a) A high-velocity air stream from a propane burner is used to loosen and remove old bituminous material and underlying disintegrated concrete on composite pavements.

(b) The percussive cutter shown in Figure 9 is used to mill away concrete to create a predimensioned opening for partial-depth repairs (Fig. 10).

(c) A cylindrical saw, similar to a coring saw but of large diameter (24 in.), is used to make full-depth, one-piece circular cuts in concrete pavements (Fig. 11).

(d) A large (7-ft diameter) power-driven wheel, fixed with carbide-tipped cutting teeth along its rim, is used as a massive concrete saw to cut full-depth, 3½-in. wide through concrete pavements (Fig. 12).

(e) A disc cutter, mounted on a motor-grader blade has been used to make longitudinal cuts in bituminous pavements.

Task 4. Remove old deck, pavement, or base materials.

(a) After saw-cutting into rectangles or circles, and breaking loose, sections of concrete can be removed intact by inserting expansion bolts in drilled holes or using pneumatic suction pads and lifting sections with crane or front-end loader arm.

(b) A vacuum suction unit has been used to remove and collect material where it has been broken, crushed, or ground.

Task 5. Clean, dry, or prepare patch area or surface area.

(a) A high-velocity air stream from a rocket burner is used to remove loose material and moisture.

(b) Water jets have been used to clean dust and loose material from a patch area while concurrently wetting the area for concrete patching.

(c) Vacuum suction units have been used to clean an area of dust and loose material.

(d) Sand blasting has been used to clean away dirt, oils, and imbedded surface materials from a patch area.

(e) Acid etching has been used to clean and roughen concrete surfaces before placing patching materials.

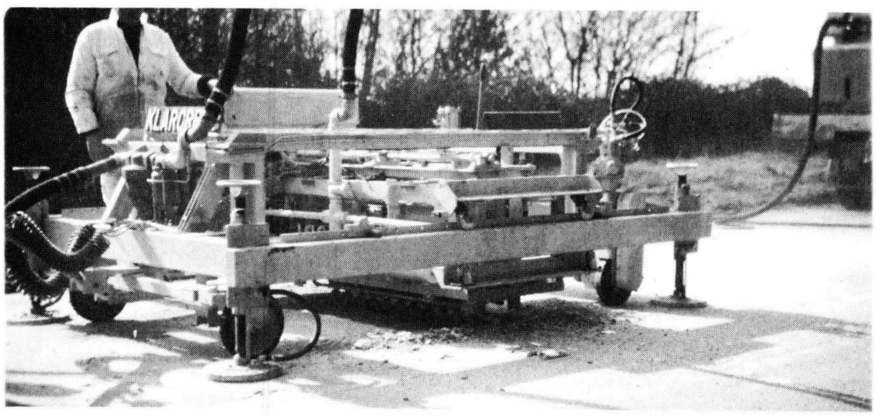


Figure 9. Percussive cutter used to make a partial-depth cut in concrete pavement.

Figure 10. Two-inch-thick precast slabs used as a partial-depth concrete patch.

Task 6. Prepare or place forms, screeds, or other material-controlling devices.

(a) For full-depth repairs to concrete bridge decks, a bottom form has been installed by pulling it into place with rope or wire dropped through the deck opening. When the form is in place it can be tied or welded to re-bars for permanent positioning during and after patch pour.

(b) Double-elbow elevating platforms have been used to provide quick access for forming under bridge decks.

Task 7. Apply tack coat or bonding material.

No innovative techniques were identified for this relatively simple task.

Task 8. Mix and place patching, surfacing, or sealing material.

(a) Precast concrete slabs have been used to replace full-depth or partial-depth sections of concrete pavement (Fig. 13).

(b) "Band-aid" prefabricated bituminous surface patches have been made by applying a surface treatment of bitumen and stone chips to sections of paper which then can be stored by rolling or stacking. Used with a tack coat to cover minor surface defects in a bituminous pavement, the patches have been applied face down (with the paper back up), where it quickly disintegrates under traffic and weather.

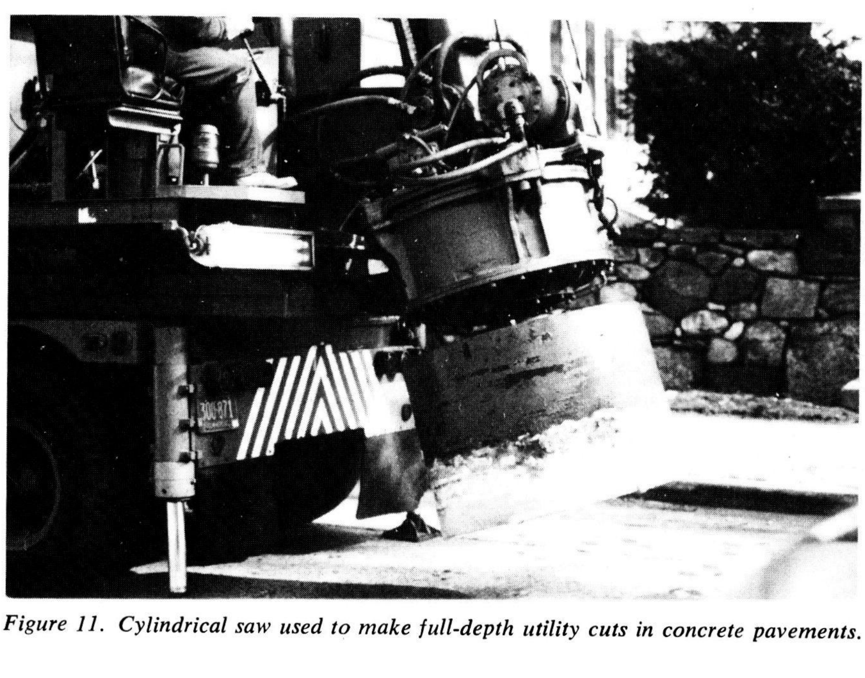


Figure 11. Cylindrical saw used to make full-depth utility cuts in concrete pavements.

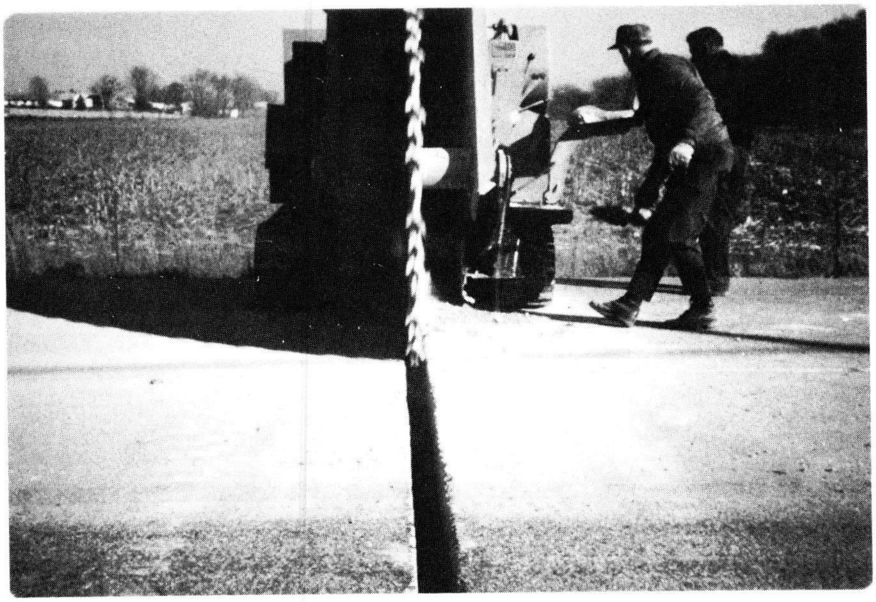


Figure 12. Wheel cutter used to cut an expansion joint in concrete pavement.

(c) Compartmented, truck-mounted concrete batch plants have been used to permit on-site mixing of concrete in various batch sizes as required (Fig. 14).

(d) Special commercial equipment units have been used to heat, soften, remove bituminous material, re-mix and re-lay as a base for resurfacing.

(e) Truck- or trailer-mounted insulated transport boxes have been used to transport new hot-mix material for patches and repairs.

Task 9. Compact, vibrate, screed, roll or finish patching or surfacing material.

(a) A vibratory-plate compactor for small bituminous patches has been carried on a tilting platform suspended beneath the dump truck bed for easy, rapid use and transport.

(b) Tailgate-transported rollers, heated or unheated, have been carried on dump trucks and unloaded by elevation of the dump bed.

(c) Drag boxes have been fabricated to apply and screed wedge courses of bituminous concrete or aggregate mixes on shoulders.

Task 10. Apply curing or blotting material.

(a) For blotting joint sealants to prevent tire pick-up, an absorbent paper roll on a spindle attached to a long

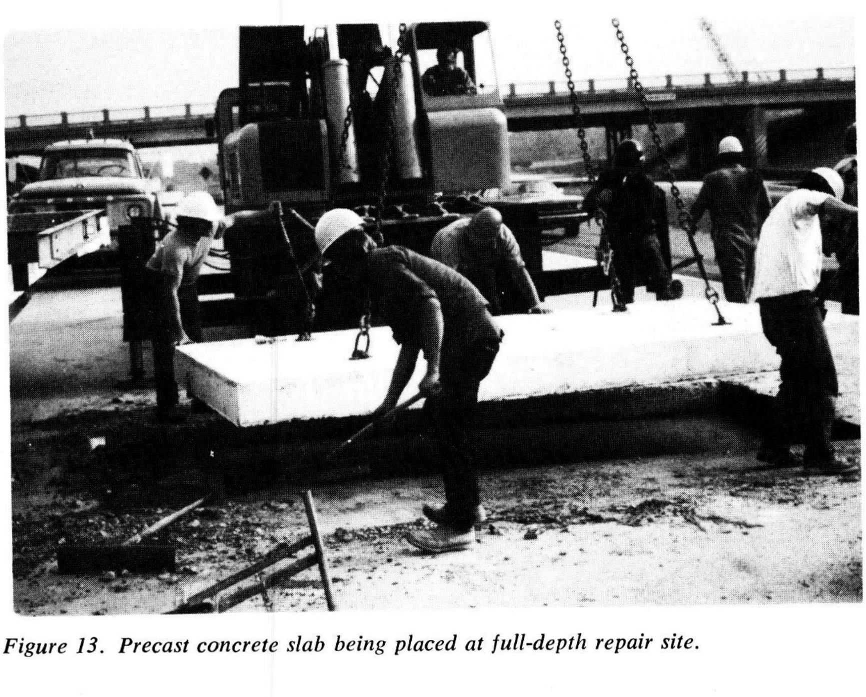


Figure 13. Precast concrete slab being placed at full-depth repair site.

Figure 14. Custom-sized concrete batches being supplied by special concrete mixing truck.

handle has been impressed in sealant surface quickly and conveniently by a crew member.

Task 11. Construct temporary travel surface over repaired area.

(a) One-inch-thick steel plates have been used to bridge concrete pavement repair sites while concrete patches are curing (Fig. 15).

Task 12. Clean out joint or crack.

(a) A high-velocity air jet from a propane burner (rocket burner) has been used to rout out bituminous concrete cracks and form a reservoir for new sealant.

(b) A plow bit or tooth mounted on a small garden-type tractor has been used to rout out old joint sealants and debris in concrete pavement joints before resealing.

(c) A power-driven rotary cone-shaped drill mounted on a small wheel carriage has been used to cut a V-groove in a concrete pavement crack to form a reservoir for sealant.

(d) A free-rolling disc, mounted on a motor-grader blade, has been used to cut a V-groove at the edge joint between concrete pavement and bituminous shoulder to form a reservoir for sealant.

(e) A large (7-ft diameter) wheel, power driven, fixed with carbide-tipped cutting teeth along its rim, has been used to saw out old fillers and sealants in wide expansion joints where no load transfer dowels were present.

Task 13. Fill joint or crack.

(a) Poured-in-place joint and crack sealants have been applied using various wheel-mounted pouring pots, some with shoes for pressure screeding of poured material.

(b) Extruded neoprene strips have been impressed into joint openings to seal precisely formed pavement joints.

(c) Reactant two-component polymers have been mixed and poured into expansion joint openings where they foam and expand to fill the void before setting up.

Task 14. Locate, layout, drill, or prepare mudjack holes.

(a) Template and paint spray cans have been used to spot hole-drilling sites on pavement surface according to pre-set standard patterns.

(b) Tractor-mounted multiple-head drills set at a standard spacing have been used to drill holes concurrently.

(c) High-frequency sonic drills for fast cutting are in the development stage.

(d) Pneumatic-hammer-driven pipes have been inserted

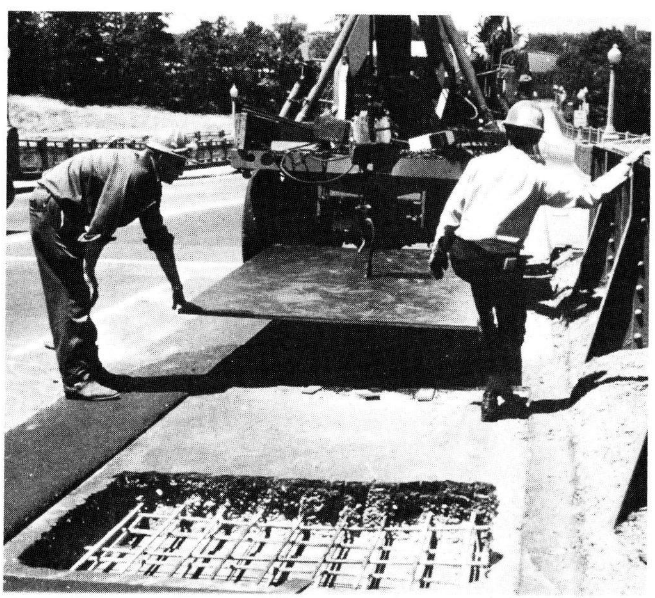


Figure 15. Steel plate used to bridge repair area so that roadway could be opened to traffic while awaiting completion of maintenance operation.

horizontally from trenches cut in the shoulder for mudjacking without holes through the slab (Fig. 16).

Task 15. Prepare slurry and perform mudjacking.

(a) Power-driven concrete mixers have been used to mix slurry pumped by one mudjack machine to a second mudjack machine for pressure pumping under pavements.

(b) Combination mixer and pump mudjack machines have been used to prepare and pump slurry under slab.

(c) Mudjack hose has been connected to a horizontally driven pipe for pumping slurry from side position off the pavement.

Task 16. Apply liquid coating to surfaces.

Small tractor-mounted slurry boxes have been used to spread emulsions and slurry seals on surface areas.

Task 17. Spread aggregate on surface.

(a) Self-propelled distributor-spreader units that permit dump trucks to discharge aggregate into hopper at front of unit while traveling forward have been used to apply aggregate cover without requiring truck to turn around and back up to spreader.

Information about some of the foregoing techniques is incomplete because of the developmental stage of the equipment or materials involved. Description sheets are included in Appendix E for the techniques where information on requirements, productivity, and costs were determined by observations of the research team.

Several planning and management tools, developed in the study, offer significant potential for reducing roadway occupancy time.

OCCUPANCY TIME DISTRIBUTION

For this study, roadway occupancy time was divided into four categories: traffic control time, delay time, work time, and cure time, as defined in Chapter One. Variations in distribution of occupancy times for a sampling of sites where good practices were observed are shown in Figures 17, 18, and 19 for bridge deck repairs, pavement repairs, mudjacking, and joint sealing.

Traffic Control Time

Traffic control time was observed to be the least variable of all the occupancy time categories. The observed time needed to set up the work zone averaged about 15 min, both for spot locations and for extended zones where a continuing activity like joint and crack sealing was performed. Likewise, zone removal required about 15 min. For moving operations and in large zones, the removal of traffic control devices began prior to completion of the last task in the work activity. With minor exceptions, maintenance crews performed this task quickly and efficiently, apparently because procedures were standard and a sense of urgency prevailed to create a zone out of the traffic stream as quickly as possible.

Delay Time

The elimination of delay time would have resulted in major reductions in occupancy times observed during the study. Delays accounted for up to 90 percent of occupancy time in some activities.

Major delays during occupancy time were occasioned by lunch periods, late equipment and material arrivals, and mechanical failure of equipment at the work site. There were also instances where poor quality control of materials extended occupancy times.

A major, frequent cause for delay was the lack of effective scheduling of resources. Haul trucks often were not available when needed. Materials shortages were common, and often equipment was not suited to the work site.

Where work was not completed within a normal work day, the road usually remained closed to traffic until work was finished the following day. This created a major delay period as defined in the study. Some agencies eliminated this type of delay by using a large steel plate to bridge the repair area and open the travelway between work periods.

Cure Time

Where it was necessary to provide for material curing time during roadway occupancy, it frequently represented a major percentage of total occupancy time. Of the three occupancy time categories other than delay, cure time offered the greatest opportunity for reduction. Figure 20 shows the distribution of occupancy time for a cast-in-place concrete repair. The distribution chart represents an average of several observed occupancy times where curing time was held to a minimum for the materials used.

Work Time

Work time was analyzed to determine the man-hours that were being invested in productive work. Figure 21 shows four representative activities where productive man-hours amounted to 48, 31, 55, and 34 percent of the total man-hours invested in the work. The average values for the four activities are shown in Figure 22, where productive man-hours represent 42 percent of the total.

Figure 16. Horizontally driven pipe used to pump slurry under pavement slab in mudjacking operation.

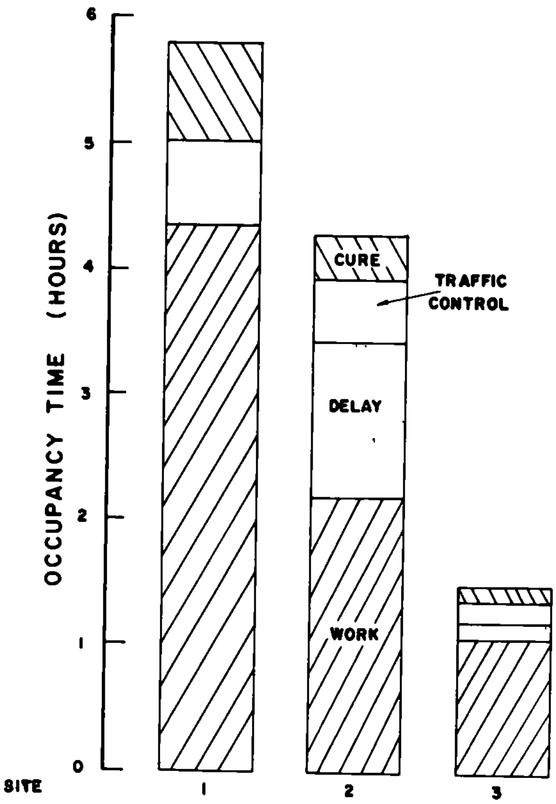


Figure 17. Observed distribution of roadway occupancy time for bridge deck repairs at three sites

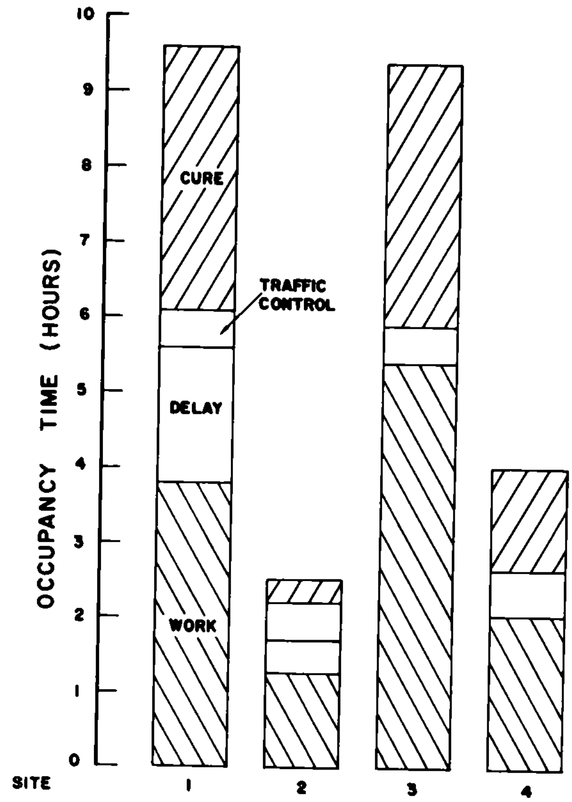


Figure 18 Observed distribution of roadway occupancy time for pavement repairs at four sites

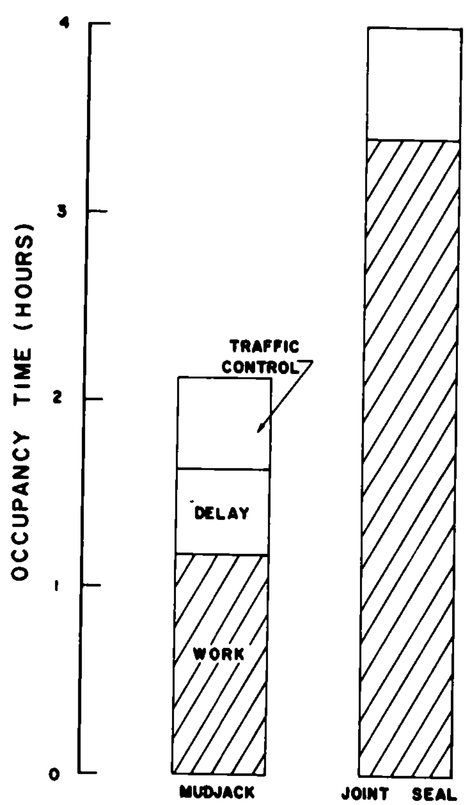


Figure 19 Observed distribution of roadway occupancy time for a mudjacking site and a joint-sealing operation site

Figure 22 shows that 58 percent of the man-hours were nonproductive. These nonproductive man-hours were divided into avoidable and unavoidable nonproductive man-hours. For this study, avoidable nonproductive man-hours were defined as time when men could have worked (i.e., when work was available to be done) but did not work. This was evaluated by plotting crew balance charts and

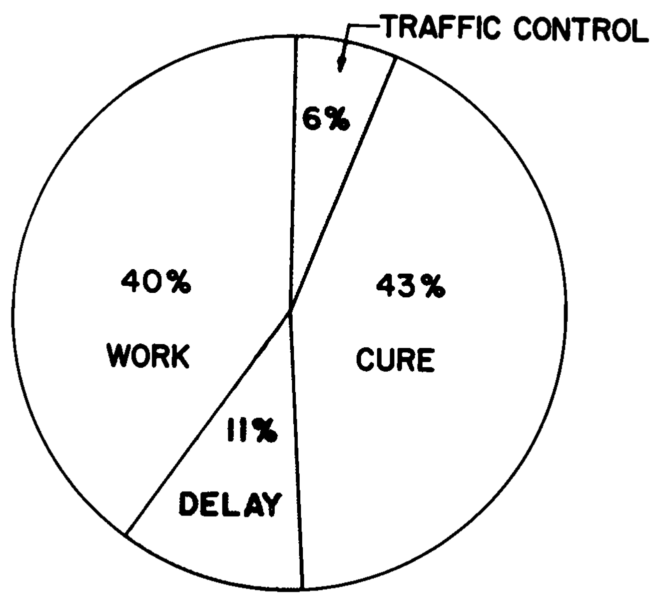


Figure 20 Average distribution of observed roadway occupancy time for concrete, cast-in-place, full-depth repairs.

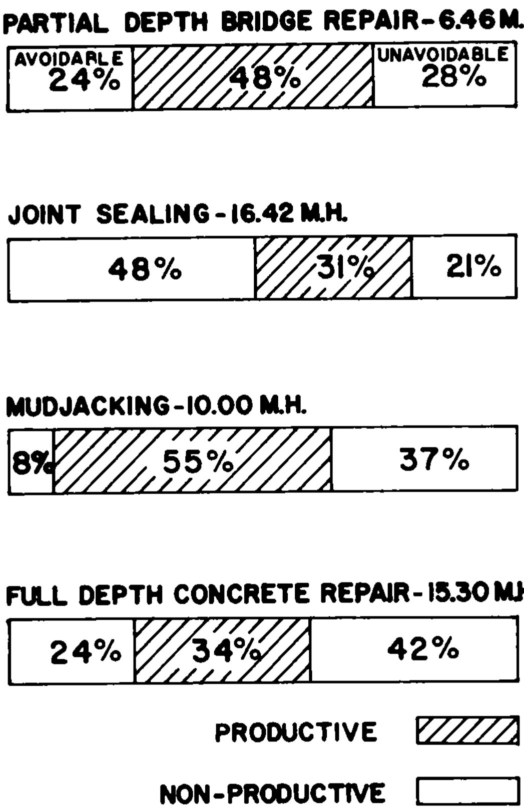


Figure 21 Distribution of man-hours of observed work time

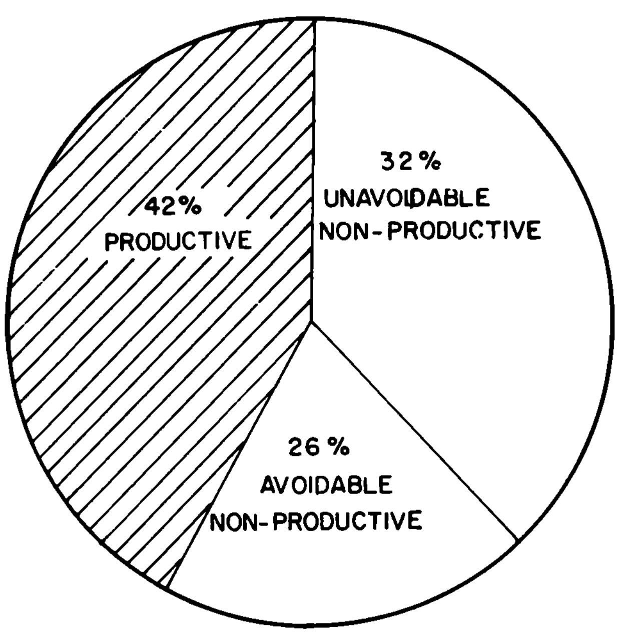


Figure 22 Average distribution of work time man-hours for activities shown in Figure 21.

establishing that work was available for the nonproductive crew members These avoidable nonproductive man-hours represented 26 percent of the total man-hours in the work time period as shown in Figure 22. Thus, the man-hours that could have been productive were (42 + 26) 68 percent of the total.

The observed productive man-hours also can be expressed in terms of efficiency Because 42 percent of the achievable 68 percent productive man-hours was realized in the observed activity, the efficiency of the crew can be computed as $\frac{42}{68} \times 100 = 62$ percent

CURRENT AND ACCUMULATIVE OCCUPANCY TIMES

Roadway occupancy time can be measured under two considerations In the first, the maintenance manager is confronted with the need to make an immediate local repair which requires that a maintenance crew occupy the roadway at a specific repair site In this situation, the manager's objective should be to minimize the single occupancy period at that worksite

The second consideration involves prescheduled maintenance work programs requiring repeated roadway occupancy over a large area and over a long period of time. In these situations, the manager may have the option of scheduling a longer continuous occupancy period so that the accumulative occupancy time for the program is less than that required by a series of short occupancy times

Figure 23 shows the savings in total occupancy time that can be realized for three representative full-depth, cast-in-place concrete repairs Performing the work on each single site separately requires an occupancy period of 5½ hr, or a total of 16½ hr for the three sites Assuming that a single traffic zone could cover all three sites, work could be performed sequentially on the three sites with the same crew. This single occupancy period would require 7 hr, a savings of 9½ hr over the three separate, short, occupancy periods.

Obviously, selection of occupancy time is controlled by traffic volumes in many instances. Although the longer single occupancy time may be the lowest alternative, the resulting encroachment on peak-hour traffic periods may represent a greater cost in terms of traffic service losses than three short-time occupancy periods scheduled on separate days in off-peak periods.

STANDARD TIME DATA

For selected maintenance techniques data were developed that can be used to predict the length of time required to perform a given amount of work using each technique. (See Appendices F and G.*)

It was recognized that the techniques observed in the study would be performed under a variety of conditions and, therefore, standard times developed for the maintenance techniques would be representative of average situations Where observations were too limited to permit an

* Appendix G, which includes detailed information on the standard time data shown in Appendix F, is not published herein, but is listed here for the convenience of qualified researchers in the subject area, who may obtain loan copies by written request to the Program Director, NCHRP, Transportation Research Board

average time to be developed, standard times were developed that are applicable to work performed under conditions similar to those observed

In developing the standard times, a number of relationships between time, work quantity, and crew size were examined. Work was expressed in a variety of accomplishment units, including volume, area, depth, length, site, and occurrence. Statistical and curve-fitting analyses were made for the various relationships and the best, in a statistical sense, selected and put into a standard time format

The majority of the standard times established during the study were for techniques that are routinely used by most highway maintenance agencies Although not complete, the standard time values developed represent an important step toward a data file on maintenance techniques useful for a variety of management and planning applications

Standard Times

Standard time models developed for several routine maintenance tasks are discussed in the following paragraphs Values are based on 100 percent efficiency In computing occupancy times, values must be modified by factors to reflect typical efficiency rates for the tasks.

Concrete, Sawing

Standard time models were developed for both carbide and diamond saw blades used for cutting concrete In both models, time is a function of the face area of the cut, which is computed by multiplying the cut depth times the length of the cut. Thus,

$$T_{diamond} = 2.0 + 1.33A$$
$$T_{carbide} = 1.5 + 4.96A$$

where T is standard time (min) and A is area (sq ft). Based on the models, a 12-ft by 1-in. concrete cut would require about 6½ min using a carbide blade and 3½ min using a diamond blade Both models are shown in Figure 24

Pavement, Concrete, Breaking, Partial-Depth with Air Hammer

A number of observations were made of air hammers being used to break concrete. Most observations covered partial-depth repairs The standard time varied with the volume of concrete broken and with the hammer size. From the observations and data collected during the study, it was possible to develop models for partial-depth concrete breaking. Thus,

$$T_{60} = 3.5 + 7.19V$$
$$T_{30} = 4.5 + 30.65V$$

where V is volume of concrete broken out (cu ft). Using a 60-lb hammer for a 3-in deep, 8-sq-ft patch area, the standard time would be about 18 min. Using a 30-lb hammer, the same operation and patch size would require about 66 min. A plot of each model is shown in Figure 25.

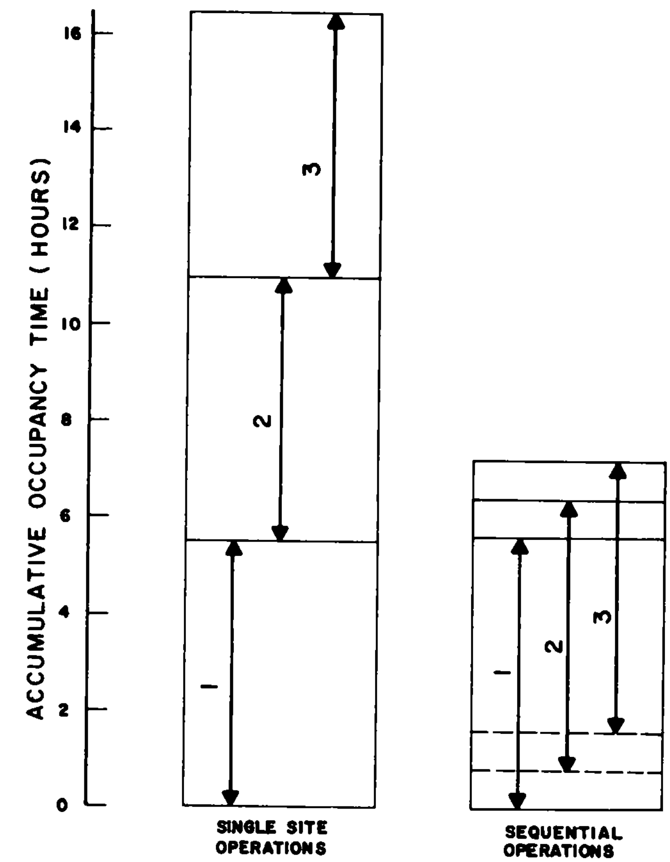


Figure 23. Comparison of the occupancy time requirements for three single-site repairs with the reduced time requirements when a sequential repair operation is performed on the three sites concurrently by the same crew

Pavement, Concrete, Breaking, Full-Depth

For full-depth, cast-in-place concrete repair operations, the hydraulic ram proved to be an effective and quick technique for breaking out full-depth concrete Performed by one man, this task could start as soon as traffic control was established

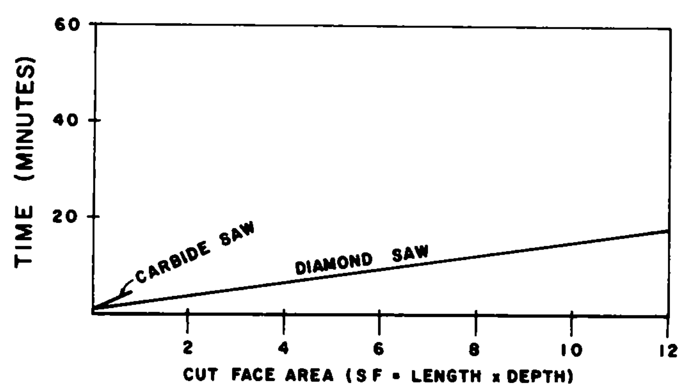


Figure 24 Concrete sawing

Also observed in a full-depth concrete breaking operation was a crane-supported drop hammer. Although more productive than the hydraulic ram, it also was less accurate Where a repair area was not defined by a full-depth saw cut, air hammers were required to break concrete in the perimeter area of the repair.

Models for each technique were developed Thus,

$$T_{\text{hydraulic ram}} = 2.5 + 0.07A$$
$$T_{\text{drop hammer}} = 3.5 + 0.05A$$

where A is repair area (sq ft) The time required to break a 12-ft by 12-ft repair area of 9-in. concrete pavement is approximately 12 min. Figure 26 shows a plot of both models

Pavement, Concrete, Cut, Full-Depth with Wheel Cutter

The wheel cutter offers a technique for cutting expansion joints or relief joints in concrete pavements in a single pass The equipment is self-propelled within the work site areas. The standard time is a function of linear feet cut Thus,

$$T_{\text{concrete}} = 3.5 + 0.33L$$

where L is length of cut (ft). Thus, a full-depth concrete cut 3½ in. wide and 12 ft long can be made in approximately 7½ min. Figure 27 shows the time curve for cutting concrete pavement

Pavement, Concrete, Breaking and Removal, Partial-Depth with a Percussive Cutter

The percussive cutter chips away concrete, thus combining the cutting and material removal operation. This equipment is capable of cutting up to a 4-sq-ft area, 4 in deep when 11 percussive cutting heads are operating. The standard time for the equipment is a function of the volume of the cut and the number of percussive heads Thus,

$$T = 3.5 + 211(V/PH)$$

where V is concrete volume (cu ft) and PH is percussive heads (number). Thus, the equipment will cut a 16-sq-ft area, 2 in deep, in approximately 50 min A plot of the model with 11 percussive heads operating is shown in Figure 28

Pavement, Concrete, Removal, Partial-Depth

For a man using a shovel to remove concrete after it has been broken by an air hammer, a model was developed Thus,

$$T = 1.0 + 6.33V$$

where V is volume (cu ft). Observed partial-depth patches ranged from ½ in to 4 in deep and from 2 to 20 sq ft in area For a volume of 2 cu ft, the required removal time is approximately 14 min The time-volume relationship is shown in Figure 29

Pavement, Concrete, Removal, Full-Depth

For a front-end loader or hydraulic hoe removing full-depth broken concrete, a model was developed·

$$T = 2.5 + 0.11V$$

where V is volume of broken concrete (cu ft). As an example, approximately 13½ min would be required to remove 100 cu ft of broken concrete from a full-depth repair site. The model is shown in Figure 30.

Base Material, Compacting, Mechanical

A gasoline-powered hand tamper was used to compact pavement base material at observed full-depth repair sites. The standard time was found to be a function of the repair area Thus,

$$T = 2.0 + 0.04A$$

where A is patch area (sq ft) For a 12-ft by 14-ft patch, the model predicts 9 min would be required to complete the compaction task. A graphic representation of the model is shown in Figure 31

Pavement, Concrete, Prepare Base, Full-Depth, Manual

Following the mechanical removal of broken concrete in a full-depth pavement repair, it was necessary to finish the preparation of the repair site manually with hand shovels Two different standard time models were developed, one following a front-end loader operation and the second following a backhoe. In both models time is a function of the repair area and the number of men working within the patch area with shovels Thus,

$$T_{\text{front-end loader}} = 22.0 + 0.037(A/C)$$
$$T_{\text{backhoe}} = 14.0 + 0.037(A/C)$$

where A is patch area (sq ft) and C is crew size (men). For a 300-sq-ft area and a three-man crew, it would take 26 min to finish preparation following a front-end loader and 18 min following a backhoe

Figure 32 shows the model for a range of crew sizes following a front-end loader. The same range is shown in Figure 33 for the model based on following a backhoe

Pavement, Concrete, Edge Forming, Full-Depth

Frequently, it is necessary to construct a form for an open side of a concrete pavement repair site prior to placing new concrete The observed time required to perform this operation was found to be a function of the length of the form required and the crew size The task was limited to the installation of the form Cutting or prefabrication requirements were accomplished prior to occupying the work site and were not a part of the task Thus,

$$T = 1.5 + 1.64(L/C)$$

where L is length of forming (ft) and C is crew size (men) A two-man crew forming a 24-ft-long concrete pavement edge would require about 18 min This relationship is shown in Figure 34

Concrete, Place, Partial-Depth

This technique involved placing ready-mix concrete in prepared partial-depth patch sites The operation included

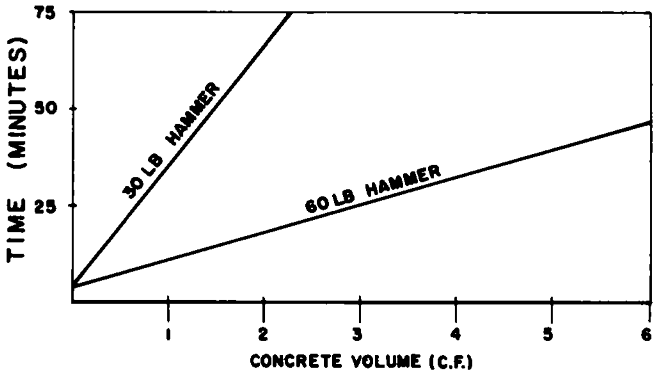


Figure 25 Partial-depth breaking of concrete with air hammers

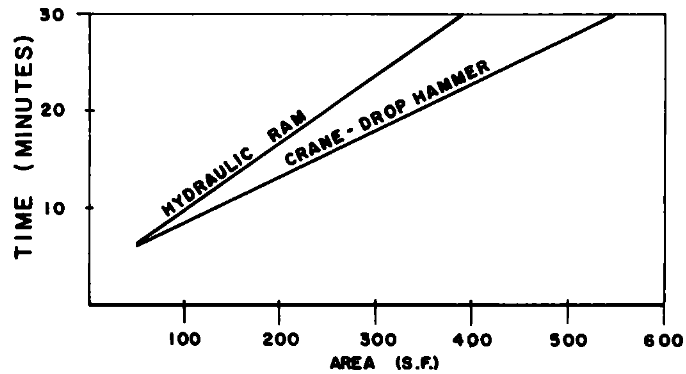


Figure 26 Break concrete full-depth

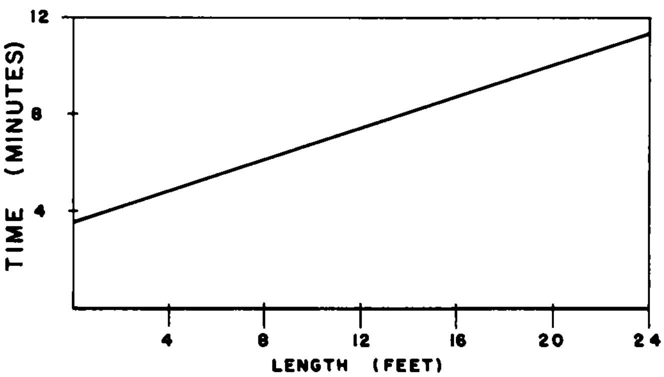


Figure 27 Concrete pavement cut, full-depth with wheel cutter

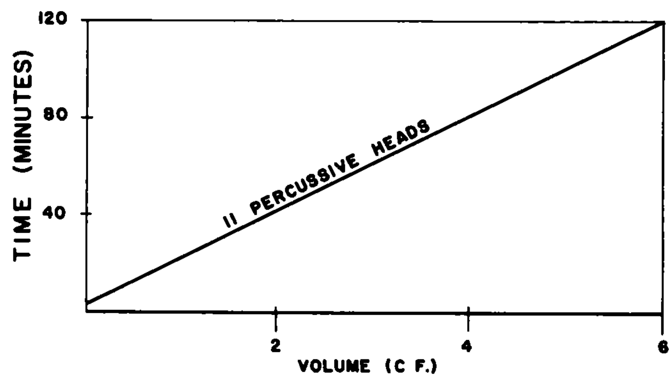


Figure 28 Break and remove concrete for a partial-depth concrete repair with a percussive cutter

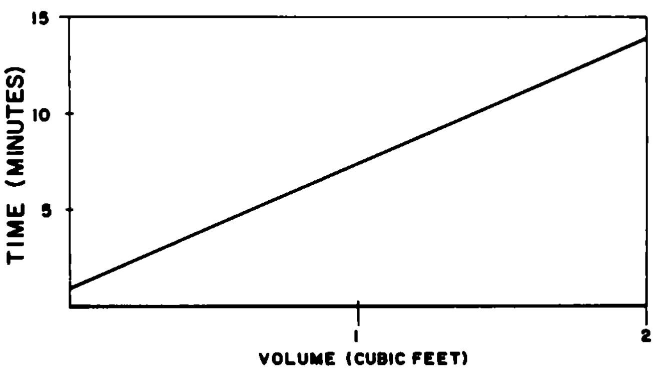


Figure 29 Remove broken concrete in a partial-depth repair site with a hand shovel

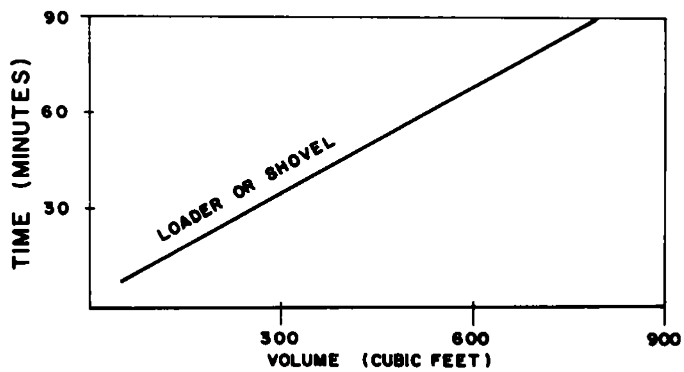


Figure 30 Remove full-depth broken concrete pavement with a front end loader or a hydraulic hoe

discharging mixed concrete into the patch site and compacting by one man using a vibrator. The standard time is a function of the volume placed in a 1- to 4-in.-deep patch site. Thus,

$$T = 0.5 + 0.56(V/C)$$

where C is crew size (men) and V is volume (cu ft). Based on the model, about 7 min would be required for one man to place 12 cu ft of concrete. Figure 35 shows a plot of the model for the range observed.

Concrete, Place, Full-Depth

Standard time for full-depth placement of ready-mix concrete, including the initial strike-off, was based on the continuous discharge of concrete from a ready-mix truck. The model is a function of the volume placed and the size of the placement crew. Thus,

$$T = 2.5 + 0.20(V/C)$$

where V is volume of concrete (cu ft) and C is crew size

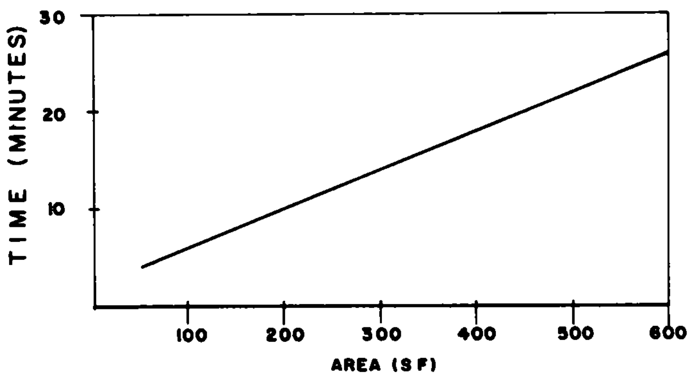


Figure 31 Compact base for a full-depth patch with a mechanical tamper

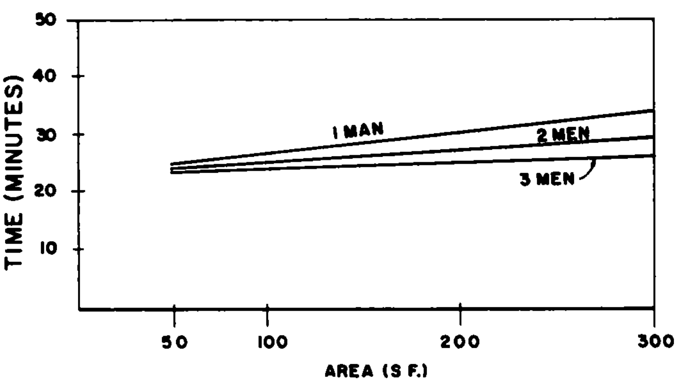


Figure 32 Manual preparation of base at a full-depth concrete patch site following removal of broken concrete with a front-end loader

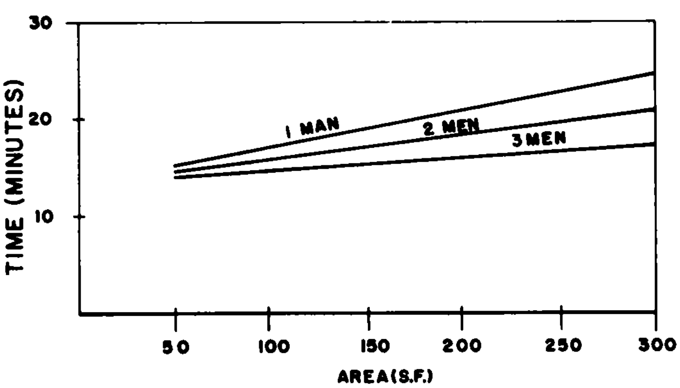


Figure 33 Manual preparation of base at a full-depth concrete patch site following removal of broken concrete with a back hoe

With a four-man crew, 200 cu ft of concrete could be placed in approximately 12 min

This model is shown in Figure 36 for a range of crew sizes.

Pavement, Concrete, Hand Mix and Place, Partial-Depth

A standard time was developed for batching, mixing in wheelbarrows, and shoveling concrete into place in partial-depth patch areas The model was developed by combining requirements for each of the components of the technique Thus,

$$T = 8.00 + 0.97V + 0.27V^2$$

where V is volume placed (cu ft) Batching, mixing, and placing a 2½-cu-ft concrete patch requires about 15 min Figure 37 shows the relationships for a range of small batch sizes.

Concrete, Batch, Mix and Place, Partial-Depth

Standard times also were developed for batching, mixing in mortar mixer, and placing concrete in partial-depth patches Thus,

$$T = 9.0 + 0.97V$$

Batching, mixing, and placing 3 cu ft of concrete requires about 12 min The time can be reduced by about one-third if materials have been pre-portioned (usually bagged in premixed units of 1 cu ft) so that they can be batched directly at the job site. Figure 38 shows both conditions for a range of placements.

Pavement, Concrete, Hand Finish, Small Patch Areas

Standard time data were developed for the use of hand floats, trowels, and brooms to smooth, finish, and texture partial-depth concrete patches The standard time is a function of the area finished and the crew size in the model Thus,

$$T = (2.5 + 0.17A)/C$$

where A is patch area (sq ft) and C is crew size (men). For a 12-sq-ft patch, one man would require approximately 4½ min to finish a new concrete surface Figure 39 shows the model plotted for a range of applicable crew sizes

Pavement, Concrete, Finish and Texture, Large Patch Areas

Standard times were developed for the use of bull floats, hand trowels, and a burlap drag to finish and texture concrete. The model is a function of area and crew size. Thus,

$$T = 16.5 + 0.066(A/C)$$

where A is area finished (sq ft) and C is crew size (men). Two men can finish a 40-sq-ft area in approximately 30 min. Figure 40 shows the model plotted for a range of crew sizes.

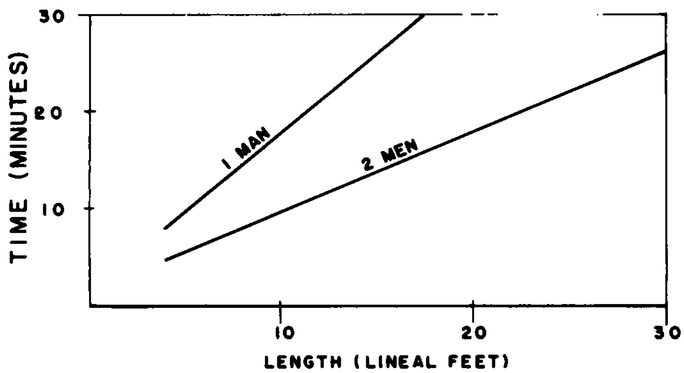


Figure 34 Place concrete forms for a full-depth pavement patch

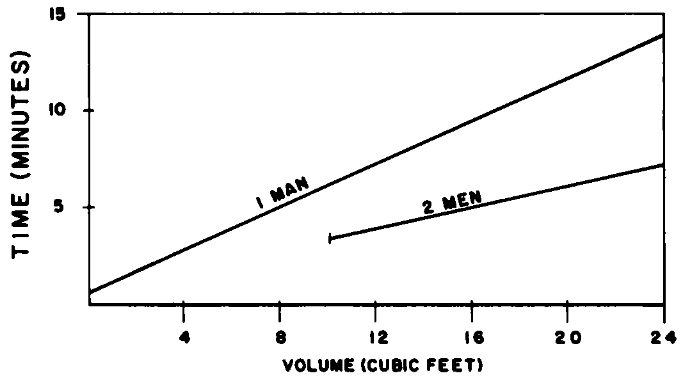


Figure 35 Place ready-mix concrete for partial-depth patch.

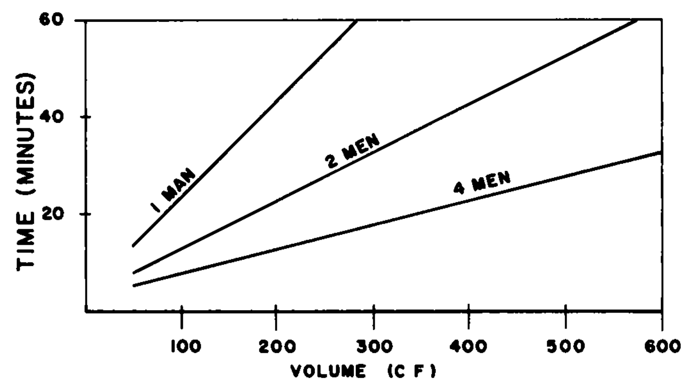


Figure 36 Place concrete from ready-mix truck into a full-depth patch

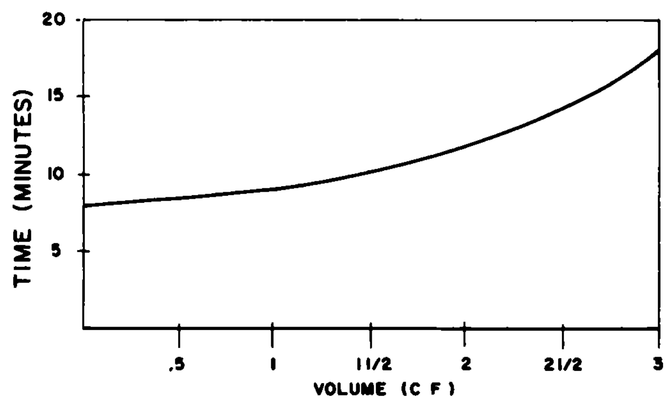


Figure 37 Batch, mix, and place concrete from a wheelbarrow

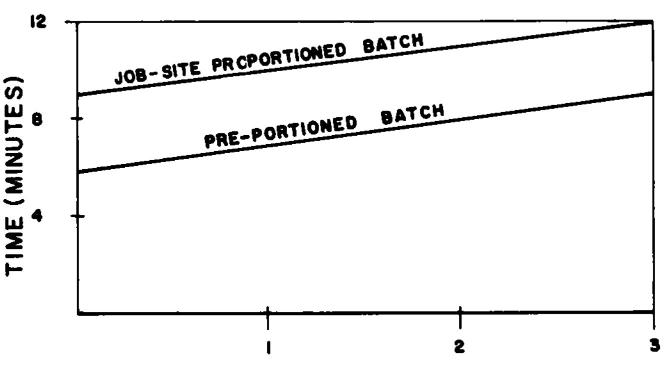


Figure 38 Batch, mix, and place concrete in partial-depth repair site using mortar mixer.

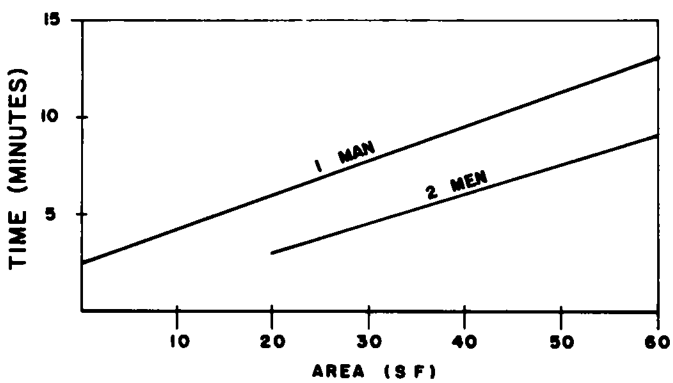


Figure 39 Hand finish and texturize a small concrete patch surface

Concrete, Spray Curing Compound

This technique consisted of one man with a hand spray pressure tank applying a concrete curing compound. The standard time is a function of the concrete surface area as shown in the model (Fig 41). Thus,

$$T = 0.5 + 0.024A$$

where A is concrete surface area (sq ft) A 200-sq-ft concrete patch would require slightly more than 5 min to cover

Concrete, Apply Burlap Curing Cover

This technique consisted of a two-man team placing 12-ft by 2-ft burlap strips in a double-layer thickness over a concrete pavement patch. The standard time is a function of patch area and the number of crew members. Thus,

$$T = 2.5 + 0.036A/C$$

where A is concrete patch area (sq ft) and C is team crew size (men) Four men can cover a 12-ft by 25-ft patch in about 5 min. This relationship is shown in Figure 42 for a range of teams.

Concrete, Clean Joints

Two different cleaning techniques were observed for cleaning concrete construction joints In one procedure, loose joint material was stripped from the joint with a hook This was followed by a mechanical router that removed the remaining material.

In the second procedure, the joint material was removed almost entirely by a pick. A wire brush was then used to clean the edges. In both techniques, the joint was blown clean prior to the application of new sealant. A mean standard time was established for each joint cleaning technique. The following models are designed to reflect the time for two men in a sequential joint cleaning operation.

$$T_{router} = 2.00 + 2.74J + (D/150)(J - 1)$$
$$T_{pick} = 2.5 + 3.70J + (D/150)(J - 1)$$

where T is operation time (min), J is number of 12-ft joints, and D is distance between joints (ft). To clean 100 joints, with a 50-ft joint spacing, will require two men approximately 6 hr using a router and 6¾ hr using a pick. A range of joint spacings is shown in Figure 43 for the router and Figure 44 for the pick.

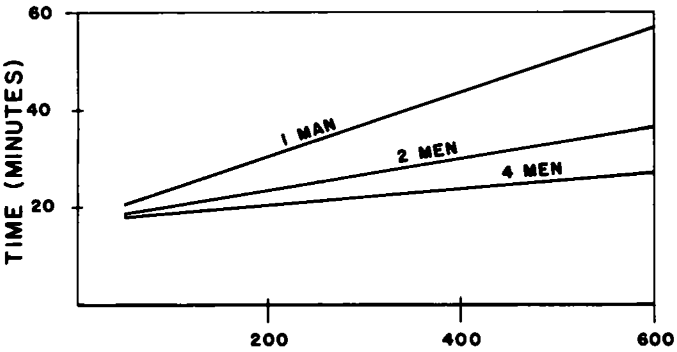


Figure 40. Finish and texturize a large concrete patch surface

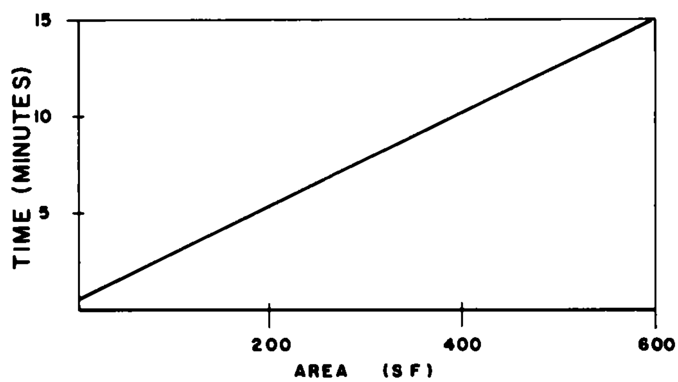


Figure 41 Apply curing compound to concrete with a pressure sprayer

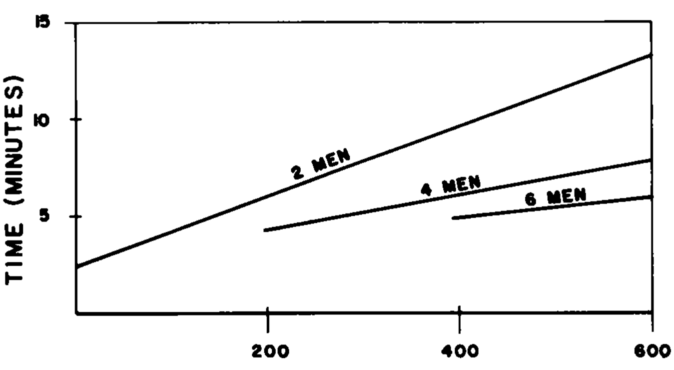


Figure 42. Place burlap curing strips over concrete patch area

Pavement, Concrete, Seal Joint

Two techniques were observed for this task Hand-held cornucopias and pressurized asphalt kettles were used for applying joint sealants A number of variables govern the time required to seal one joint. Among these variables are the length of the joint, the discharge rate of the sealant, the number of times each joint is covered, and the time required for the sealant to seep into the joint between passes The viscosity of the sealant and the width of the joints both affect time between passes The following standard time models reflect the time required for two men to seal joints

$$T_{cornucopia} = 6.5(P - 1) + 0.042(LP)J + (D/150)(J - 1)$$
$$T_{pressurized} = 6.5(P - 1) + 0.024(LP)J + (D/150)(J - 1)$$

where D is distance between joints (ft), L is length of joint (ft), P is number of passes per joint, and J is number of joints When the joint spacing is 50 ft, the moving time is equal to 0 33 min Based on two passes per 12-ft joint, the time required to seal 150 joints is 290 min (4 8 hr) using a cornucopia and 210 min (3 5 hr) using pressurized equipment Figure 45 shows the time in hours as a function of the number of joints at 50-ft spacing for both techniques

Mean Standard Times

Mean standard times were established for a number of other observed tasks and are given in Table 2

TABLE 2

MEAN STANDARD TIMES FOR VARIOUS TASKS

TASK	STANDARD TIME (MIN)
Place preassembled contraction joint assembly	8 6
Batch and mix concrete in a mortar mixer	5.7
Batch and mix epoxy in mortar mixer	13.3
Install 12-in pre-formed expansion filler	9.3
Establish road closure (three men)	15 0
Drill concrete with air hammer	4.8

CONCLUSIONS

Improvements in managing the entire maintenance activity showed the greatest potential for significant reduction of roadway occupancy time by maintenance crews.

Major opportunities for improvements were in the areas of

1. Selection of maintenance techniques best suited to carrying out the activity.
2. Organization of the activity by task with manpower assignments and scheduling preplanned and designated.
3. Job-site supervision and control.
4. Equipment selection, readiness and reliability.

These management procedures are discussed in detail in Chapter Three, "Application and Use of Findings."

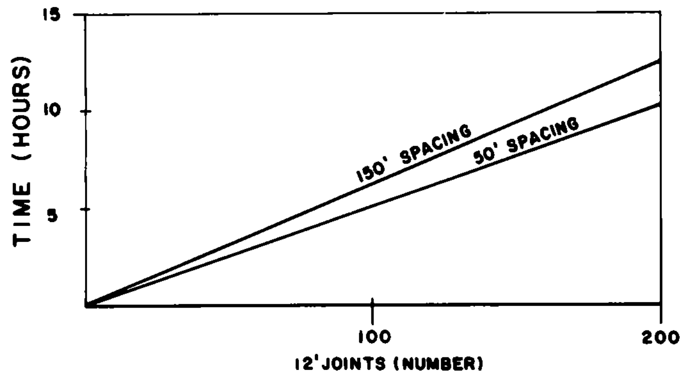


Figure 43 Clean concrete contraction joints with router

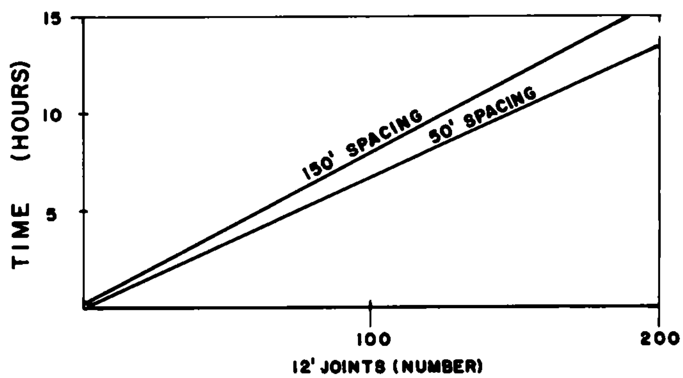


Figure 44 Clean concrete contraction joints with pick and brush

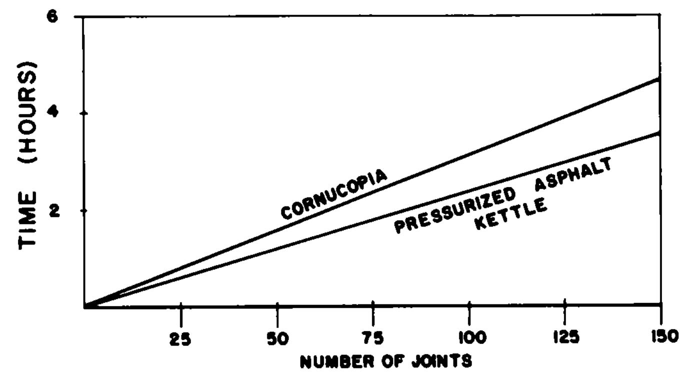


Figure 45 Seal concrete pavement transverse 12-ft joints that are 50 ft apart, making two passes with pressurized asphalt kettle or cornucopia.

CHAPTER THREE

APPLICATION AND USE OF FINDINGS

Aside from eliminating delays and reducing curing time, the major area for reducing roadway occupancy time for maintenance activities is in the performance of the work. The bulk of the data collected and the findings included in this report are directed toward improving work techniques.

PROCEDURES

A procedure was developed for preplanning a maintenance activity. It allows the best available techniques to be incorporated into an operational plan designed to accomplish the required work as quickly as possible. The procedure uses data on techniques and standard times to perform each task in a maintenance activity. This information, together with a crew balance chart, permits the occupancy time for a combination of selected techniques comprising a maintenance activity to be determined and alternative procedures evaluated.

Selection of Maintenance Techniques

It is necessary to determine the tasks that will be required in performing the planned maintenance work. For each task, a technique can be selected that is compatible with the equipment, men, and materials available to the maintenance organization performing the work. Further, it can be the quickest technique practical for the workload being considered The techniques described in this report offer a limited pool from which to draw for each task

Computation of Technique Work Time

A standard time model was developed for each of the techniques included in Appendix Table F-1 The required time can be computed for each of the techniques In most cases the workload and crew size must be used to make the calculations

Modification of Techniques for Efficiency

Associated with each technique included in the report is an efficiency factor based on observations of good practice, and on information in the literature related to reasonable levels of work efficiency In general, efficiency for mechanized and short-duration tasks is high, whereas longer manual activity has been set at 80 percent Each computed technique work time should be divided by its efficiency factor to produce a realistic projection of required work time

Organization of Activity by Task

After the tasks within the activity are identified, they can be arranged in an orderly time sequence, and overlapped to the extent possible, to reflect opportunities to work on several tasks concurrently, or to initiate a new task prior to the completion of a preceding task. This scheduling can be achieved by preparing a crew balance chart where the crew members and tasks can be plotted on a time scale.

Development of Crew Balance Chart

The standard times computed for each technique can be plotted on the crew balance chart Appropriate traffic control times and cure times, where applicable, also can be plotted After the crew chart is drawn, opportunities for further refinement may become evident In some cases, the crew size may be decreased by rescheduling the work assignments with little or no effect on the occupancy time Reassigning or alternating onerous duties between crew members may result in a better balanced workload and may minimize fatigue as a factor in crew efficiency. Variations in crew size and crew member assignments can be experimented with until a satisfactory organization for the activity has been achieved The final crew balance chart will indicate the total roadway occupancy time to be expected for the planned activity.

Examination of Alternative Techniques

It is possible to evaluate new or innovative techniques by substituting these techniques in the crew balance chart, and analyzing the effect on both time and crew requirements for the activity. Thus, the standard data approach to planning maintenance activities permits an activity to be structured to satisfy a given set of objectives, conditions, and constraints.

EXAMPLE OF PLANNING PROCEDURE

To illustrate the application of the activity planning procedures outlined in the foregoing discussion, the following example is offered.

Assume that it is necessary to make a full-depth concrete pavement repair on a four-lane divided highway where peak-hour traffic flows must not be restricted. Occupancy time, then, is restricted to the hours between 9 30 AM and 3 30 PM The repair area will include a contraction joint and one pavement lane extending 6 ft on both sides of the joint The pavement thickness is 10 in The initial crew size should be the minimum feasible and will be based on technique requirements

Step 1 Tasks must be identified. This activity will require the following tasks

1 Set up and remove work zone materials and traffic controls.

2 Identify, locate, detect, or delineate areas of deteriorated material to be removed

3. Cut, grind, mill, plane, or break deck or pavement materials

4 Remove broken or disintegrated deck, pavement, or base material.

5. Clean, dry, prepare patch area or surface area.

6 Prepare and place forms, screeds, or other material-controlling devices.

7. Mix and place patching, surfacing, or sealing materials.

8. Compact, vibrate, screed, or finish patching or surfacing material

9 Apply curing or blotting material.

Step 2. Techniques selected for performing the required tasks are given in Table 3. For each technique, a standard time must be computed In this example, the number of equipment units requiring drivers is five so the crew minimum is set at 5 men Standard times or models are obtained from Appendix Table F-1. The following quantities must be used to compute standard times·

1. Saw area.
2. Patch area.
3. Patch volume.

Assume that a 2-in -deep transverse saw cut at each end of the repair area will adequately delineate the repair area. Thus,

$$A_s = 2W(D/12)$$
$$= 2 \times 12 \times 2/12 = 4 \text{ sq ft}$$

in which A_s = area of saw cut (sq ft); W = transverse pavement width (ft); D = depth of saw cut (in). The patch area and patch volume can be computed:

$$A = W \times L$$
$$= 12 \times 12 = 144 \text{ sq ft}$$
$$V = A \times D/12$$
$$= 144 \times 10/12 = 120 \text{ cu ft}$$

in which A = patch area (sq ft), V = patch volume (cu ft), W = transverse width (ft); D = pavement thickness (in), L = length of patch (ft). The models are used to compute the standard time for each technique.

Step 3. The standard times must be adjusted by efficiency factors from Appendix Table F-1 Each standard time is divided by an efficiency factor to produce the technique time shown in Table 3.

TABLE 3

TECHNIQUE STANDARD TIMES FOR REPAIR OF FULL-DEPTH CONCRETE (Example Procedure)

TECHNIQUE	STANDARD VALUE	GROSS TIME (MIN)	EFFICIENCY FACTOR	NET TIME (MIN)
Make perimeter cut with diamond saw	$2.0 + 1\ 33A$	7.32	1.00	7.32
Break concrete with hydraulic ram	$2\ 5 + 0\ 07A$	12.58	0.95	13.24
Remove concrete with hydraulic hoe	$2\ 5 + 0\ 11V$	15 7	0 95	16 53
Manually prepare base	$14\ 0 + 0.037A/C$	15 33	0 80	19.16
Place prefabricated joint	8 6	8 6	0.80	10 75
Place ready-mix concrete	$2\ 5 + 0\ 20(V/C)$	7 3	0 80	9 10
Manually finish concrete	$16\ 5 + 0\ 066(A/C)$	18 88	0 80	23 60
Burlap cover to cure	$2\ 5 + 0\ 036(A/C)$	3.80	0 85	4 47

Step 4 The crew balance chart is prepared and plotted on a time scale to produce a picture of each crew member's time commitment to the activity The chart can be studied and restructured to improve the use of crew members

PLANNED ACTIVITY DESCRIPTIONS

Five frequently performed maintenance activities that required substantial roadway occupancy time were.

1. Partial-depth concrete pavement repairs
2. Full-depth concrete pavement repairs
3. Expansion joint repairs.
4. Contraction joint sealing.
5. Mudjacking.

The analytical procedure using standard time data was employed to plan each of these maintenance activities. The resulting activity descriptions follow. For each activity, a time curve is presented to predict occupancy times for a range of workloads A precast, full-depth concrete repair also is presented because it eliminates the cure period associated with the cast-in-place repair and represents a promising new technique for this activity

ACTIVITY Pavement, Concrete, Patch, Full Depth

CONDITIONS Single site, single patch area, cast in place

SUMMARY OF TECHNIQUES

Full-depth breakout, removal and replacement of a defective section of portland cement concrete pavement using the following techniques

Saw the limits of the defective area with a concrete saw

Break the concrete inside the limits of the saw cut with a ram

Remove the broken concrete with a hydraulic hoe

Manually remove the remaining debris and level the patch area with shovels

Manually place a prefabricated joint device

Place reinforcing mesh and ready-mix concrete

Manually finish concrete with bull floats, trowels and edging tools, drag with burlap

Manually cover concrete with wet burlap

The activity does not include yard preparation or travel to and from work site

RESOURCES REQUIRED

MEN		EQUIPMENT		MATERIAL
NO	CLASSIFICATION	NO.	DESCRIPTION	DESCRIPTION
2	operators	1	Concrete saw (with diamond blade)	water
3	maintenance men	1	Truck (with water tank and trailer for saw)	ready-mix p c c
		1	Ram	burlap (12' x 2' strips)
		1	Hydraulic Hoe	prefabricated joint device
		*	Dump trucks+	reinforcing mesh
			* as needed + for hauling away broken out concrete	accelerating admixture

APPLICABLE QUANTITY RANGE		OCCUPANCY TIME	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
200 c f	100 c f	6 92 hours	5.22 hours

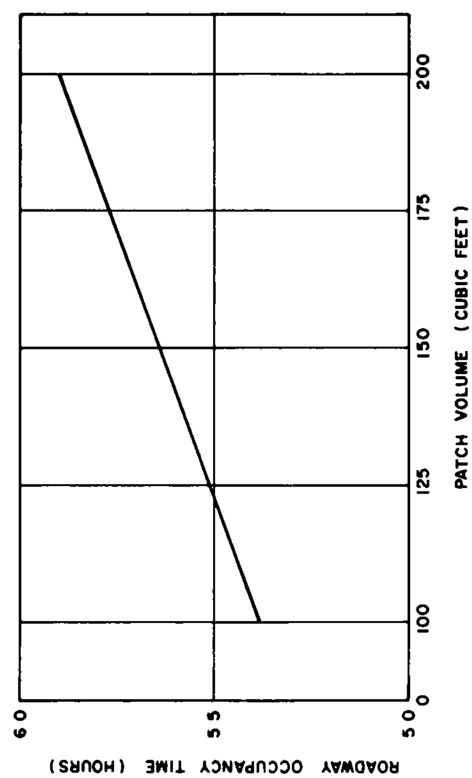


Figure 46 Roadway occupancy time requirement for a single full depth, cast in place concrete repair

DETAILED ACTIVITY DESCRIPTION

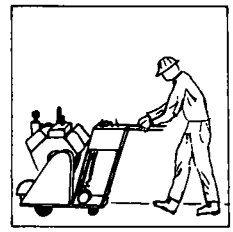
This procedure is structured for the repair of a localized area of deteriorated concrete at an isolated site With the entire crew present for the duration of the activity, they are all available to perform any of the required tasks or support work

After the work site is zoned off, the perimeter saw cut, the breakout and the removal operations are each performed by one man Three men remove any loose debris and level the subgrade with shovels Next, the prefabricated joint assembly is placed and secured by two men Finally the concrete is placed, finished, and covered with burlap by four men The accelerated concrete is allowed to cure for 3½ hours after which the work site is reopened to traffic

Procedure

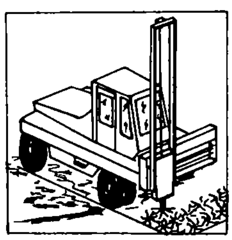
1 Traffic Control - zone off work site with warning signs and devices

2 Set Up Cut
- remove concrete saw from transporting vehicle
- attach hose from water tank to the saw
- position and start the saw



3 Cut - saw 2 inch deep across the width of the lane perpendicular to the centerline at the limits of the defective section

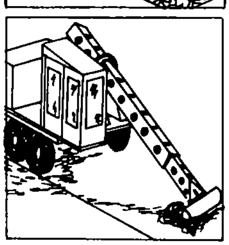
4 Clean Up Cut
- turn off saw
- detach water hose
- replace saw on transporting vehicle



5 Set Up Break - position the ram adjacent to patch area

6 Break - fracture the concrete inside the limits of the saw cuts with the ram

7 Clean Up Break - move the ram away from the patch area



8 Set Up Removal - position the Hydraulic Hoe adjacent to the patch area

9 Remove - dig out broken concrete with a hydraulic hoe and load into hauling trucks

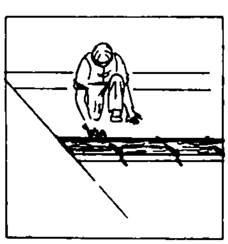
10 Clean Up Removal - move hydraulic hoe away from patch area

11 Set Up Level - remove shovels from materials truck

12 Level Subgrade - manually remove loose debris and level subgrade with shovels

13 Set Up Joint Device - remove joint device from materials truck

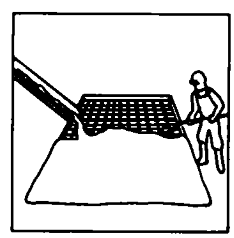
14 Joint Device
- manually place a prefabricated joint device and align it with the original contraction joint
- secure the device in position with metal spikes



15 Set Up P C C
- remove tools from materials truck
- add concrete accelerator to the concrete in the ready-mix truck and mix as per manufacturer's specifications

15 Set Up P C C (cont)
- position ready-mix truck
- assemble the chute for the ready-mix truck
- remove reinforcing mesh from materials truck and cut to the required dimensions
- start concrete vibrator

16 P C C
- place a layer of concrete 6 to 7 inches deep over entire patch area
- position concrete with shovels and concrete vibrator
- place reinforcing mesh on first layer of concrete
- place remaining concrete over entire patch area until it is slightly above the level of surrounding pavement
- strike-off the surface of the patch area with a 2" x 4"
- remove excess or place additional concrete in front of the strike-off operation with a shovel as needed



17 Clean Up P C C
- discard excess concrete off the roadway
- wash tools and return them to materials truck

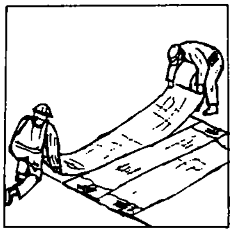
18 Set Up Finish - remove tools from materials truck

19 Finish - manually finish the concrete surface with bull floats, trowels, hand floats and edgers
- drag wet burlap over the surface of the concrete

20 Clean Up Finish - wash tools and return them to materials truck

21 Set Up Cover - saturate burlap strips with water

22 Cover - cover the entire surface of the patch with two layers of burlap



23 Cure - allow concrete to cure for 3½ hours

24 Traffic Control - remove warning sign and devices

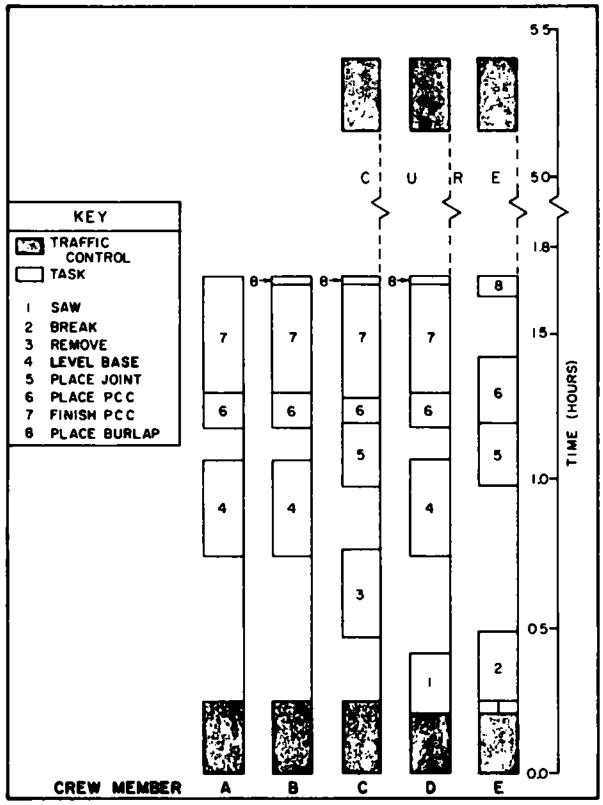


Figure 47 Crew balance chart for making a 12' x 12' x 9" cast in place concrete pavement repair

ACTIVITY Pavement, Concrete, Patch, Full Depth

CONDITIONS Single site, single patch, precast slab

SUMMARY OF TECHNIQUES

Full-depth cutout, removal and replacement of a defective section of portland cement concrete pavement using the following techniques

Cut pressure relief trenches along the limits of the defective area with a wheel cutter

Drill 4 lift holes in the defective section

Insert pins and lift out defective section with a crane

Remove any remaining debris with a backhoe

Mix and place sand-cement mortar with mortar mixer

Place a pre-cast slab with a crane

Fill longitudinal joints with sand-cement mortar to within 1 or 2 inches from top

Manually place fiber board in the transverse joints and seal all joints with hot poured rubberized asphalt

Manually broadcast blotting sand over joint sealant

RESOURCES REQUIRED				
MEN		EQUIPMENT		MATERIAL
NO	CLASSIFICATION	NO	DESCRIPTION	DESCRIPTION
2	operators	1	truck (with trailer for wheel cutter)	water
3	maintenance men	1	wheel cutter	cement
		1	air compressor	sand
		1	air drill	pre-cast slab
		1	truck (tow compressor)	fiber joint filler
		1	crane	rubberized asphalt joint sealer
		1	asphalt kettle	chains
		1	backhoe	lift pins
		1	mortar mixer	ratchet type chain binders
		1	materials truck	

APPLICABLE QUANTITY RANGE		OCCUPANCY TIME	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
168 S.F.	72 S.F.	1.6 hours	1.4 hours

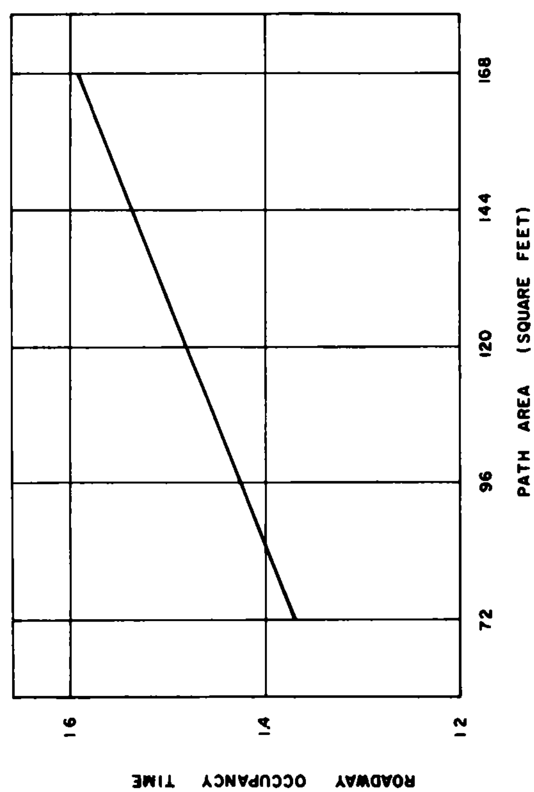


Figure 48 Roadway occupancy time requirement for a single full depth concrete repair using a precast slab

DETAILED ACTIVITY DESCRIPTION

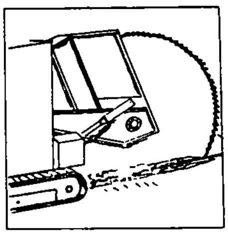
This activity includes a full-depth perimeter cut, removal, and replacement of a section of deteriorated concrete pavement with a precast concrete slab After the traffic controls have been erected, a large diameter wheel cutter is used to make a full-depth, 4-inch wide perimeter cut around the patch area At the same time, four lift holes are drilled in the slab with an air drill The small triangular pieces of concrete not removed from the trench by the wheel cutter are broken loose with the air drill Lift pins are inserted in the holes and the slab is lifted out with a crane Any debris remaining in the hole is removed with a backhoe Sand-cement mortar is prepared in a mortar mixer and placed in the hole to a depth of approximately one inch The correct elevation of the surface of the mortar is obtained with a strike-off frame and bar

Lift pins are inserted into the precast slab and it is lifted into place with a crane The joints are filled with fiberboard and sealed with rubberized asphalt The joints are covered with blotting sand and the site is reopened to traffic

Procedure

1 Traffic Control
- zone off the work site with warning signs and devices

2 Set Up Trench
- drive wheel cutter off of its trailer and into position
- set up stringlines across pavement to direct wheel cutter

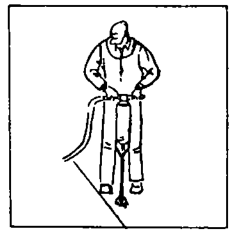


3 Trench
- cut a 4 inch pressure relief trench around the perimeter of the patch area with a wheel cutter

4 Clean Up Trench
- drive wheel cutter onto its trailer

5 Set Up Drill
- remove drill from storage bin

5 Set Up Drill (cont)
- attach air hose
- start air compressor

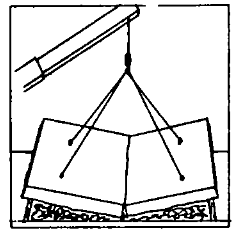


6 Drill
- drill 4 lift holes (1½ inches diameter) in the defective slab
- break out the wedge of concrete remaining in the trench after the wheel cutter is finished

7 Clean Up Drill
- turn off the air compressor
- return drill to the storage bin

8 Set Up Lift
- position crane and hauling truck on roadway or shoulder adjacent to patch area

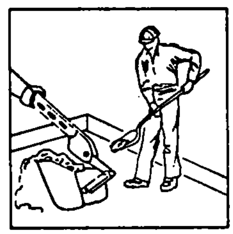
9 Lift
- insert and secure lift pins
- attach chains from crane to the lift pins
- lift out the defective slab and place on a hauling truck
- detach chains and remove lift pins



10 Set Up Prepare Subgrade
- position backhoe on roadway adjacent to patch area

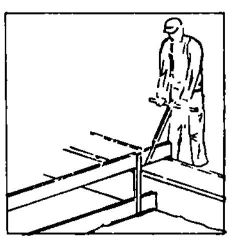
11 Prepare Subgrade
- remove remaining debris from patch area with a backhoe

12 Clean Up Prepare Subgrade
- move backhoe



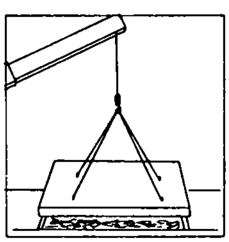
13 Set Up Mortar
- remove strike-off frame from materials truck
- position strike-off frame over the patch area
- fill buckets with sand and cement
- start mortar mixer
- combine and mix sand and cement and water in the mortar mixer

14 Place Mortar
- place the sand-cement mortar in the patch area
- position the mortar with shovels
- set the mortar elevation with a strike-off bar
- remove excess mortar with shovels



15 Clean Up Mortar
- remove the strike-off frame and return it to the materials truck

16 Place Precast Slab
- screw lift pins into the threaded lift holes in the precast slab
- lift the precast slab and lower it into the patch area
- adjust the plane of the slab such that it is parallel to the surface of the mortar This is accomplished by altering the length of the chains with ratchet type chain binders

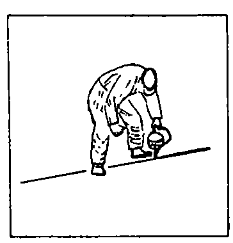


16 Place Precast Slab (cont)
- manually assist the placement of the slab with crowbars
- inspect the alignment of the slab relative to the adjacent pavement with a straight edge
- detach the lift pins

17 Clean Up Precast Slab
- secure the lift chains to the crane
- move the crane

18 Set Up Joints
- remove fiber joint filler from materials truck
- position asphalt kettle adjacent to patch area
- fill cornucopia with hot asphalt

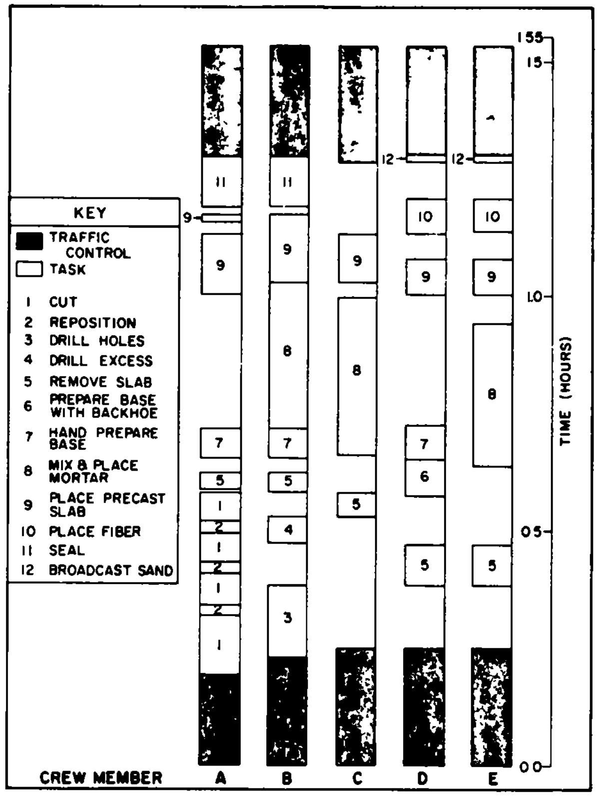
19 Fill Joints
- place fiber joint filler in the two transverse joints
- fill the longitudinal joints with cement mortar to within 2 inches of the surface
- restore shoulders in kind
- seal the joints and the lift holes with hot poured rubberized asphalt



20 Blot
- manually broadcast blotting sand over the joint sealant

21 Clean Up Joints
- remove debris from roadway with a broom
- move equipment

22 Traffic Control - remove warning signs and devices



F[illegible] 49 Crew balance chart for [illegible]king [illegible] 12 x 12 x 9" precast concrete [illegible] repair

ACTIVITY Bridge Deck, Concrete, Patch, Partial Depth

ACTIVITY Bridge Deck, Concrete, Patch, Partial Depth

CONDITIONS Single site, cast in place

SUMMARY OF TECHNIQUES

Location, partial-depth removal, and replacement of localized areas of deteriorated portland cement concrete bridge deck using the following techniques

- Locate exact perimeter of delamination by sounding with hammer and mark with keel
- Saw cut perimeter of patch to a depth of 1 inch
- Break out delaminated concrete with a 2½ inch chisel bit attached to a 60 pound air hammer
- Remove debris from patch area with shovel
- Blow patch areas clean with compressed air
- Mix epoxy tack coat
- Mix fast setting mortar in mortar mixer
- Apply epoxy tack coat with paint brush
- Place mortar
- Manually finish with hand float and texturize with broom

RESOURCES REQUIRED				
MEN		EQUIPMENT		MATERIAL
NO	CLASSIFICATION	NO.	DESCRIPTION	DESCRIPTION
4	maintenance men	1	60 pound air hammer	fast setting cement
		1	air compressor (150 CFM)	sand
		1	60 horsepower concrete saw	water
		1	mortar mixer (truck mounted)	
		1	crew truck	
		1	shovel	
		2	hand floats	
		1	street broom	
		1	materials truck	

APPLICABLE QUANTITY RANGE		OCCUPANCY TIME	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
10 S F	2 S F	2 2 hours	1 5 hours

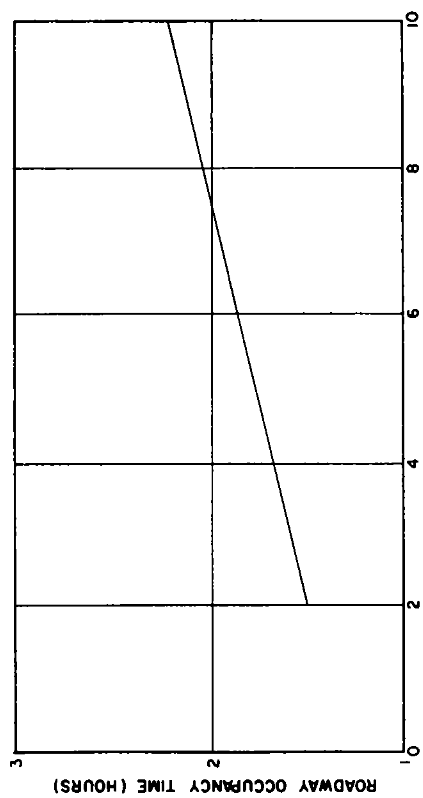


Figure 50 Roadway occupancy time requirement for three cast in place partial depth concrete bridge deck repairs at a single site

DETAILED ACTIVITY DESCRIPTION

This is a three-phase activity which is suitable for a number of repair locations on a bridge deck The entire crew zones off the work site prior to beginning Phase One

Phase One consists of locating, marking and sawing the perimeters of the patches The second phase, which consists of break out and removal of delaminated concrete and the cleaning of the patch area, begins when the first patch has been sawed Phase Three consists of mixing and applying epoxy bonding material, mixing and placing of mortar, and finishing and texturizing the surface of the patch When the last patch is blown clean the only remaining operations of the third phase are applying epoxy bonding material, placing the mortar, finishing, and texturizing of the last patch

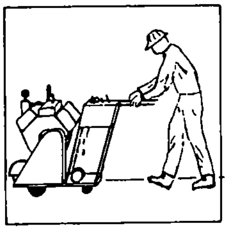
The clean up for the third phase is completed during the necessary cure time When all the patches have cured, the work site is reopened to traffic

Procedure

Traffic Control - zone off work site

PHASE I
Procedure

1	Initial Set Up	- remove saw from truck - connect water hose to saw - turn on water - start saw
2	Mark	- locate perimeter of patch by sounding with hammer - mark perimeter with keel
3	Saw	- saw perimeter of patch to a depth of one inch
4	Recycle	- repeat steps 2 and 3 for each patch
5	Final Clean Up	- turn off saw - turn off water - disconnect water hose from saw - return saw to truck

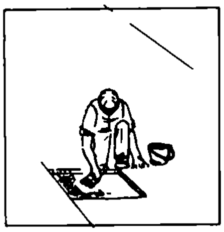


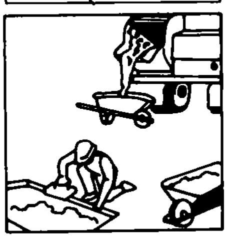
PHASE II
Procedure

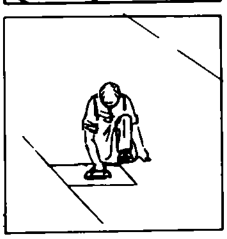
1	Initial Set Up	- remove airhose and hammer from storage bin
2	Set Up Break	- attach airhose to hammer - switch on airvalve
3	Break	- break out delaminated concrete with 2½ inch chisel bit attached to 60 pound hammer
4	Clean Up Break	- switch off air valve - disconnect airhose from hammer
5	Set Up Blow Out	- switch on airvalve
6	Blow Out	- use airhose to blow concrete chips and dust from patch area and adjacent bridge deck
7	Clean Up Blow Out	- switch off airvalve
8	Recycle	- repeat steps 2 thru 7 for each patch
9	Final Clean Up	- return airhose and hammer to storage bin

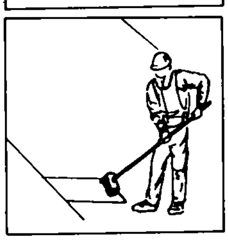
PHASE III
Procedure

1	Initial Set Up	- start mortar mixer
2	Set Up Mix Mortar	- fill bucket with sand, cement and water
3	Mix Epoxy	- fill buckets with proper quantities of the two epoxy components - manually mix the components
4	Mix Mortar	- charge mortar mixer with prefilled buckets of sand, cement and water - allow mortar to mix
5	Apply Tack	- spread coat of epoxy bonding material on surface with brush
6	Place	- dump mortar from mixer into wheelbarrow - place mortar from wheelbarrow into patch
7	Finish	- finish mortar with hand floats - texturize surface by dragging with street broom
8	Return	- repeat steps 5 thru 7 until one batch of mortar has been used
9	Recycle	- repeat steps 2 thru 8 for next batch of mortar
10	Final Clean Up	- rinse mortar mixer - rinse hand floats and street broom - clean epoxy mixing bucket - clean epoxy spreading brush









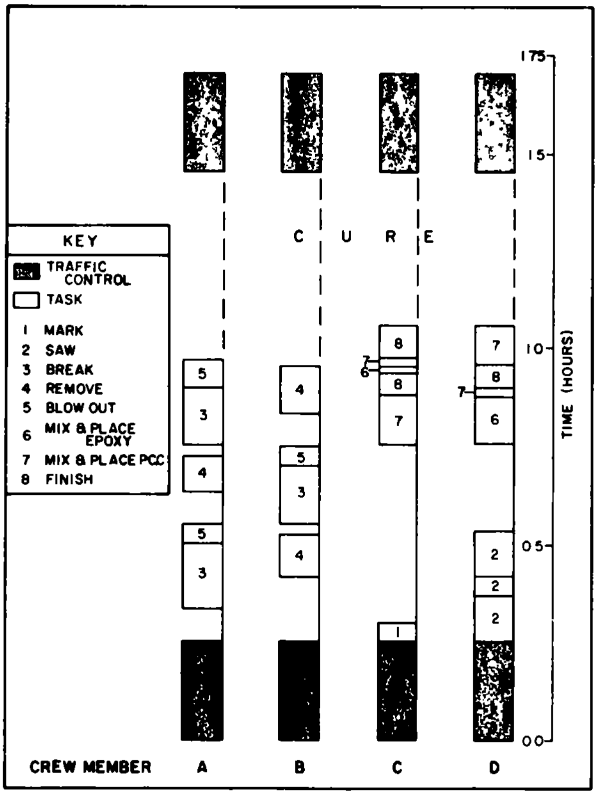


Figure 51 Crew balance chart for making three 4 square foot partial ... n concrete bridge deck repairs

ACTIVITY Pavement, Concrete, Mudjack

CONDITIONS One site, five holes

SUMMARY OF TECHNIQUES

Raising a settled portland cement concrete slab or filling a void beneath slab with cement grout using the following techniques

- Drill mudjack holes with hand-held air drills
- Blow holes clean with compressed air
- Prepare grout in a combination mixer and mudjack machine
- Pump grout from mudjack machine into the drilled holes
- Insert plugs into adjacent mudjack holes

RESOURCES REQUIRED

MEN NO	MEN CLASSIFICATION	EQUIPMENT NO	EQUIPMENT DESCRIPTION	MATERIAL DESCRIPTION
4	maintenance men	2	air drills (1½ inch	portland cement
				soil (within A-4 classification)
		1	air compressor	
		1	water tank	water
		1	combination mixer and mudjack pump	wetting agent
		2	trucks	

APPLICABLE QUANTITY RANGE MAXIMUM	APPLICABLE QUANTITY RANGE MINIMUM	OCCUPANCY TIME MAXIMUM	OCCUPANCY TIME MINIMUM
162 CF	10 CF	4 38 hours	1 84 hours

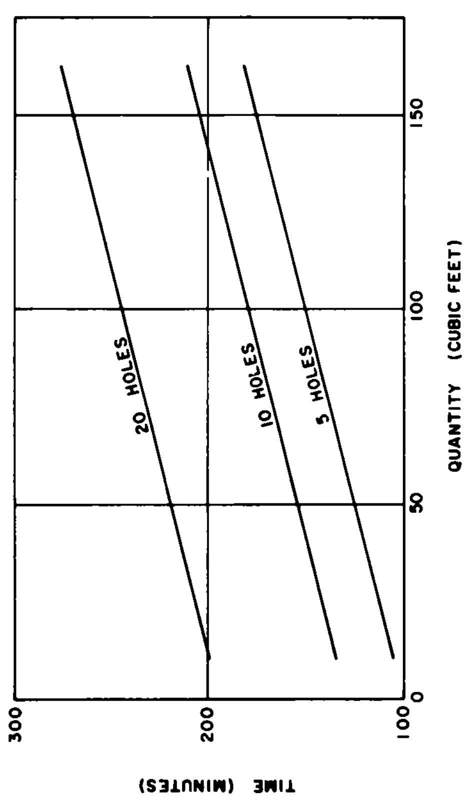


Figure 52 Roadway occupancy time for mudjacking one slab concrete pavement

DETAILED ACTIVITY DESCRIPTION

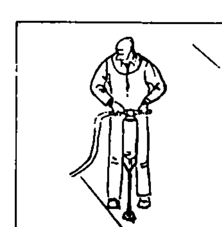
This activity includes laying out and drilling the mudjack holes followed by the mixing and pumping of the mudjack grout beneath the pavement After the traffic controls have been erected, the foreman determines and indicates the location of each hole on the pavement with keel Two men perform the drilling with hand-held drills While the holes are being drilled, two men prepare the mudjack machine and mix the grout When the pumping begins, two men operate the mudjack machine, handle the nozzle and insert plugs into any of the holes emitting grout The other two men shovel additional material into the mudjack machine hopper

Procedure

1 Traffic Control - zone off the work site with warning signs and devices

2 Locate - mark the location of each hole with keel

3 Set Up Drill
- remove air drills from storage bin
- attach compressor air hoses to drills
- switch on air valve
- walk to keel marks

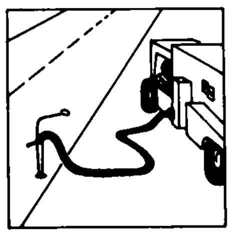


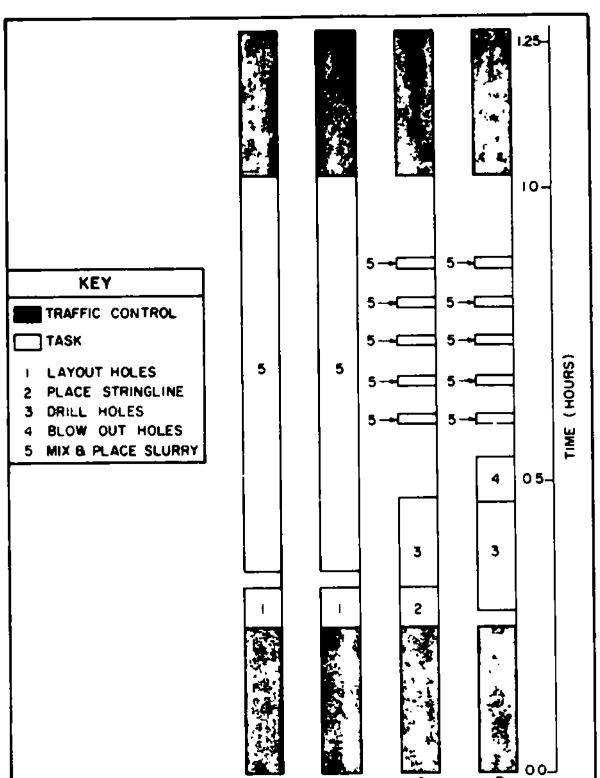
4 Drill - drill holes through the concrete slab

5 Clean Up Drill
- walk to compressor
- turn off air valve
- detach air hoses from drills
- replace drills in storage bin

6 Set Up Blowout
- attach air cleaning devices to air hoses
- switch on air valve
- walk to holes

7	Blow Out	- blow out debris from each hole with compressed air
8	Clean Up Blow Out	- walk to compressor - disconnect cleaning devices from air hoses - replace air cleaning devices in the storage bin and return air hoses to take up reels
9	Set Up Pump	- place string line - attach hoses to mudjack machine - mix grout in specified proportions in mudjack machine
10	Pump	- wedge mudjack hose nozzle into hole and pump grout - alternate pumping between the holes as determined by the foreman - shovel additional grout components into the mudjack hopper as needed - insert plugs in holes that begin discharging grout - inspect the raising of the slab with the stringline
11	Clean Up Pump	- remove excess grout from the pavement with shovels and water hose - remove plugs from mudjack holes
11	Clean Up Pump (cont)	- pump any grout remaining in the machine off the roadway - pump water through the mudjack machine - return hoses, plugs and tools to the materials truck
12	Traffic Control	- remove warning signs and devices





[illegible] balance chart for m[illegible] one concrete [illegible]

ACTIVITY Pavement, Concrete, Seal, Joint

CONDITIONS One site, contraction joints

SUMMARY OF TECHNIQUES

Cleaning contractions joints of debris and filling with rubberized asphalt using the following techniques

- Clean contraction joint of live material with hook
- Clean joint with gas-powered router
- Blow joint clean with compressed air
- Seal joint with rubberized asphalt from a pressurized asphalt kettle

RESOURCES REQUIRED

MEN NO	MEN CLASSIFICATION	EQUIPMENT NO	EQUIPMENT DESCRIPTION	MATERIAL DESCRIPTION
4	maintenance men	3	trucks	rubberized asphalt
		1	air compressor	
		1	pressurized asphalt kettle	
		1	router	
		2	cleaning hooks	

APPLICABLE QUANTITY RANGE		OCCUPANCY TIME	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
200 joints	25 joints	9 62 hours	1 38 hours

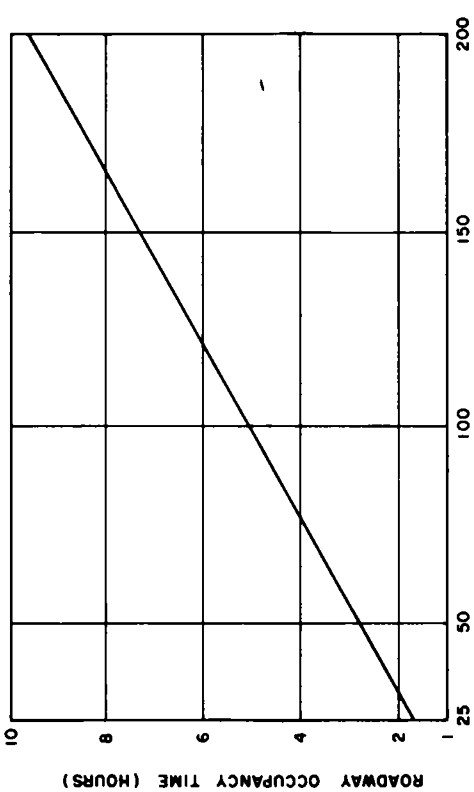


Figure 54 Roadway occupancy time for sealing concrete pavement contraction joints, fifty feet apart

DETAILED ACTIVITY DESCRIPTION

This is a two-phase activity suitable for cleaning a number of contraction joints sequentially The entire work site is zoned off by the four man crew prior to beginning work

The crew begins Phase One from the far end of the zone Two men begin cleaning alternate joints with hooks until half of the joints have been hooked One of these men returns to blow all the joints while the other continues hooking the remaining joints When the first joint has been hooked the other tow men start cleaning each joint with the router When all the joints have been hooked, this man returns to perform Phase Two The second phase consists of sealing each joint with rubberized asphalt from a pressure applying asphalt kettle

When Phase One has been completed the three men working on this phase return and begin collapsing the work zone

PHASE I
Procedure

1 Traffic Control - zone off work site

2 Hook - pick defective material from joint

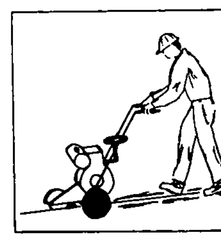
3 Set Up Rout - remove router from truck
- start router

4 Rout - remove existing defective material

5 Move Blow Out - return to beginning of work site

6 Set Up Blow Out - start air compressor
- unwind air hose
- switch on air valve

7 Blow Out - blow debris from joint and off the roadway with compressed air



8 Move Seal - return to beginning of work site

9 Set Up Seal - adjust controls on pressurized asphalt kettle to obtain the temperature recommended in manufacturer's specification for rubberized asphalt

10 Seal - use the hose and nozzle from the pressurized asphalt kettle to seal joint with rubberized asphalt

11 Support Seal - charge kettle with additional rubberized asphalt
- lubricate motor
- change nozzle tips

12 Clean Up Seal - place nozzle in asphalt kettle for continuous recycling of rubberized asphalt

13 Traffic Control - open work site to traffic

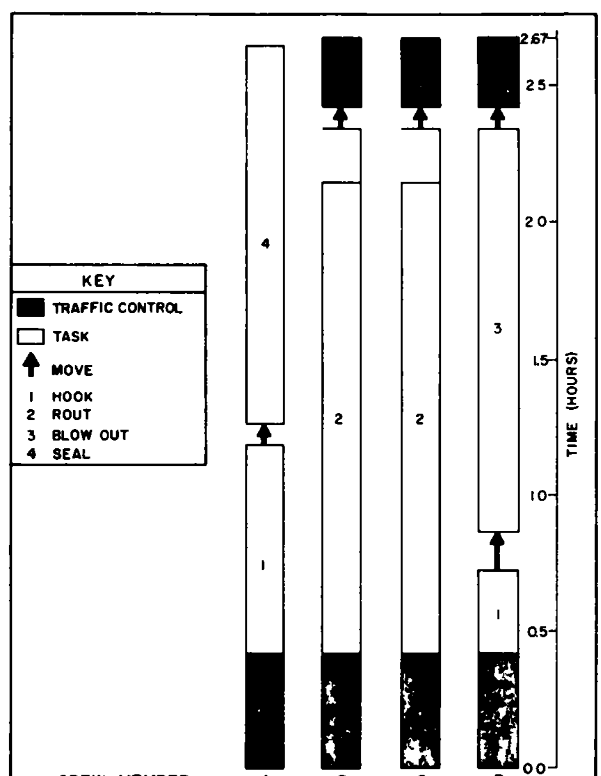


Figure 55 Crew balance chart for sealing 52 concrete pavement contraction joints fifty feet apart

ACTIVITY Pavement, Concrete, Repair, Joint

CONDITIONS Expansion joint, 1 site, four 12 foot long joints

SUMMARY OF TECHNIQUES

The installation of expansion joints in portland cement concrete pavement using the following techniques

Cut a 4-inch wide trench across the pavement and perpendicular to the centerline with a wheel cutter

Fill the joint with a preformed filler

Seal the joint with rubberized asphalt using a hose and nozzle from a pressurized kettle

Blot the rubberized asphalt with sand

RESOURCES REQUIRED				
MEN		EQUIPMENT		MATERIAL
NO	CLASSIFICATION	NO	DESCRIPTION	DESCRIPTION
4	men	1	wheel cutter	rubberized asphalt
		2	trucks	filler
		1	pressurized kettle	sand
		1	broom	

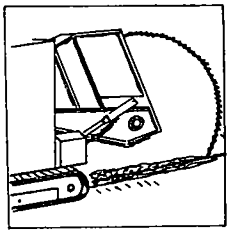
APPLICABLE QUANTITY RANGE		OCCUPANCY TIME	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
4 - 12' joints	4 - 12' joints	1.57 hrs. per site	

DETAILED ACTIVITY DESCRIPTION

This procedure is designed for installing 12-foot long expansion joints with 2 joints being done in one lane then changing the traffic controls to do the remaining 2 joints in the other lane The crew is made up of 4 men with 1 man operating the cutter, 1 man sealing the joints and the entire crew doing the other required tasks

Procedure

1 Set Up Cut - remove cutter from trailer
- position cutter for the first cut



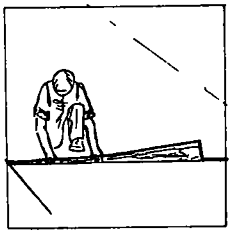
2 Cut - cut a 4-inch wide trench across the pavement and one foot into the adjacent lane

3 Move - move cutter to next joint

4 Sweep - sweep area clean

5 Move - move to next joint

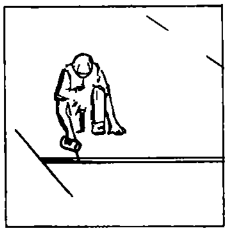
6 Set Up Fill - take preformed filler out of truck



7 Fill - place and tamp preformed filler into the joint

8 Move - move up to next joint

9 Set Up Seal - move pressurized kettle up to joint
- adjust controls to correct setting



10 Seal - fill joint using hose and nozzle from kettle

11 Move - move kettle to next joint

12 Repeat - repeat steps 1,2,4, 6,7,9,10 for the second joint

13 Traffic Control - move the traffic controls and equipment to the adjacent lane and repeat steps 1 thru 12

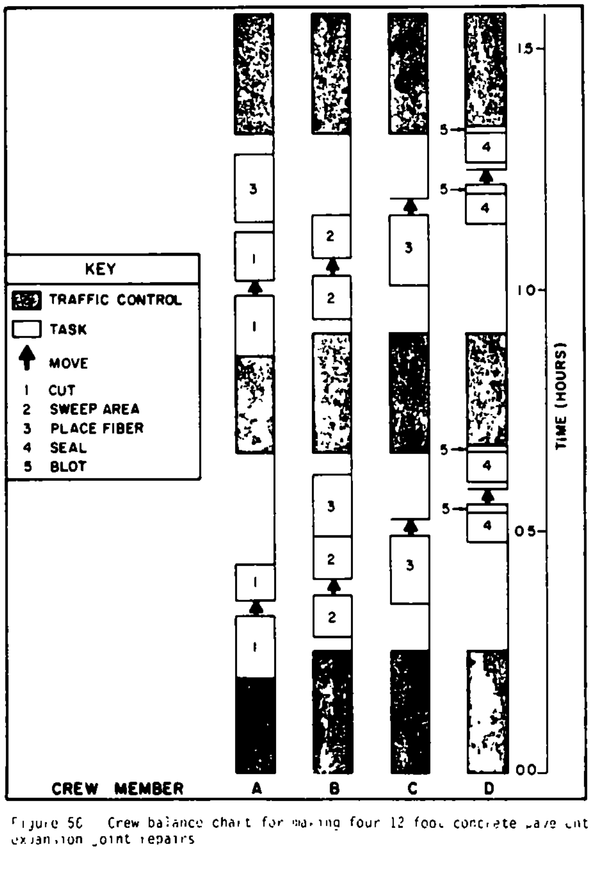


Figure 50 Crew balance chart for making four 12 foot concrete pavement expansion joint repairs

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

New and innovative methods for performing highway maintenance were sought throughout the study to reduce roadway occupancy time A number of promising techniques were revealed in this search, but no potential breakthroughs were identified for most of the tasks studied Many of the new techniques involved special equipment, material, or circumstances not encountered in many maintenance activities

Dependence in the short range on innovative material and equipment developments for occupancy time reductions offers less promise for most maintenance activities than do improvements in managing the work

However, there are several developments that are sufficiently promising to merit current consideration by agencies performing on-the-road maintenance activities under high-volume and/or high-speed traffic conditions

One development is the use of precast or prefabricated units for pavement repair Prefabrication offers a number of significant potential advantages Quality control in a yard or shop environment can be exercised much more successfully than is often the case in the field Further, when poor quality does occur in prefabrication, the unit can be wasted without incorporating it in the pavement, the resulting loss is low and no occupancy time is attributed to the failure

Prefabricated repair units can be prepared and stockpiled in anticipation of need. This results in a readiness to complete roadway repairs quickly when they are required It also permits maintenance crews to be used in shop or yard prefabrication at times when they might otherwise be nonproductive or less productive on field assignments (i e , during heavy rainfall or cold-weather periods between snow storms)

Although the use of prefabricated partial-depth or full-depth concrete pavement slabs still should be classified as experimental, sufficient data are available on these techniques to permit most maintenance agencies to advance their own procedures and capabilities to make use of them The significant occupancy time reductions made possible by prefabrication of repairs justify such efforts by maintenance managers

Another development of importance in reducing occupancy time is in the area of cutting hardened portland cement concrete Using air hammers and saws, this task has been time consuming and often imprecise The recent availability of large-diameter cutting wheels for full-depth, wide cuts in concrete slabs represents a new and useful capability to maintenance crews Also new is the precise, partial-depth cutting or "milling" capability represented by equipment now in use in England This type of controlled cutting away of deteriorated concrete makes the use of partial-depth prefabricated pavement slabs a practical time-saving alternative to cast-in-place repairs.

The field observations undertaken during the study revealed that an important potential exists for reducing roadway occupancy time through the increased use of basic project management principles

The time spent on the road by observed crews exceeded the time that was necessary in most instances. The delay time occurring during the occupancy period often represented a major portion of the total time Significant time savings could have been realized through changes in observed scheduling and sequencing of tasks.

Field observation procedures developed and used in this study offer valuable tools for use by managers in reducing roadway occupancy time.

Time-lapse photography has proved to be an economical, effective means of observing and capturing data on field procedures

Commercial equipment providing complete camera and project systems, currently on the market for less than $2,000, can be used by technicians without extensive training Maintenance activities covering an 8-hr period can be captured on 200 ft of 8-mm film, and the developed film shown for review in less than one hour Often, major opportunities for improvements in activities are obvious to experienced managers by this first review

The minimum expense involved in acquiring and using this photographic technique makes it a valuable and desirable tool for all maintenance agencies Where managers cannot go to the field, as is often the case, the time-lapse film can bring much of the field experience to the manager in an efficient, condensed form.

Time-lapse photographic techniques also proved to be effective in obtaining time data on maintenance activities The film revealed the impact of equipment, material, and procedures on roadway occupancy time Time-lapse photography provided a basis for careful, orderly analysis of procedures for productivity measurements and potential value in classroom training of supervisors and maintenance crews

The system developed during the study can be used to organize a maintenance activity prior to the occupancy of the roadway and to predict the occupancy time that will be required.

The system makes use of standard time data, established for each task in a maintenance activity, and permits reasonably accurate predictions of roadway occupancy time for various activity configurations

Although there are many variables that affect highway maintenance performance, managers recognize the necessity for careful planning of maintenance activities and the opportunity to control a significant amount of the maintenance program Management systems in most agencies are founded on the use of standards for performance of activities.

Development of standard data for tasks carries this concept one step further than prior practice By standardizing individual techniques for performing tasks, these individual building blocks, with known dimensions of time, crew size, and equipment needs, can be used to construct an optimum procedure for a total activity under varying sets of constraints The primary constraint in this study was occupancy time, but the standard data approach can respond just as readily to other constraints such as lowest unit cost, minimum crew size, or equipment limitations

Data files or standards for tasks should be acquired by maintenance agencies Most standards will be common to agencies throughout the United States and cooperative efforts in developing them can be arranged

SUGGESTED RESEARCH

As indicated in the foregoing discussion, there are several important areas for further research and development that promise valuable returns in terms of reduced roadway occupancy time during maintenance

1 The elimination or reduction of cure time would permit a major reduction in occupancy time for many necessary roadway maintenance activities. Continued research directed to quick-setting, strong, durable patching materials offers high payoff potential

2 Prefabrication of repair units continues to require research Composition and configuration of precast concrete for handling, bedding, and bonding repair units with existing pavements needs to be studied The techniques for providing load transfer need to be explored Procedures for preparing old pavement sections for precast inserts warrant further study also

In the bituminous pavement field, the only prefabricated unit identified was the "band-aid" surface patch. Further study is needed to determine the need for and utility of prefabrication of flexible pavement repairs

3 Many research needs exist in the area of mechanization of maintenance tasks. Promising developments are already being applied to maintenance tasks in concrete cutting Research is being carried on in the use of sonic energy, infrared heat, high-pressure water jets, and other means for cutting or breaking concrete Continued research efforts in these and other areas are warranted to achieve roadway occupancy time reduction—and to satisfy the growing need for noiseless, dustless, cutting techniques to meet environmental requirements

Mechanization of material-handling tasks continues to need many improvements The custom-batching of ready-mix concrete now possible is a recent development of much value in maintenance repair projects Similar equipment to produce small batches of hot-mixed bituminous concrete at the repair site could be equally useful

4 Standard time data, developed during the study, proved valuable in planning efficient and productive activity procedures Development of standard time data covering an entire range of maintenance tasks warrants serious consideration for future research. Such information would provide highway maintenance agencies with a uniform data base for developing productive and efficient work procedures covering any highway maintenance requirement A cooperative research effort in this area could establish uniform procedures for presenting standard data and for collecting and computing the times, rates, and efficiencies used. The study could identify the variables influencing these values for given tasks and could develop models and curves representing these relationships

Because the resulting standards would need to be updated regularly to accommodate new materials and equipment developments, the research should include the development of a system whereby reliable data could be collected and submitted by a maintenance agency to a central data file where computations and output of new standards could be distributed to all interested agencies.

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APPENDIX A
GLOSSARY

ACTIVITY — Complete work program consisting of a number of separate tasks producing an end-product or end-result

TASK — The principle elements or subdivisions of an activity (For this project, the definition has been applied to a specific list of tasks that have been identified and given code numbers) The task list is intended to encompass all actions required to accomplish any of the activities under study

TECHNIQUE — A unique way of performing a given task

OCCUPANCY TIME — The total elapsed time during which a section of roadway is not available to traffic because of a maintenance activity.

WORK ZONE — The section of a roadway enclosed by traffic-control devices

TRAFFIC CONTROL TIME — The time required prior to the initiation of the other tasks and following the completion of the other tasks during which the traffic controls are erected and removed

CURE TIME — The elapsed time between the completion of the other tasks and the initiation of the removal of traffic control, during which material curing takes place

DELAY TIME — An interruption in the work time when no crew member is working, e g., the crew takes a lunch break or awaits materials arrival

WORK TIME — Any time during roadway occupancy time when at least one crew member is working on a task

PRODUCTIVE MAN-TIME — The man-hours accumulated by crew members on the road during occupancy time actively working on a task.

NONPRODUCTIVE MAN-TIME — The man-hours accumulated by crew members on the road during occupancy time when they are not working on a task

AVOIDABLE NONPRODUCTIVE MAN-TIME — The nonproductive man-time accumulated by crew members when work was available to be done

UNAVOIDABLE NONPRODUCTIVE MAN-TIME — The nonproductive man-time accumulated by crew members when work was not available

EFFICIENCY — Ratio determined by dividing actual productive man-time by potential productive time (the sum of actual productive time plus avoidable nonproductive time).

APPENDIX B

QUESTIONNAIRES

Two mailing questionnaires were developed during the project One was sent to elicit information from agencies and individuals performing street or highway maintenance, and a second was sent to manufacturers and suppliers of highway maintenance equipment and materials.

Questionnaire

NCHRP 14-2

BYRD, TALLAMY, MacDONALD and LEWIS

"Techniques for Reducing Roadway Occupancy During Routine Maintenance Activities"

After reviewing the packet of maintenance techniques which accompanies this questionnaire, please answer the following

1 Of the techniques shown, please list any for which you have methods which will better reduce roadway occupancy time

Maint Tech No	Comment
______	______
______	______
______	______
______	______
______	______
______	______

2 Do you have entirely different techniques to reduce roadway occupancy time for any of the following activities

Activity	Comment
a) Travelway patching	______
b) Shoulder patching	______
c) Travelway resurfacing and sealing	______
d) Shoulder resurfacing and reconditioning	______
e) Crack and joint sealing	______
f) Mudjacking and sub-sealing	______
g) Bridge deck repairing	______

3 If you have field directives, photographs or other literature on any of the above, we would appreciate receiving copies if available

4 To obtain full information on applicable maintenance techniques at a minimum of inconvenience to maintenance agencies, project team members may wish to place phone calls or arrange visits to observe maintenance procedures Whom should we contact in your agency for this purpose?

Name (please print) ______

Title ______

Agency ______

Address ______

______

Phone Number ______

Questionnaire

NCHRP 14-2

Byrd, Tallamy, MacDonald and Lewis

"Techniques for Reducing Roadway Occupancy During Routine Maintenance Activities"

1 Do you manufacture materials or equipment that are currently being used or that can be adapted for use by road and highway maintenance organizations for any of the following maintenance activities

Activity	Yes	No	Comment
a Travelway patching	___	___	______
b Shoulder patching	___	___	______
c Travelway resurfacing & sealing	___	___	______
d Shoulder resurfacing & recond	___	___	______
e Crack & joint sealing	___	___	______
f Mudjacking and subsealing	___	___	______
g Bridge deck repairing	___	___	______

2 If "yes", please enclose descriptive literature and photographs

3 Where and with which maintenance agency may this material or equipment be seen in use or operation?

______

______

______

4 Should it be necessary to obtain further information, please list the individual in your firm to be contacted

(Please Print)

Name ______

Title ______

Firm ______

Address ______

______

Phone No ______

APPENDIX C

FIELD DATA LOG

During the filming of maintenance activity, support information was recorded on the field data log Although the field log duplicated some information captured on the film, there were times when continuous film coverage was missing because the view became temporarily obstructed The field data log filled these voids Details on classes of labor and types of equipment and materials, not always discernible from the film, also were recorded on the log.

The procedure log documented each task from the beginning of the roadway occupancy period until it was terminated This form proved valuable in evaluating the total occupancy period because it caught both the initial traffic-control installation and the traffic-control removal which was not possible to film in most instances because the roadway could not be occupied by the camera crew

FIELD DATA LOG OF MAINTENANCE TASKS

NCHRP 14-2 MAINTENANCE TECHNIQUES FOR REDUCING ROADWAY OCCUPANCY TIME

BYRD, TALLAMY, MacDONALD and LEWIS, CONSULTING ENGINEERS

WEATHER Windy-Sunny BY
TEMP 65°-75° REEL T 43-T43 S
DATE 2/24/72

ACTIVITY Bridge deck p.c.c. partial depth epoxy patch

LOCATION I 1 over R.R. west of Main Ave.
city, state

PAVEMENT: (Concrete) Bituminous Composite
AREA: (Urban) Suburban Rural
DIRECTION: N S E (W)
TERRAIN: (Flat) Rolling Hilly Mountainous
TRAFFIC ROUTING: Left Shoulder, Left Lane, Right Shoulder, (Right Lanes), Median, None
OPERATION: One Way, Controlled Access, (Limited Access), Unrestricted Access
LANES: 2 lanes, 3 lanes, 4 lane divided, (6 lane divided), 6 lane undivided

POSTED 60 MPH TEMP 60 MPH
WORK ZONE 500 FEET

TIME	DIRECTIONAL TRAFFIC CT(5 MIN)
12:38	186
1:34	197

LABOR NO	LABOR DESCRIPTION	EQUIPMENT NO	EQUIPMENT DESCRIPTION	MATERIALS QUANTITY	MATERIALS DESCRIPTION
1	Working Foreman	1	Dump truck		Epoxy resin
3	Laborers	1	Conc. saw 16" dia.		Coarse sand
1	Flagman		carbide saw		
		1	Jackhammer 60#		
			2½" steel chisel bit		
			Sand blaster		
			Oxygen-Acetylene torch		
			Air compressor 600 c.f.m.		

TASK NO	DESCRIPTION	ACCOMP UNITS
2	Supervisor marks area with keel	
3	Saw area	
3	Break with jackhammer	
4	Hand remove with shovels	
5	Sand blast	
7	Apply epoxy with paint brush	
8	Mix epoxy with coarse sand and place	
9	Strike off	
10	Accelerate with oxygen-acetylene torch	

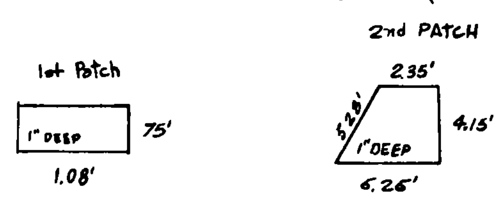
COMMENTS Torch rating 1200°F however epoxy should not be heated above 200°F

OBSERVED PROCEDURE LOG

TASK NO	START HR	START MIN	STOP HR	STOP MIN	REMARKS
	12	10	12	20	Set up cones
	12	20	12	21	Sound 1st patch area with hammer
	12	20	12	21	
	12	23	12	27	Saw cut 1st patch area with saw
	12	23	12	24	Set up jackhammer
	12	24	12	26	Sound 2nd patch area
	12	29	12	31	Break 1st patch area with jackhammer
	12	28	12	36	Cut 2nd patch area
	12	36	12	40	Replace blade
	12	34	12	36	Sand blast 1st patch
	12	40	12	42	Cut 2nd patch with saw
	12	43	12	55	Break 2nd patch with jackhammer
	12	45			Remove broken conc. with shovel
	12	47	1	00	Sand blast 2nd patch
	12	59	1	04	Mix epoxy resin
	1	04	1	10	Mix epoxy resin with 100# of sand in wheelbarrow
	1	05	1	09	Mix epoxy tack coat
	1	09	1	11	Apply epoxy tack coat to 2nd patch
	1	11	1	12	Apply epoxy tack coat to 1st patch
	1	12	1	13	Place epoxy mortar in 1st patch
	1	14	1	15	Strike off 1st patch with 2x4
	1	14	1	16	Place epoxy mortar in 2nd patch
	1	16	1	19	Strike off 2nd patch with 2x4
	1	19	1	21	Remove excess mortar from road with shovel
	1	20	1	22	Apply heat to 1st patch with torch
	1	22	1	35	Apply heat to 2nd patch with torch
	1	35	1	36	Apply heat to 1st patch with torch
	1	44	1	52	Apply heat to 2nd patch with torch

SKETCHES

2 00 2 05 Remove cones and open to traffic



APPENDIX D

DATA ANALYSIS FORMS

Two forms were developed to expedite the time-lapse film data take-off process. The cyclic operations form was used for tasks that were representative of and restricted to one equipment unit or one crew member, as an example, a front-end loader removing broken concrete, one crew member pouring sealant and moving between contraction joints or one man sawing a patch perimeter The second form was used for the noncyclic operation classification where the analysis was limited to tasks occurring at a single spot location and encompassed the total task time at that location To expedite the analysis for the noncyclic condition, the take-off was based on five-frame intervals

NCHRP 14-2

BYRD, TALLAMY, MacDONALD and LEWIS
CONSULTING ENGINEERS

TIMELAPSE TAKEOFF -- CYCLIC OPERATIONS

Task No 14 — Activity Code I A 3
Technique No 5 Des ____ — Reel No T46
Drill mudjack holes
Total Units 6 holes — Total No Frames 256
Subject 40# Airhammer — Interval 2 (Sec)
2½" Bit (2 men)

Cycle No	Action	No of Frames	Time (Sec)	Units/Cycle	Remarks
1	Drill	31	62	1 hole	
	Move	6	12		
2	Drill	37	74	1 hole	
	Move	8	16		
3	Drill	33	66	1 hole	
	Move	7	14		
4	Drill	36	72	1 hole	
	Move	9	18		
5	Drill	37	74	1 hole	Trouble starting
	Move	11	22		Delay
6	Drill	32	64	1 hole	
	Clean up	9	18		

Date 4/5/72 Reviewer D.B.

NCHRP 14-2

BYRD, TALLAMY, MacDONALD and LEWIS
Consulting Engineers

Timelapse Takeoff-Noncyclic Operation

Task No 9 — Activity Code I A 1c
Technique No 4 Des ____ — Reel No T 87 CAN 33
Hand finish large patch — Timelapse Interval 2 SEC.
State

Labor No	Labor Description	Equipment No	Equipment Description	Materials Description	Materials Units
4	laborers	1	Bull float		
		3	Hand floats		
		2	Edgers		

A = Total Accomplishment Units = 276 SF
B = Total No of Frames = 690
C = Total No of Periods = (B÷5fpp)* = 138
D = No of Work Periods = 121
E = No of Man-Work Periods = 232
F = Effective Crew Size @ 100% Efficiency = (E÷D) = 1.91
G = Observed Time = (C÷6 ppm)* = 23.0 MIN
H = Productive Time = (D÷6 ppm)* = 20.16 MIN
I = Observed Productivity = (A÷G) = 12.00 SF/MIN
J = Adjusted Productivity = (A÷H) = 13.69 SF/MIN.

Remarks ____

*fpp = frames per period, ppm = periods per minute

Date 6/20/72 Reviewer ____

Frame Ending frame number of the five frame period

Men Total number of men working three or more frames during the five frame period

Frame	Men	Frame	Men	Frame	Men	Frame	Men	Frame	Men	Frame	Men
5	1	215	1	425	2	635	0				
10	2	220	2	430	3	640	0				
15	2	225	2	435	2	645	0				
20	2	230	1	440	3	650	0				
25	1	235	2	445	3	655	0				
30	2	240	1	450	3	660	0				
35	1	245	2	455	2	666	2				
40	1	250	3	460	2	670	2				
45	1	256	2	465	1	675	2				
50	2	260	3	470	3	680	2				
55	3	265	3	476	3	685	2				
60	3	270	3	480	1	690	2				
65	3	276	4	485	0						
70	3	280	4	490	1						
75	3	285	4	495	1						
80	1	290	4	500	1						
85	1	295	3	505	1						
90	1	300	3	510	2						
95	2	306	3	516	2						
100	2	310	2	520	1						
105	2	316	1	525	1						
110	3	320	1	530	1						
115	2	325	1	535	2						
120	1	330	1	540	2						
125	3	335	1	545	1						
130	3	340	0	550	1						
135	3	346	0	555	1						
140	2	350	0	560	1						
145	2	355	0	565	1						
150	1	360	0	570	1						
155	1	366	0	575	2						
160	2	370	0	580	1						
165	3	375	1	585	0						
170	3	380	1	590	1						
175	3	385	1	595	1						
180	3	390	2	600	1						
185	2	395	3	605	1						
190	2	400	3	610	1						
195	1	406	3	616	1						
200	2	410	2	620	1						
205	2	415	1	625	0						
210	2	420	1	630	0						

APPENDIX E

TECHNIQUE DESCRIPTIONS

Task 1

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Use of diminishing work zone

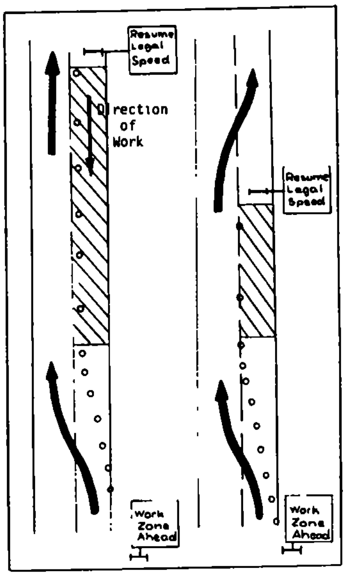
For Activities - Pavement, shoulder or bridge deck maintenance

Description of Technique

The roadway length occupied for maintenance activities may be reduced faster if a diminishing zone arrangement is used

After the work zone is coned or signed off to traffic, work is to progress against traffic within the zone and the "downstream" end removed as the work progresses "upstream "

This operation allows the work zone to diminish in length as the work progresses Also, time requirements for periodically moving the major traffic controls at the beginning of the zone are eliminated These controls need only be removed at the completion of the maintenance activity



Evaluation

An effective technique for returning the highway to traffic where the type of maintenance activity permits

Equipment Required Traffic signs & cones, truck
Material Required None
Crew Required Two highway maintenance men

Task 2

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Detecting deteriorated concrete by use of electrical resistance measurements

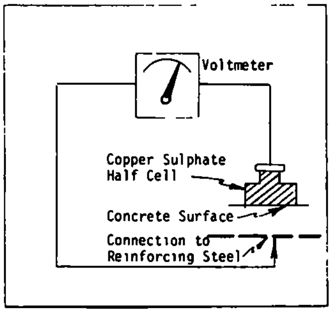
For Activities - Bridge deck pàtching and repair

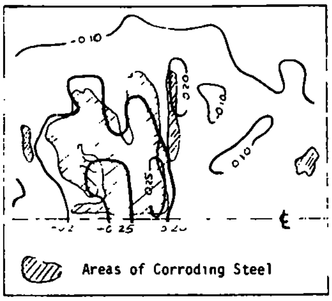
Description of Technique

A demonstration project is under way to determine the degree of steel corrosion in bridge decks by use of electrical resistance measurements

The presence of chlorides in moist decks sets up galvanic action between the steel reinforcing and the surrounding concrete A voltmeter can be used to measure the electrical potential of this galvanic cell

One lead from the voltmeter is attached to the reinforcing steel The other lead is attached to a saturated copper sulfate half cell which is set down anywhere on the deck By moving the half cell over the deck it is possible to measure and plot the equi-potential contours and obtain a "picture" of the deteriorated areas The greater the voltage, the greater the steel-concrete corrosion Measurements may also be taken through bituminous overlays





Evaluation

Experimental

Equipment Required Resistance measuring device
Material Required None
Crew Required 2 Technicians

Task 2

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Infra-red Photography

For Activities - Concrete bridge deck patching and repair

Description of Technique

An infra-red photograph is taken of the bridge deck Since the infra-red film is sensitive to minute differences in temperature, proper photo interpretations can determine areas of bridge deck deterioration because the temperature of sound concrete will be slightly different from that of deteriorated concrete with air and moisture entrainment

Evalutation

Experimental Requires high technical skills

Equipment Required Camera and accessories
Material Required Film
Crew Required One or two technicians Photo interpreter

Task 2

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Elastic-wave interval timer for detecting deteriorated concrete

For Activities - Concrete pavement and bridge deck patching and repair

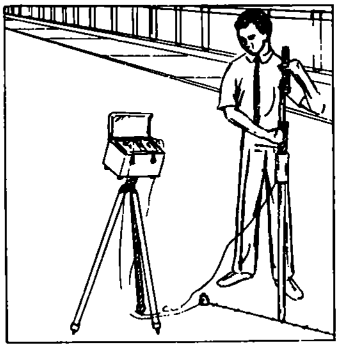
Description of Technique

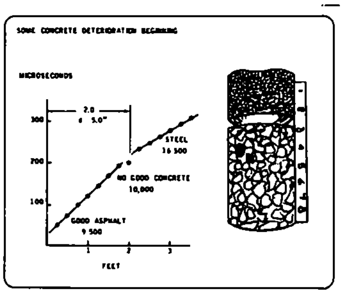
Concrete condition may be indicated by use of the principal that direct and refracted wave velocities are slower in deteriorated concrete than in sound concrete

Low-energy hammer impacts are applied on the surface of the material at 3-inch spacings and up to 3 feet from the receiver

The measured velocity in microseconds is compared with standard velocities of concrete having known properties

In addition, an indication of the condition of an asphalt-concrete interface may be obtained





Evaluation

Experimental Requires skilled technicians for interpretation of results

Equipment Required Micro-seismic interval timer
Material Required None
Crew Required 2 Technicians

Task 2

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Prototype equipment to detect delamination in concrete bridge decks

For Activities - Concrete bridge deck patching and repair

Description of Technique

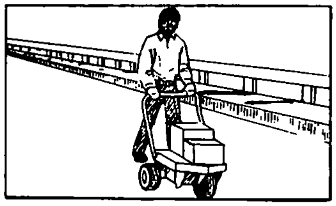
The Texas Transportation Institute has developed a prototype detector called a "Thumper "

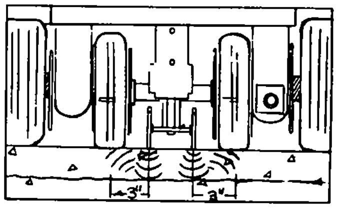
Two steel wheels transfer the impact created by an oscillating solenoid enclosed in the housing of the tapping device illustrated

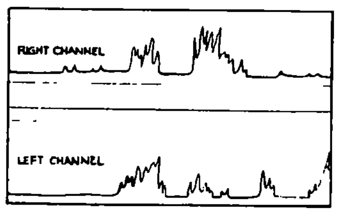
Two liquid filled rubber tire tubes are run in parallel with the tapper Pressure sensitive crystal microphones, located within the tubes, detect a return signal where delamination exists

A signal conditioner processes the detected signals and creates the paper tape readout illustrated

The readout tape speed is coupled to a wheel tachometer so that the exact location of delamination can be established







Evaluation

Experimental Requires skilled technicians to interpret results

Equipment Required	Thumper
Material Required	Paper tape
Crew Required	1 Technician
Production Rate	200 lin ft /min for two parallel 3-inch wide paths

Task 3

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Dislodge existing deteriorated pavement materials using Rocket Burner

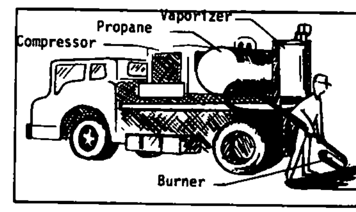
For Activities - Pavement surface repair or patching Joint repair

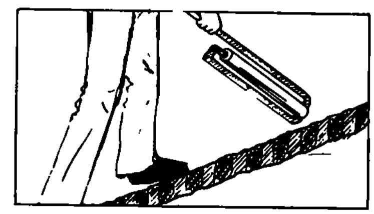
Description of Technique

A hand-held, cylindrical high-velocity air-fuel burner is used to break up and blow out decayed and cracked concrete or bituminous material prior to patching or joint repair

Nozzle velocity is 2000 to 3000 feet per second

Eliminates need to clean and dry patch or surface areas prior to material application





Evaluation

An effective and rapid technique for cleaning and drying patch areas and cracks

Equipment Required	Rocket Burner, compressor, propane tank, vaporizer, truck
Material Required	Propane gas and air supply
Crew Required	2 Maintenance Men
Production Rate	24 sq feet per min per inch of depth

Task 3

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Precise, rapid cutting of existing concrete with a Klarcrete Cutter

For Activities - Partial depth concrete pavement patching and repair

Description of Technique

Damaged or deteriorated areas in the surface of a rigid pavement can be precisely removed up to four inches deep and four square feet in area with the British-developed Klarcrete Cutter

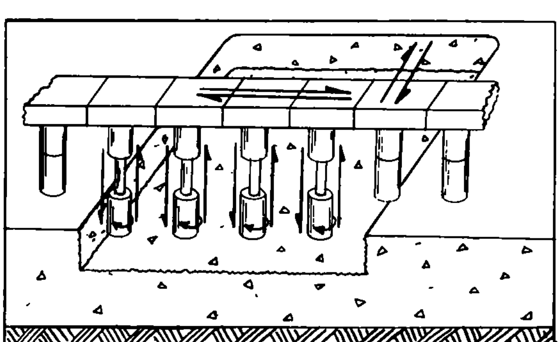
The machine is placed over the area to be removed and a series of pneumatic percussive hammers or cutters mounted on a rigid frame traverse the area, removing approximately 1/8 inch of concrete at a time

Evaluation

An advantage in using this technique is that surrounding concrete is not damaged

The precise cutting permits a precast slab to be used as the replacement material with a resulting reduction in roadway occupancy time

The automated design permits a two-man team to control up to three machines operating day or night



Equipment Required	Klarcrete Cutter, compressor
Material Required	None
Crew Required	2 Equipment Operators
Production Rate	4 ft x 4 ft x 4 in per 30 min

Task 3

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Cutting or sawing with a circular "cookie" cutter

For Activities - Full depth patching and repairing of pavement and pavement base or subgrade

Description of Technique

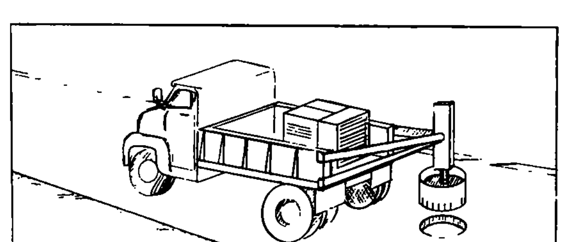
This water-cooled circular saw has carbide tipped blades and operates like a coring device or hole saw

It uses two sizes of saw heads either 36 or 60 inches in diameter

An experienced operator may be able to lift a sawed core out of the pavement as the saw head is extracted A three jaw tong is also available for lifting the cut disk

Evaluation

This technique of use to utility companies operating on urban streets



Equipment Required	"Cookie" cutter, electrical generator
Material Required	Water supply
Crew Required	1 Equipment Operator
Production Rate	3" asphalt and 6" concrete/20 minutes

Task 3

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Cutting and cleaning expansion joints with a trencher

For Activities - Sealing pavement joints

Description of Technique

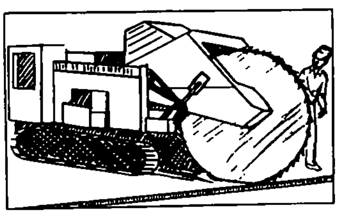
A concrete expansion joint, 3½ inches in width, can be cut quickly using a large self-propelled saw blade

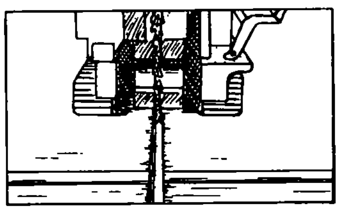
The Vermeer Trencher, illustrated, makes a full depth cut through an existing pavement slab in a single pass

The equipment has a 7-foot diameter wheel with 132 carbide tipped cutting teeth which are rotatable in their sockets to permit extended life

Evaluation

Efficient method for cutting and cleaning expansion joints to be filled with extruded neoprene, preformed bats or foamed in place chemicals Can also be used in lieu of concrete saw





Equipment Required	Vermeer or Ditchwitch Trencher
Material Required	Saw teeth, coolant
Crew Required	1 Equipment Operator, 1 Maintenance Man
Production Rate	1 lin ft full depth, pcc/min

Task 3

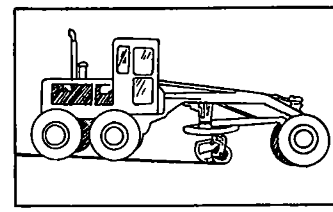
HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Cut perimeter of bituminous patch area or open longitudinal joint between P C C pavement and AC shoulder

For Activities - Bituminous pavement patching or repair, and joint sealing

Description of Technique

An adjustable cutter disk is mounted on a road grader or other equipment capable of forcing the disk into the surface of a bituminous concrete surface

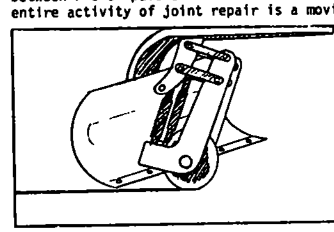


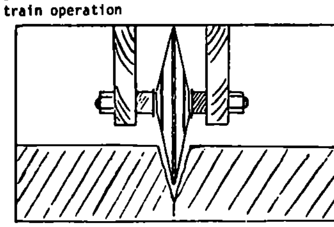
This operation delineates the area of pavement surface needing replacement

The technique is particularly suitable for longitudinal cuts prior to replacing the outer edge of a pavement

Evaluation

Useful only where long straight cuts are needed Particularly useful in opening longitudinal joint between P C C pavement and AC shoulder where the entire activity of joint repair is a moving train operation





Equipment Required	Mounted mobile wheel disk
Material Required	None
Crew Required	1 Operator
Production Rate	200 lin ft /min

Task 4

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Drill and lift sawed sections of concrete pavement

For Activities - Concrete pavement patching and repair, full depth

Description of Technique

The slab is sawed to a depth of 6 inches into 2' x 3' sections

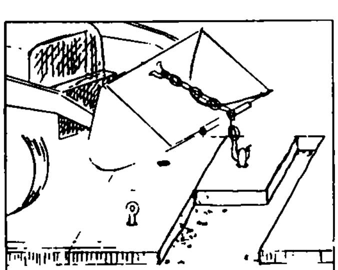
1½-inch diameter holes are then drilled into the center of each section

The slab sections are broken loose from the adjacent concrete by using a drop hammer

A lift pin or expansion bolt is inserted into the drilled hole and a front end loader is used to lift the pavement section out

Evaluation

This technique for removing deteriorated concrete combined with sawing the pavement into slabs and breaking them loose with an impact hammer is a rapid and effective method for preparing an area of reasonable size for a full depth patch



Equipment Required	Concrete saw, drill, tractor mounted drop hammer, front end loader
Material Required	Expansion eye bolts
Crew Required	1 Equipment Operator, 1 Maintenance Man

Task 4

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Vacuum Suction

For Activities - Concrete pavement repair

Description of Technique

After concrete P C C slab is sawed to 2' x 3' sections, the slab sections are then removed by a crane using vacuum pads to grasp the slab

Evaluation

Potentially a quicker method than technique 1 using eyebolts Still experimental Requires the development of practical hardware Method on a smaller scale is currently being used to place 4' x 2' x 4" pre-cast slabs for partial depth patches

Equipment Required	Concrete saw, or Vermeer cutter, crane, vacuum pads, air compressor
Material Required	None
Crew Required	One equipment operator, one maintenance man

Task 6

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Pull-in-place bottom deck forming for concrete bridge

For Activities - Concrete bridge deck repair

Description of Technique

The deteriorated area in the bridge deck will be removed back to sound concrete and cleaned in preparation for patching

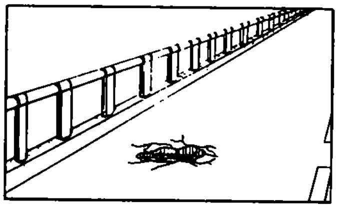
Ropes, wires or cable are lowered through the hole in the deck

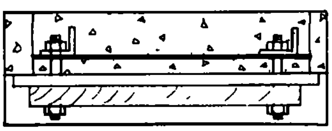
The ropes are fastened to the prefabricated form and lifted up to the underside of the deck

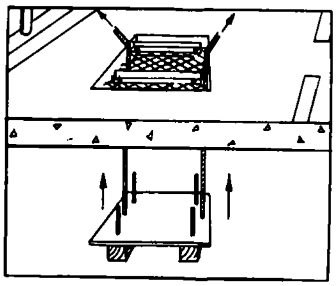
The forms are bolted through steel angles resting on the deck reinforcing steel The entire assembly is left in place after patch is poured

Evaluation

Fast and excellent technique for small patches and where access to the underdeck is not immediately available







Equipment Required None
Material Required Plywood forms, bolts and angles of various sizes as indicated
Crew Required 2 Maintenance Men

Task 8

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Klarcrete precast concrete partial depth repair system

For Activities - Concrete pavement patching or repair

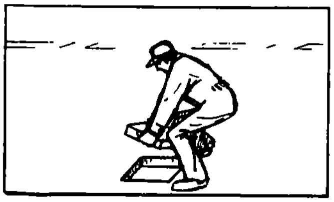
Description of Technique

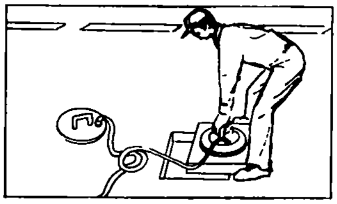
Concrete pavement sections are precast in specific dimensioned units for insertion into prepared holes

Small sections may be lowered into the hole by hand Vacuum suction plate(s) also may be used to lift the concrete section into place

The slab is firmly seated and leveled in a cement or epoxy mortar bed

The precast slab may be preheated for faster set of the mortar bed in cold weather





Evaluation

A rapid technique for making partial depth patches with minimum road closure time

Equipment Required Compressor, vacuum suction plates
Material Required Precast slab sections
Crew Required 1 Maintenance Man

Task 8

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Placing band-aid prefabricated bituminous patch

For Activities - Bituminous pavement surface repair

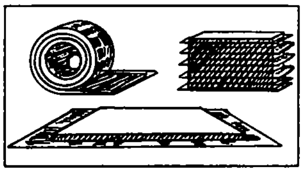
Description of Technique

The patches consist of a rubberized asphalt poured on newspaper or roofing paper and covered with a layer of stone chips and dusted with hydrated lime

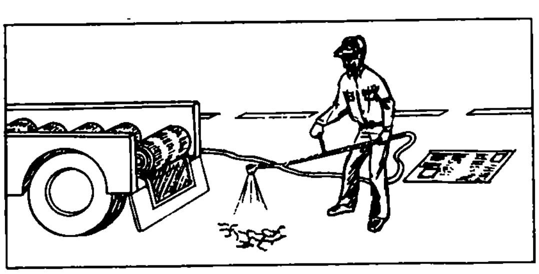
The patches may be prefabricated during winter months and stored for spring or summer application in rolls or pre-cut patches.

Lightly cracked bituminous pavement is first blown or swept clean of debris and deteriorated material A bituminous tack coat is sprayed in place

The band-aid patch is applied, paper up, over tack coat Traffic provides compaction as necessary and the newspaper soon wears off.



Evaluation More applicable to urban streets Has not received acceptance for highway application



Equipment Required Compressor, air hose and nozzle
Material Required Prefabricated Band-Aid patches
Crew Required 2 Maintenance Men

Task 8

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Compartmented truck-mounted batch plant for concrete

For Activities - Concrete pavement and bridge deck repair and patching

Description of Technique

On site mixing of concrete for large repair projects may be accomplished by a self-contained mobile mixer

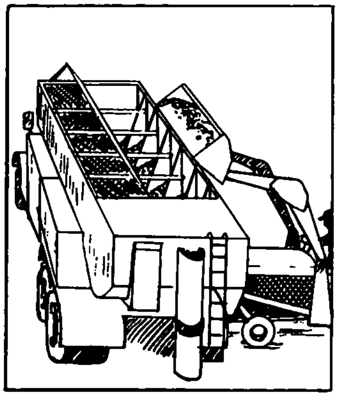
Compartments are filled with unmixed dry materials

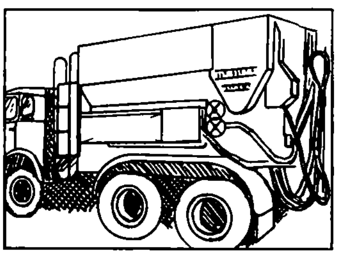
Upon arrival at the repair site, mix proportions and volume are selected and mixing of the required volume is accomplished at the site

The Concrete-Mobile unit illustrated is available in 4, 6, 8 or 10 cubic yard capacities

Evaluation

An excellent but expensive piece of equipment for mixing varying batch sizes of P C C for partial or full depth patches





Equipment Required Self-contained mobile concrete batch plant
Material Required Concrete materials as desired
Crew Required 1 Equipment Operator and 2 Maintenance Men
Production Rate 1 cubic yard/2-4 minutes

Task 8

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Insulated transport boxes

For Activities - Hot AC pavement patches and repair

Description of Technique

Truck or trailer mounted insulated transport boxes and infra-red heaters can be used to soften existing deteriorated bituminous surfaces and to add new hot-mix material for well-bonded patches and repairs

Evaluation

A valuable piece of equipment where a great deal of AC patching is required, can be purchased commercially or fabricated by highway shops Since patching is a seasonal operation, some highway departments fabricate or purchase units for insert on dump truck bodies

Equipment Required	Specially equipped truck with infra-red heater, insulated boxes for hot mix, receptacle for removed material and place for hand tools and portable roller
Material Required	Hot mix
Crew Required	Two Maintenance Men

Task 8

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Use of pre-cast concrete slabs for repair replacement

For Activities - Concrete pavement patching and repair

Description of Technique

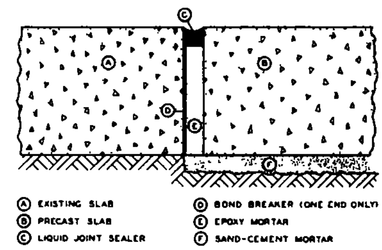
The Michigan Highway Department is repairing deteriorated concrete pavement with pre-cast concrete slabs

Following the removal of the concrete within a full-depth saw cut perimeter, the base is leveled with a template

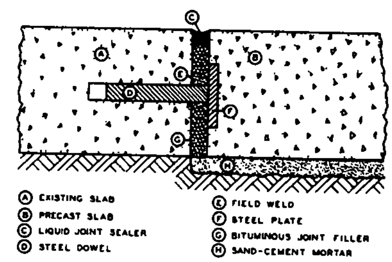
A sand-cement mortar slurry is mixed and poured in the excavated area and it is leveled to a required depth using a template

A pre-cast slab is lowered into place and held by pipes until mortar sets sufficiently to carry the slab weight

The two different joints being used by Michigan are illustrated



NON-DOWELED JOINT



DOWELED JOINT

Evaluation

An effective technique for replacing full depth deteriorated slabs with curing time cut to a minimum Lane closure is usually a maximum of four hours

Equipment Required	Crane, concrete mortar mixer, pipe
Material Required	Pre-cast concrete slab, mortar
Crew Required	1 Operator, 2 Maintenance Men

Task 9

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Compaction of small bituminous patches with portable vibratory compactor

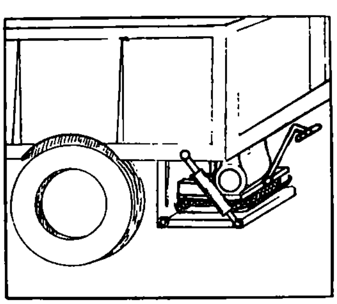
For Activities - Bituminous pavement patching and repairing

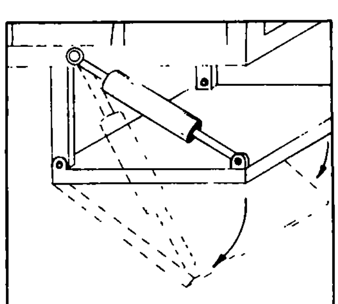
Description of Technique

Compaction of small bituminous patches may be accomplished using portable hand operated vibratory compaction plates

A convenient and rapid method to transport, load and unload such equipment is to use a truck mounted, hydraulically operated platform

By lowering the platform, the compactor may be loaded or unloaded easily by one man





Evaluation

An easily transportable valuable tool for compacting small asphalt patches

Equipment Required	Truck-mounted platform
Material Required	None
Crew Required	1 Maintenance Man

Task 10

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Cover joint or crack sealant with paper from roll

For Activities - Joint and crack sealing

Description of Technique

Once joints or cracks have been cleaned and filled, it is necessary to cover the uncured sealant on the pavement surface to prevent tracking

Rolled paper on a spool with an attached handle can be used to apply cover rapidly and conveniently

Evaluation

A simple and rapid technique to prevent tracking Traffic eventually wears away the paper

Equipment Required	Long handled paper roller
Material Required	Roll of paper
Crew Required	1 Maintenance Man
Production Rate	200 lin ft /min

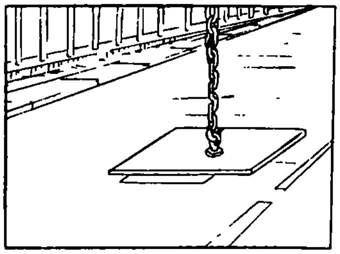
Task 11

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Construct temporary steel plate travel surface over patch

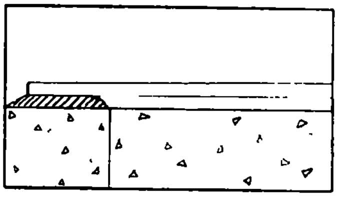
For Activities - Concrete pavement or bridge deck patching and repair

Description of Technique



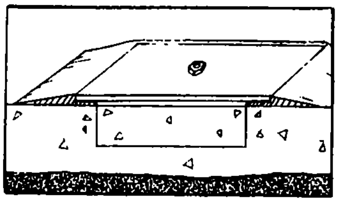
Steel plates of several thicknesses up to 1 inch and several dimensions should be carried in the supply truck ready for installation

A front end loader or small crane may be used to unload and place the plate by use of an eyebolt screwed into a nut welded to the center of the plate This nut is not removed from the plate



For concrete patches a 1-inch layer of bituminous cold mix may be spread around the edge of the patch to help seat the plate and allow space for plate deflection and avoid damage to the new concrete

Bituminous wedge courses are applied around the entire plate but are not required if the plate is beveled on the edge



Evaluation

Permits traffic to use lanes while concrete is curing Where lanes must be opened for heavy traffic, this is an effective technique Normally limited to pavements with traffic speeds less than 35 mph Traffic with greater speeds tend to move the plate

Equipment Required	Front-end loader or crane, hook, eyebolt
Material Required	Steel plate, bituminous mix
Crew Required	1 Equipment Operator, 2 Maintenance Men

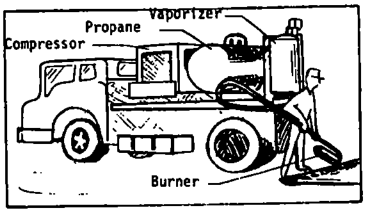
Task 12

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Clean out cracks with rocket burner

For Activities - Pavement crack sealing

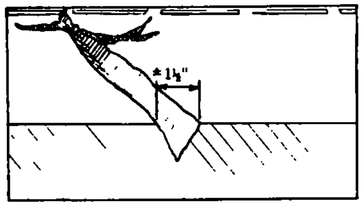
Description of Technique



Cracks and joints may be cleaned of debris or deteriorated material prior to filling or sealing with a propane fueled Rocket Burner

In bituminous pavement cracks, the Burner forms a V-shaped section which is clean and ready for application of crack filler material

Also moisture in the cracks or joints is removed in the process of cleaning



Evaluation

An effective technique in AC pavement or AC overlays

Equipment Required	Rocket Burner, compressor, propane tank, vaporizer, truck
Material Required	Propane and air supply
Crew Required	2 Maintenance Men
Production Rate	Summer--50 joints/day, Winter--100 joints/day

Task 13

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Fill expansion joint with foamed polymer

For Activities - Concrete pavement expansion joint sealing

Description of Technique

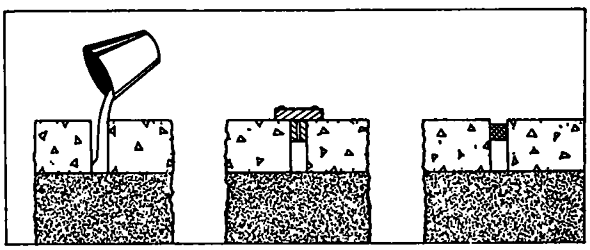
After thoroughly cleaning the expansion joint, a foamed polymer is mixed in a bucket with a small power-driven paint mixer

It is immediately poured to within two inches of the pavement surface Forms are placed to contain the polymer during curing and to insure a two-inch deep space for the asphalt material

Once cured, the joint is sealed with a poured rubberized asphalt

Evaluation

Precisely cut joints are not necessary Adhesion to the concrete sides of the joint is not long lasting under most environmental conditions



Equipment Required	Bucket and paint mixer
Material Required	Polymer, rubberized asphalt, block form
Crew Required	1 Maintenance Man

Task 13

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Fill expansion joint with preformed bats

For Activities - Concrete pavement expansion joint sealing

Description of Technique

Preformed expanded bats are used as relief filler for newly sawed expansion joints

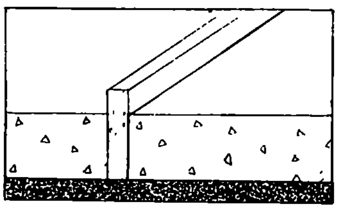
After thoroughly cleaning, hot asphalt is poured into the bottom and the bat is compressed into the open joint Asphalt may also be poured along the sides of the filler after it is in place to eliminate flotation

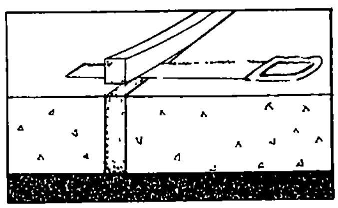
After placing, the filler material is sawed flush with the top of the pavement

Resawing a new joint should take place when the joint compresses to ¼ inch in width

Evaluation

Expanded bats have better compressibility than felt or fibre bats All tend to work loose because adhesion under adverse environmental conditions deteriorates





Equipment Required	Saw
Material Required	Expanded polyethylene, polyurethane or polystyrene or asphalt impregnated felt or fibre bats
Crew Required	2 Maintenance Men
Production rate	To be determined

Task 14

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Layout mudjack holes with the aid of a template

For Activities - Concrete pavement mudjacking

Description of Technique

Prior to drilling holes through a concrete pavement for mudjacking the holes must be laid out

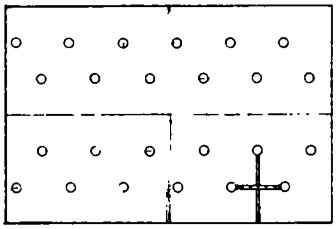
Frequently specifications exist for the mudjack holes layout pattern A pattern or ruled template can expedite the hole layout operation and insure compliance with specifications

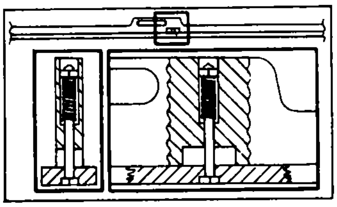
A paint spray can also is useful in noting the locations indicated by the template

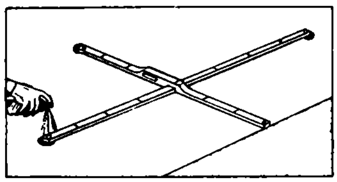
The template shown rotates about a spring-loaded bolt and the two arms may be lined up for storage

Evaluation

Template expedites hole location where standardized hole locations are required







Equipment Required	Template
Material Required	1 Paint spray can
Crew Required	1 Maintenance Man
Production Rate	18 holes/minute
Production Unit Cost	$ 08/hole

Task 14

HIGHWAY MAINTENANCE TECHNIQUE DESCRIPTION

Technique - Trench shoulder area and drive pipe horizontally beneath pavement, using pneumatic hammer

For Activities - Concrete pavement mudjacking

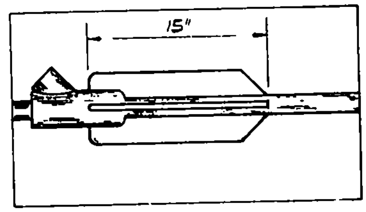
Description of Technique

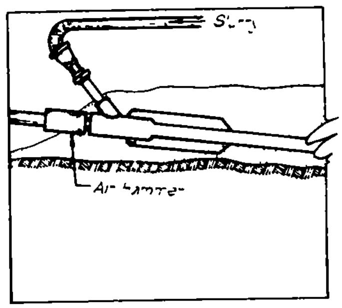
Dig trench perpendicular to pavement shoulder to accommodate pipe and pipe driver with hand tools

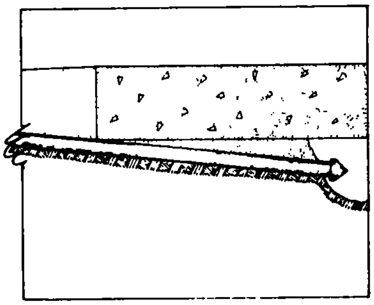
Drive pipe with pneumatic hammer horizontally into void beneath pavement

Evaluation

This approach to mudjacking eliminates the need to occupy the pavement







Equipment Required	Hand tools, air compressor, pneumatic hammer, special mudjack head, pipe
Material Required	None
Crew Required	2 Operators

APPENDIX F

STANDARD TIME DATA

All the information that could be obtained from the film records collected during the field studies was transcribed for analysis Each activity element identified and studied is briefly described in summary form in Table F-1. A mathematical statement of the relationships established is presented under the standard time model heading and makes use of the following variable terms

T = time estimate (min)
A^* = saw cut area, length $\times$ depth (sq ft)
A = surface area (sq ft)
V = volume (cu ft)
L = length (lin ft)
P = applications (number)
R = rate (lbs/sq ft)

Where applicable, the statistics developed for each activity element are shown These fall under the following headings:

n = number of observations
$S\,D.$ = standard deviation of the mean time estimate
$S\,E$ = standard error of the relationship established in a regression analysis
Corr Coef. = coefficient of correlation for the regression
t = student's t for the regression coefficient
F = Fisher F for the regression analysis of variance
$E\%$ = the efficiency factor assigned to the model

TABLE F-1

STANDARD TIME DATA

Techniques and Technique Elements	Standard Time Model	n	S.D.	S.E.	Corr. Coef.	T	F	E % Factor
Task 3								
Saw Concrete								
Carbide Blade	T = 0.2+4.96A*	133	--	0.3	0.81	16	242	100
Diamond Blade	T = 0.3+1.33A*	96	--	1.0	0.96	39	1134	100
Break with Air Hammer								
F.D.[a] P.C.C. Pavt-60#	T = 3.5V	1	--	--	--	--	--	90
P.D.[b] P.C.C. Pavt. or B.D.[c]-60#	T = 1.9+7.19V	47	--	1.8	0.97	27	718	90
P.D. P.C.C. B.D.-30#	T = 3.1+30.65V	26	--	14.8	0.79	6	39	90
P.D. Comp. B.D.-90#	T = 20.7+12.8V	3	--	5.3	0.94	3	8	90
Break with Hydraulic Ram								
9" P.C.C.	T = 1.8+.07A	18	--	4.6	0.87	7	47	90
11" P.C.C.	T = 1.8+.22A	2	--	6.0	--	--	--	90
Cut with a wheel cutter								
P.C.C.	T = 0.33L	6	--	.7	--	--	--	100
Bituminous	T = 0.16L	3	--	.2	--	--	--	100
Break Concrete with Percussive Cutter	T = 3.2+211(V/PH)	(Model based on manufacturer's data) --	--	--	--	--	--	90
Burn bituminous pavement with Propane Burner	T = 0.012A	5	--	.6	--	--	--	100
Break Concrete with Crane/ Drop Hammer	T = 0.05A	3	--	.5	--	--	--	90
Task 4								
Lift Concrete with Crane								
Insert Pins	T = 4.7	6	0.9	--	--	--	--	90
Lift w/Crane	T = 1.7	6	0.5	--	--	--	--	90
Remove Pins	T = 2.2	6	0.7	--	--	--	--	90
Remove Broken Concrete With F.E. L. or Hydraulic Hoe	T = 2.2+0.108V	23	--	6.1	0.96	16	254	95
Remove Broken Concrete With Backhoe From 2' Expansion Joint	T = 0.54V	2	--	.7	--	--	--	90
Remove Broken Concrete Manually								
Full Depth	T = 4.67V/C	1	--	--	--	--	--	80
Partial Depth	T = 0.1+6.33V	39	--	2.8	0.98	34	1153	80
Task 5								
Blow Clean Patch Area								
P.D.	T = 0.7+0.07A	64	--	0.8	0.97	31	956	95
Surface	T = 4.0+0.003A	3	--	0.4	0.90	2	4	95
Sandblast								
P.D.	T = 0.30A	4	--	1.5	1.00	63	4011	80
Surface	T = 0.095A	2	--	.3	--	--	--	80
Prepare Base for Pre-cast Slab With Backhoe	T = 7.4	5	2.0	--	--	--	--	90
Manually Prepare Base								
Following Hoe	T = 13.7+0.037A/C	7	--	2.2	0.87	4	15	80
Following F.E.L.[d]	T = 22.0+0.037A/C	3	--	2.2	--	--	--	80
Compact Base with Mechanical Tamper	T = 0.9+0.04A	6	--	0.6	1.00	26	687	90

TABLE F-1 (*continued*)

Techniques and Technique Elements	Standard Time Model	n	S.D.	S.E.	Corr. Coef.	T	F	E % Factor
Task 6								
Form Full Depth Concrete Patch	T = 1.64L/C	5	--	13.4	0.89	3	11	80
Place Construction Joint Assembly	T = 8.60	7	1 8	--	--	--	--	80
Place Dowels								
Drill and Move	T = 1.82D	12	--	.5	--	--	--	90
Mix Grout	T = 1.1	1	--	--	--	--	--	80
Place and Move	T = 1.18D	24	--	.5	--	--	--	90
Task 7								
Place Tack Coat								
Epoxy - Brush	T = 0.3+0.20A	23	--	0.8	0.99	31	974	95
Epoxy - Rag	T = 1.1+0.44A	20	--	0 8	0 77	5	29	95
Cement Grout - Broom	T = 1 0+0 09A	25	--	1 5	0 80	6	40	95
Asphalt - Broom	T = 1.0+0.044A	2	--	.5	--	--	--	95
Task 8								
Place Large Pre-cast Concrete Slab								
Insert Pins	T = 1.5	7	0.7	--	--	--	--	90
Lift and Place	T = 4 7	5	1.4	--	--	--	--	90
Check Level	T = 1 0	4	0.5	--	--	--	--	90
Remove Pins	T = 0 9	7	0 4	--	--	--	--	90
Place Ready-mix Concrete								
Full Depth	T = 0.205V/C	23	--	10.7	0 88	8	72	80
Partial Depth	T = (0 2+0 56V)/C	10	--	1.9	0 90	6	34	80
Pre-cast Mortar	T = 2.4+.03A	4	--	.9	0.67	1	1	80
Hand Mix Patch Material								
Batch	T = 4.4	7	0.6	--	--	--	--	80
Mix Cement	T = 1.1+.27V^3	23	--	.3	0.98	25	647	80
Mix Epoxy	T = 11 37	1	--	--	--	--	--	80
Place	T = 0 5+0 97V	113	--	0.8	0 87	18	338	80
Mix Concrete in Mortar Mixer								
Batch Cement (Prefilled) (Buckets)	T = 1 2	2	0.4	--	--	--	--	90
Batch Cement (Filling) (Buckets)	T = 4 1	5	0.4	--	--	--	--	100
Mix Cement	T = 1 6	7	1.0	--	--	--	--	100
Mix Epoxy	T = 13.3	3	1 2	--	--	--	--	100
Place	T = 0.5+0.97V	113	--	0 8	0.87	18	338	90
Task 9								
Hand Finish								
F D P.C C.	T = 15.8+0.066A/C	10	--	6 1	0 70	3	8	80
P D. Cement	T = (1 9+0 17A)/C	51	--	1.2	0.93	18	327	80
*P.D Epoxy	T = (2 2+0 5A)/C	21	--	3 7	0.88	8	67	80
Manually Compact Bituminous Patch	T = 0 097A	1	--	--	--	--	--	--
Roll Bituminous Patch With Truck	T = 0.097A	2	--	.4	--	--	--	95
Vibrate Concrete								
Full Depth	T = 0 02V	6	--	1.3	0.92	5	23	90
Partial Depth	T = 0.3V	9	--	0.3	0.81	4	14	90
Vibrate & Screed Concrete	T = 0 20L	8	--	0.8	0.98	11	119	80
Compact Bituminous Patch With Pneumatic Roller	T = 0.003A	1	--	--	--	--	--	-

Techniques and Technique Elements	Standard Time Model	n	S.D.	S.E.	Corr. Coef.	T	F	E % Factor
Task 10								
Spray Curing Compound	T = 0.024A	37	--	1.2	0.92	14	105	95
Place Burlap Cure Strips	T = 0.036A/C	18	0.1	--	--	--	--	85
Hand Broadcast Sand	T = 0.038A/C	2	--	.3	--	--	--	80
Cure Epoxy With Acetylene Torch	T = A/(0.2+ 07A)	3	--	1 0	0.99	18	324	80
Task 12								
Clean Routed Bituminous Cracks With Rocket Burner	T = 0.05L	4	--	.5	--	--	--	95
Clean Contraction Joints Router Method								
Hook	T = 0.59/Jt.	14	0.4	--	--	--	--	80
Rout	T = 1 50/Jt.	13	1.0	--	--	--	--	95
Blow Clean	T = 1.24/Jt.	20	0.4	--	--	--	--	95
Wire Brush Method								
Pick	T = 3.73/Jt	8	1.9	--	--	--	--	80
Brush	T = 0.891/Jt	10	0.3	--	--	--	--	95
Blow Clean	T = 1 24/Jt	20	0.4	--	--	--	--	95
Task 13								
Pour Sealant Into 12' Joint With Cornucopia	T = .50	60	.3	--	--	--	--	85
Pressure Apply Sealant to 12' Joint	T = .29	62	.2	--	--	--	--	95
Install Preformed Filler	T = 9.29	5	3.3	--	--	--	--	80
Task 14								
Drill Concrete With Air Hammer	T = 1.85/hole	101	0.7	--	--	--	--	90
Task 16								
Use Squeegee to Apply Seal	T = 5 5+0.028A/C	10	--	5.8	0.65	2	6	80
Task 17								
Apply Sand Blotting With Wheel Mounted Spreader	T = 0.015AR	2	--	.2	--	--	--	90
Apply Sand Blot Manually	T = 0 024AR/C	3	--	2.5	--	--	--	80

[a] F D = Full Depth
[b] P D = Partial Depth
[c] B D = Bridge Deck
[d] F E L = Front End Loader

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