NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 98

RESEALING JOINTS AND CRACKS IN RIGID AND FLEXIBLE PAVEMENTS

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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RESEALING JOINTS AND CRACKS IN RIGID AND FLEXIBLE PAVEMENTS

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of special interest to maintenance engineers and others seeking information on resealing joints and cracks in pavements. Detailed information is presented on materials, procedures, and evaluation criteria.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Sealing inhibits the entrance of water into the pavement structure through cracks and joints. This report of the Transportation Research Board includes information on materials and techniques for resealing and criteria for deciding when to reseal.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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Adrian G. Clary, Engineer of Maintenance, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

RESEALING JOINTS AND CRACKS IN RIGID AND FLEXIBLE PAVEMENTS

SUMMARY

Many pavement maintenance engineers believe that crack and joint sealing is beneficial, whereas others argue that its value is questionable because of its short life. Crack and joint sealing can be considered as both corrective and preventive maintenance in that it corrects a leaking surface and prevents or slows development of pavement problems.

A total of 35 of the 43 agencies responding to the questionnaire reseal joints in rigid pavements; the average frequency is once every 5 yr. A total of 33 agencies seal cracks in rigid pavements (also about once every 5 yr), and 39 agencies seal cracks in flexible pavements (3.6-yr frequency). The most common reason given for sealing and resealing is to keep out water and thus extend pavement life. Several agencies reported that sealing or resealing also prevents or retards spalling and raveling at cracks and joints.

The criterion most often used in determining when to reseal is the width of crack. A pavement condition survey or evaluation is also often used. Several states have developed policy statements on the sealing and the resealing of joints and cracks; these are based on studies or operating experience.

Temperature and moisture cause pavements to expand and contract, which stresses the sealant in joints and cracks and may cause cohesive or adhesive failure. The shape of the sealant reservoir is important in preventing these failures. The shape factor—the ratio of width to depth—of a sealant contributes to its effectiveness. Various studies of sealants indicate that the proper shape factor for the particular sealant increases the life of the sealant.

Most states use some type of asphalt material to seal and reseal cracks and joints. The addition of rubber to the asphalt significantly increases the effectiveness of the material. However, unless the sealant is installed properly, the chance of failure increases. Various equipment and techniques are used to install sealants; resealing, for example, may require removal of the existing sealant, sawing or routing the joint or crack, cleaning and drying the joint or crack, and installation of new sealant. Many agencies have written procedures for resealing joints and cracks; and it is important to make sure that maintenance crews are actually following the procedures.

Among the factors to be considered in deciding whether cracks and joints in a section of pavement should be resealed are the highway classification, traffic volumes, climate, pavement type and condition, subgrade type and characteristics, joint and crack type and condition, and crack frequency. Many agencies have maintenance performance standards that not only describe the sequence of operations, but also provide a measure of performance in both the quality of the end product and the quantity of work to be accomplished. A moisture accelerated distress index and a moisture distress index, which have been developed recently, are potential tools for determining whether crack and joint sealing is desirable.

Recommendations of this synthesis include:

- More experimental work is needed under a wide range of conditions to document the effectiveness of sealing cracks and joints. The results should be compared to unsealed control sections.
- Information is needed on the costs of sealing, including materials, preparation, and traffic control.
- More data are needed on the effective life of the various sealing materials and on the effect of the various placement techniques on sealant life.

CHAPTER ONE

INTRODUCTION

There has not been universal agreement among pavement maintenance engineers regarding the effectiveness of crack and joint sealing operations. Crack and joint sealing is considered to be beneficial by some, whereas others question its value, contending that the operation is not cost effective because of its short life and the resultant need for frequent renewal. In addition, there is the argument that it may not make any difference if the cracks or joints of some pavements are left unsealed. Variations in pavements, subgrades, climate, traffic, and sealing materials can affect the performance of the pavement, masking the effects of sealing or not sealing cracks or joints.

Other questions considered to be of significance regarding crack and joint sealing operations include: (a) If crack and joint sealing is beneficial, then at what point in the development of a crack or failure of a joint sealant should it be sealed or resealed? (b) What sealant material(s) should be used and how should it be applied? (c) What preparation is required for a joint or crack to assure a durable and effective seal? (d) After sealing a joint or crack, when should it be resealed? (e) What are the benefits of a crack and joint sealing or resealing program? (f) Is it cost effective?

When done properly, resealing joints in rigid pavements is both difficult and expensive. It can also be expensive when it is not done correctly. Among the variables that influence the effectiveness of sealing or resealing joints in concrete pavements are: pavement type, joint spacing, subgrade, climate, traffic, pavement age, sealing materials, techniques, and quality of inspection at time of installation. Failure to properly consider these variables can result in short life.

Hogan (*1*) stated:

> Most engineers tend to underestimate the amount of surface water that can enter the structural section from above. It is not uncommon for engineers to concern themselves with highway pavement while paying too little attention to subdrainage, despite the fact that most pavement failures originate in the base and subgrade. Recurring spring maintenance problems—potholes and broken pavement—result from freeze-thaw action of ground water. It is in the prevention of these failures, rather than their patching, that engineering should be more evident. Water enters the base course and subbase through cracks in flexible pavement, cracks in rigid pavement, and joints between the pavement and shoulder. Rainwater and melting snow can enter the subbase through unpaved medians and shoulders. Groundwater can also be drawn into the base course by capillary action. Preventing water from reaching the pavement foundation is extremely difficult, however, it is the only practical alternative since the other governing factors are nearly impossible to control.
>
> The solution to the highway and roads problem of excess water in the subgrade is to provide drainage for its collection and removal. An attempt has been made to solve the problem by sealing water out of the structural section or by increasing structural strength of the roadway pavement or underlying subbases to overcome the weakening effect of wet subbase.
>
> The elimination of as much water as possible from the roadway base is of paramount importance. Many maintenance functions are essential to achieve this objective including cleaning ditches and drainage structures to lower water table, filling cracks and potholes to prevent infiltration of surface drainage, and resurfacing when these preventative maintenance measures no longer are cost effective.

Crack sealing and joint resealing can be considered as both corrective and preventive maintenance. They correct an existing problem of a leaking surface and they help to prevent or slow the development of more serious pavement problems. The timing for undertaking a maintenance activity is considered to be an important factor in delaying the onset of more serious problems. Thornton and Gulden (*2*) stated:

> Studies done by such states as California and Georgia have shown that the entrance of free surface water through these joints and cracks, in combination with heavy loads and the presence of erodible materials, causes the types of pavement distress commonly found on heavily traveled jointed concrete pavements—e.g., faulting and slab cracking.

Thornton and Gulden (*2*) also identified six discrete philosophies concerning joint sealing:

> 1. Watertight sealing of joints is not possible and may as well not be attempted.
> 2. Joints should be sealed with relatively inexpensive sealant. Although adhesive or cohesive failure occurs in cold weather, the sealant is very effective in reducing the quantity of water that can infiltrate a joint.
> 3. Joints should be filled with a material that will keep incompressibles from restricting closing movement. The sealant probably will not be watertight but will keep water infiltration through joints to a minimum.
> 4. Sealing of transverse contraction joints is of no value unless the longitudinal shoulder joint is sealed.
> 5. Sealing of transverse contraction joints in conjunction with edge drains located near the longitudinal shoulder joint is effective.
> 6. A pavement system can be effectively sealed with sealants now available. An attempt should be made to keep transverse and longitudinal joints sealed. Edge drains will not be needed to remove infiltrated water. Underdrains should be used as required to remove subsurface water.

These philosophies are also applicable to sealing cracks on both flexible and rigid pavements.

PURPOSE OF SYNTHESIS

The objectives of this synthesis are:

1. To identify the various materials and techniques used to reseal joints and cracks in rigid pavements and cracks in flexible pavements;
2. To determine the costs associated with the use of these materials and techniques;
3. To determine changes in pavement performance resulting from resealing joints and cracks; and
4. To develop criteria for resealing joints and cracks if this practice is found to be beneficial.

The scope of this report is limited to the sealing of individual cracks and joints; such area-wide crack sealing techniques as surface treatments, slurry seals, or squeegee-type applications are not described. However, it should be noted that slurry-seal material is used, in some cases, to seal individual cracks and as such is discussed in this synthesis.

Information was obtained for this synthesis through literature searches, observations, and questionnaires sent to the 50 states, the District of Columbia, Puerto Rico, Guam, New Brunswick, Northwest Territories, Nova Scotia, Ontario, Virgin Islands, and the New Jersey Turnpike Authority. Responses were received from 40 states and 3 other agencies regarding joint and crack resealing practice. Various materials and techniques that have been used are identified and evaluated.

GLOSSARY

Flexible Pavement Cracking

Flexible pavements crack for a variety of reasons. A knowledge of the various types of cracking is important in determining the proper treatment. Several reports (*3–10*) describe various forms of cracking along with illustrative examples. The various forms of cracking in flexible pavements and the probable causes are identified below.

Alligator Cracking (Chicken Wire Cracking)—"Interconnected or interlaced cracks forming a series of small polygons that resemble an alligator's hide" (*10*). Probable cause: "Generally, unstable base or roadbed; weakening of pavement caused by embrittlement over a resilient foundation" (*10*).

Block Cracking (Map Cracking)—"Interconnected cracks forming a series of large polygons usually with sharp corners or angles" (*10*). Probable cause: "Hardening and shrinkage of the asphalt; roadbed becoming unstable. Unless corrected, block cracking may increase until it becomes alligatored as a result of water entering the roadbed and decreasing its stability" (*10*).

Contraction Cracking (Transverse Cracking, Shrinkage Cracking)—"Horizontal separation of a pavement layer. . . . A crack approximately at right angles to the pavement centerline" (*10*). Probable cause: "When the temperature of a bituminous material is lowered, the bitumen undergoes a relatively large reduction in volume. The change may be so great that when the surface overlay is not properly bonded to the underlying material or if the binder is very stiff, the overlay will crack in order to relieve the contracting stresses".

Longitudinal Cracking—"A crack or break approximately parallel to the pavement centerline" (*10*). Probable cause: "Cold or improperly constructed joint between pavement sections; reflection of underlying joint; settlement of roadbed under traffic; possibly shrinkage of surface course of insufficient pavement thickness" (*10*).

Reflection Cracking—"Cracking of a resurface or overlay above underlying cracks or joints" (*10*). Alligator cracks, longitudinal cracks, and block cracking can also be reflection cracks. Probable cause: "Movement of underlying pavement, or lack of bridging over underlying cracks or joints; possibly shrinkage of underlying layer" (*10*). Also, the differential thermal expansion and contraction of the composite layers can cause reflection cracking.

Edge Cracking—"Longitudinal Cracking near the edge of the pavement" (*10*). Probable cause: "Inadequate thickness of the pavement to support traffic; vertical settlement or lateral displacement of embankment or both if there are no traffic loads" (*10*). Also, lack of sufficient lateral support can cause edge cracking. Infiltration of water softens the base at pavement edges; i.e., poor shoulder drainage causes edge cracking.

Rigid Pavement Cracking

The three basic types of rigid pavements are: jointed plain concrete, jointed reinforced concrete, and continuously reinforced concrete. Several reports (*3–12*) describe the types of cracks and joint distress relating to concrete pavements along with the causes of the defects and photographs of the distress.

Corner Cracking (Corner Break)—"A break in a pavement at the corner of the slab near the junction of the transverse joint and longitudinal joint or slab edge" (*10*). Probable cause: "Overloading the pavement slabs at or near the corners; an unstable foundation or voids formed because of loss of foundation material under the slab" (*10*). Underdesigned pavements contribute to this problem.

Diagonal Cracking—"A crack similar to a corner crack except that the fracture extends diagonally across the end of the slab" (*10*). Probable cause: "Overloading at slab ends; insufficient thickness of pavement or lack of support from the roadbed" (*10*). Frost action and undersealing also contribute to this form of cracking.

Longitudinal Cracking—"A crack or break approximately parallel to the pavement centerline" (*10*). Probable cause: "Lateral contraction; lateral movement and settlement of the roadbed; possible lateral bending or curling" (*10*). Inadequate depth of constructed center-line or longitudinal joint (sawed or formed with polyethylene strips) and excessive slab width can create this problem.

Transverse Cracking—"A crack or break approximately at right angles to the pavement centerline" (*10*). Probable cause: "Insufficient contraction joints or weakened plane joints; overloading an upward curled slab having inadequate roadbed support" (*10*). Other probable causes are late sawing of joints, resulting in minute cracking that eventually will be visible, sawing joints too shallow and panel lengths too long, inadequate steel, and locked dowels.

Random Cracking—"Unrestrained, or uncontrolled, irregular break or separation of the slab" (*10*). A transverse crack is also a random crack as is a longitudinal crack. Probable cause: "Overloading of unreinforced slab; inadequate roadbed support" (*10*).

Rigid Pavement Joints

Three basic types of joints are associated with rigid pavements: transverse joints, longitudinal joints between traffic lanes, and longitudinal joints between traffic lanes and paved shoulders. The transverse joints may be expansion joints, contraction joints, and construction joints [for detailed discussion of these joints see *NCHRP Synthesis of Highway Practice 19*

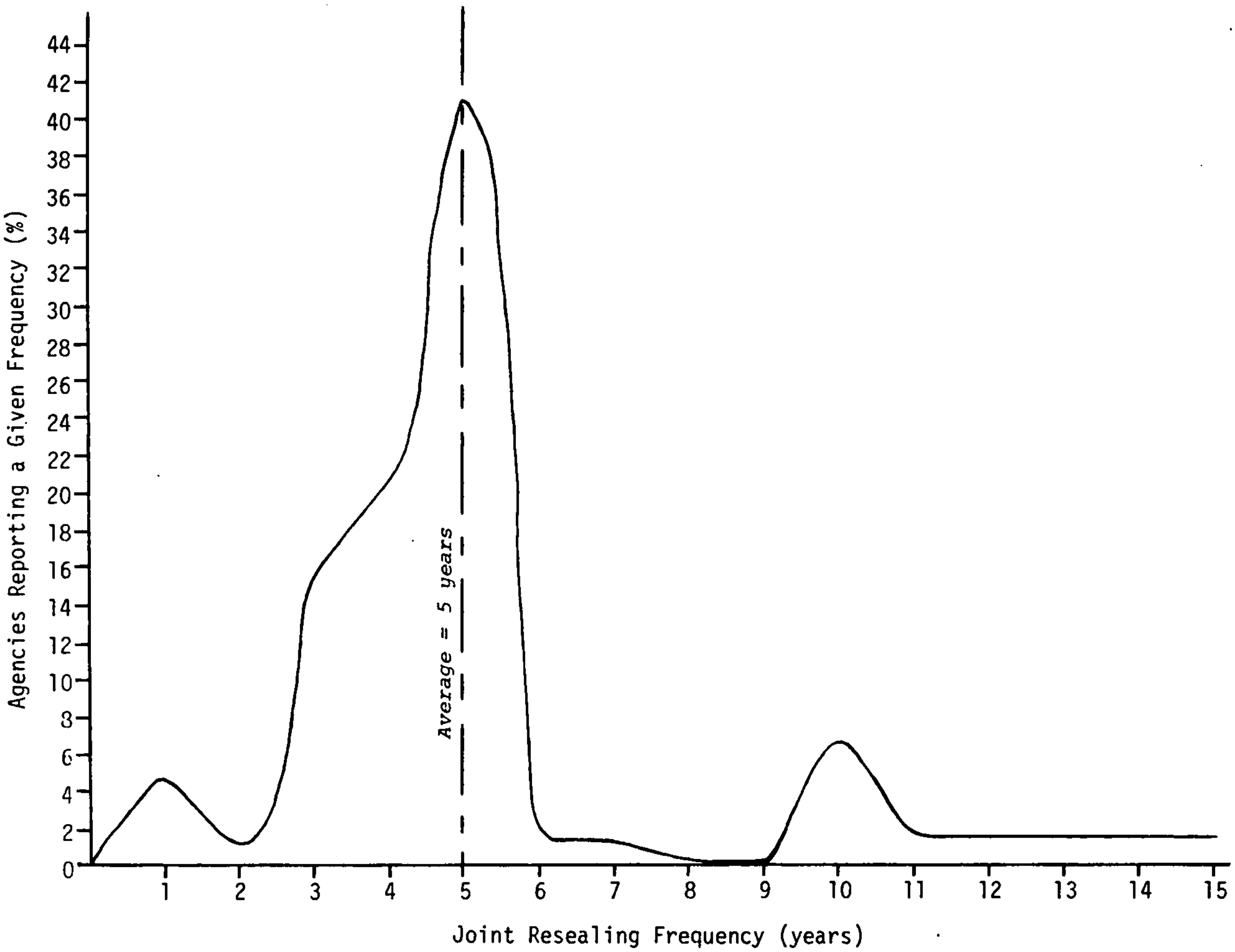

FIGURE 1 Frequency for resealing joints in rigid pavements.

(*11*)]. Joint sealant failures include joint sealant extrusion, cohesion failure, loss of seal, bond (adhesion) failure, hardening of the sealant, and stripping of the joint sealant.

JOINT AND CRACK RESEALING PRACTICE

Rigid Pavement Joints

In response to the questionnaire, 35 (81 percent) of the 43 responding agencies indicated that they reseal joints in rigid pavements. The amount of activity in this area varied considerably from agency to agency and ranged from a low of 5 lane-miles (8 km) per yr to 2,095 lane-miles (3,400 km) per yr. The least amount spent by a state to reseal joints was $11,379 per yr and the highest annual expenditure was $3.5 million.

The frequency for resealing joints in rigid pavements varied from once per yr to once every 10 to 15 yr. A frequency distribution for time to resealing as reported by the agencies is presented in Figure 1. The average frequency is approximately once every 5 yr.

The agencies reported various reasons for resealing joints. The reason most frequently given was to extend the life of the pavement. This was followed by: (a) to keep water out of the base and subbase, (b) to keep incompressibles out of the joint itself, and (c) to retain the riding qualities of the pavement. Extending pavement life and retaining the riding qualities of the pavement were generally reported as being the direct result of keeping water out of the base and the subbase and incompressibles out of the joint. Other reported reasons included reducing blow-ups and pumping and preventing spalling, which are associated with keeping water and debris out of the pavement system. Geographical differences do not appear to be a factor in the reasons given for resealing joints; both northern and southern states reported the same reasons for resealing joints in rigid pavements.

Rigid Pavement Cracks

Thirty-three agencies reported that they seal or reseal cracks in rigid pavements. It was not possible to ascertain how much work is being done or how much money is being spent in sealing or resealing cracks in rigid pavements because these funds are generally included in the amounts specified for resealing joints. The frequency for resealing cracks in rigid pavements as reported by the various agencies is shown in Figure 2. The av-

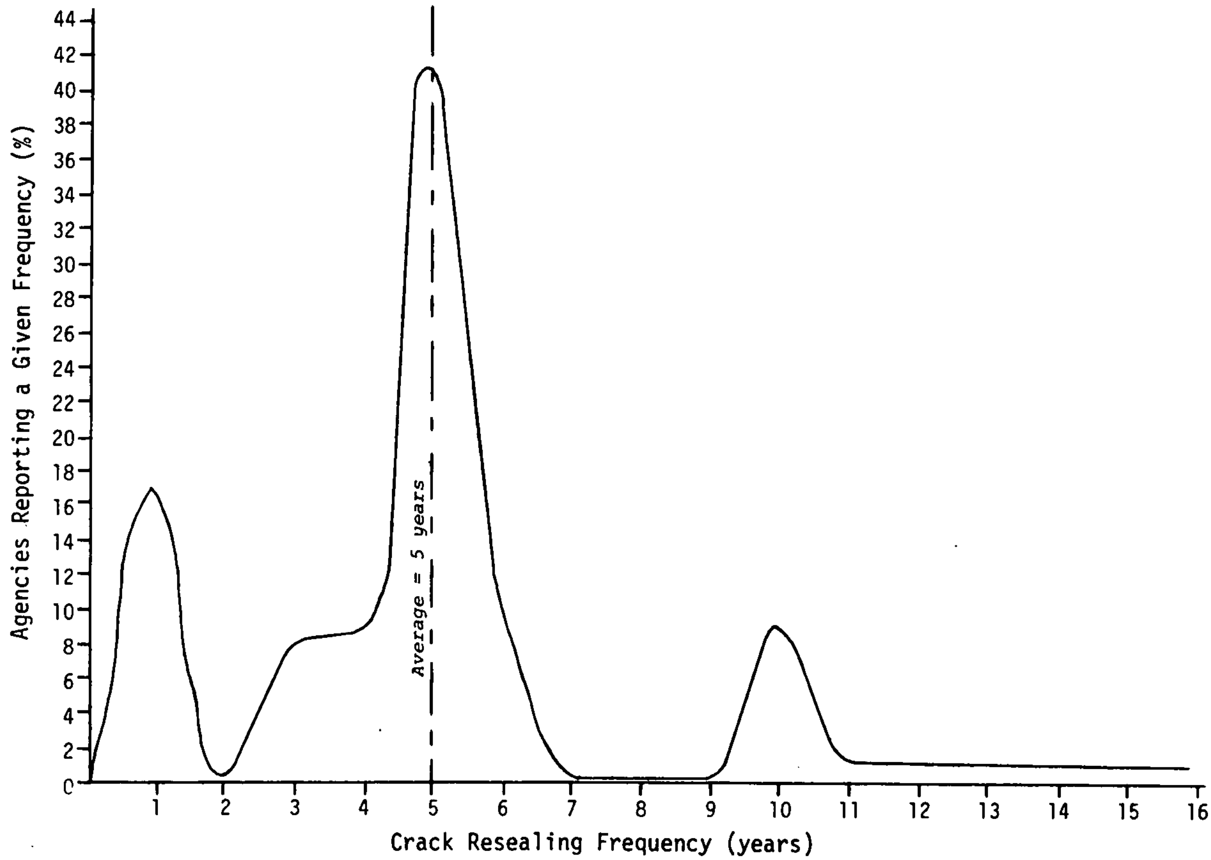

FIGURE 2 Frequency for resealing cracks in rigid pavements.

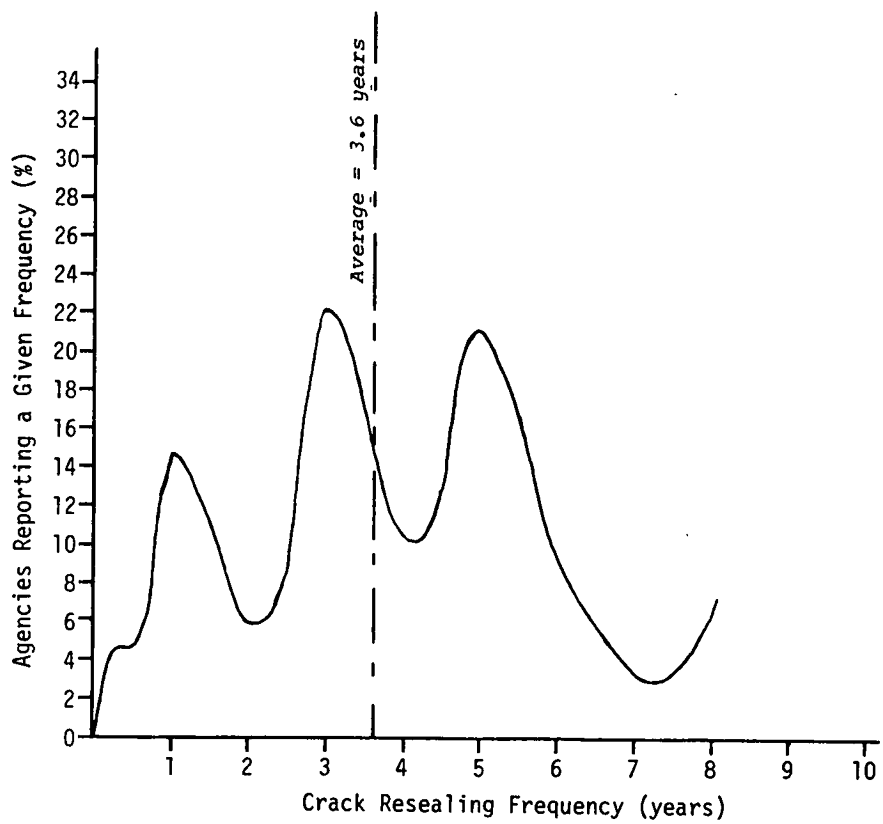

FIGURE 3 Frequency for resealing cracks in flexible pavements.

erage frequency for resealing cracks in rigid pavements is about once per 5 yr. The frequency reported ranged from once per yr to once per 10 to 15 yr.

The primary reasons given for resealing cracks in rigid pavements were to keep out surface water, extend pavement life, and prohibit infiltration of incompressibles. Keeping out surface water and incompressibles was identified as a key to extending pavement life and reducing pumping and blow-ups in the pavement. Spalling at cracks is also directly associated with incompressibles in the cracks.

Flexible Pavement Cracks

Thirty-nine of the 43 responding agencies indicated that they seal or reseal cracks in flexible pavements. Of the agencies that reported costs, the greatest annual cost was $2,149,600 and the least was an insignificant amount. The greatest number of lane-miles resealed per yr was 8,000 (13,000 km). The frequency for resealing cracks in flexible pavements is shown in Figure 3. The average frequency derived from the responses of the agencies is approximately 3.6 yr. The frequency for resealing is from as little as once per 3 months to a maximum of once per 8 yr. No geographical difference is apparent.

The most frequently identified reasons for resealing were to extend pavement or roadway life and to prevent water from penetrating base materials (pavement life is extended if water is kept from penetrating the base materials). Other reasons given for resealing that are related to water penetration include preventing raveling or spalling and reducing popouts; the purpose of stopping reflection cracking through overlays by crack sealing the old surface before overlaying was also identified.

CHAPTER TWO

CURRENT POLICY, EXPERIENCE, AND COSTS

Joints and cracks are resealed for various reasons (Chapter 1); however, there is also a variety of site conditions that contribute to the decision to initiate resealing. The questionnaire responses of the agencies regarding the criteria used in initiating joint or crack resealing in rigid pavements are listed in Table 1. The most common criterion specified was the width of the crack. Once the crack opened to a specified width, sealing was to be undertaken. The criteria identified for flexible pavements are listed in Table 2. Crack width was also the most frequent criterion identified for flexible pavements. Resealing of cracks is performed at a certain width in order that conventional equipment can be used to seal the crack and the sealing material will penetrate the crack. Crack preparation, such as routing, allows conventional equipment to be used for sealing narrower cracks.

TABLE 1
CRITERIA FOR INITIATING JOINT OR CRACK RESEALING IN RIGID PAVEMENTS

Criterion	Number of Agencies
Pavement Related or General	
Pavement survey or evaluation	8
Scheduled time interval	4
Pavement deterioration (spalling, blow-ups)	2
Preventive	1
Pavement growth	1
Evidence of pumping	1
Joint or Crack Related	
Width of crack	15
Condition of joints or cracks (raveling, dirt, etc.)	3
Loss or failure of sealant material	3

TABLE 2
CRITERIA FOR INITIATING CRACK RESEALING IN FLEXIBLE PAVEMENTS

Criterion	Number of Agencies
Pavement Related or General	
Pavement survey or evaluation	8
When pavement system takes on water through cracks	7
Scheduled time interval	4
Before overlay or seal coat	2
Crack Related	
Crack width	12
Raveling or spalling of cracks	4
Crack visibility	3
Crack density	2

CURRENT POLICIES

Several agencies have developed official policy statements pertaining to the sealing or resealing of joints and cracks in pavements. These policies are generally based on study or on actual operating experience and reflect the best practices of the agencies. The details of the policies vary considerably among agencies.

The Kansas Department of Transportation bases its policy for filling cracks on almost a year's statewide study and experimentation (*14*). The results of implementing the policy will be studied and improvements will be developed as needed. The Kansas policy is as follows:

Type I Cracks:

A. Definition: Major cracks over ⅜" in width. May be associated with shoving, depressions, and secondary cracking.
B. Cracks will be filled using one of the following methods:

1. Shallow cracks nominally ⅜" to 1½" wide can be filled with rubber asphalt crack filler.
2. Type I cracks of any size can be filled with slurry crack filler mix.
3. Type I cracks of any size can be filled within an inch of the surface with slurry crack filler mix, then the top portion filled with rubber asphalt crack filler.

C. Rubber asphalt crack filler and slurry crack filler shall be as set out in the attachment to this policy.

Type II Cracks

A. Definition: Cracks ⅛" to ⅜" in width. May be associated with secondary cracking.
B. Cracks will be filled with one of the following methods:

1. All Type II cracks can be filled with rubber asphalt crack filler. Smaller Type II cracks may require routing prior to filling.
2. During the transition period of 1979 when equipment is being modified to handle rubber asphalt crack filler, cutback asphalt or asphalt cement may be used to fill cracks.

Type III Cracks

A. Definition: Hairline cracks less than ⅛" in width. May occur as map or alligator cracking.
B. Cracks will be treated by one of the following methods:

1. Type III cracks will not be poured individually.
2. Dilute seals with emulsified asphalt can be used to treat Type III cracks.
3. Spot seals can be used in areas of severe map or alligator cracking using either cutback or emulsified asphalt and available cover material.

The Illinois Department of Transportation's policy pertaining to rigid pavements is as follows (*15*):

SUBJECT: Policy on Sealing of Pavement Cracks and Expansion Joints. The following general policies will govern the sealing of cracks and expansion in existing pavements:

1. It will *not* be our policy to perform regular and extensive sealing of cracks in the pavement.
2. Exceptionally wide cracks located in areas especially vulnerable to infiltration of water and noncompressibles shall be cleaned and sealed.
3. Expansion joints, including the 4-inch sawed joints, shall be cleaned, sealed and restored when pavement growth endangers functioning of the joint. Special emphasis should be placed on the sealing of expansion joints near the end of structures; failure of these joints to properly function may result in damage to the structure.
4. Joints to be sealed must be cleaned of noncompressible material by plowing, routing, air jet or any approved method and sealed with an asphaltic or other approved material.
5. Cracks in continuously reinforced concrete pavements shall not be sealed unless authorized by the District Maintenance Engineer after consultation with the Central Bureau of Maintenance.

Missouri's policy (*16*) specifies that joints and cracks that are open ⅛ in. (3 mm) or more shall be sealed or filled by pouring. The objective is to exclude foreign matter and prevent spalling and to preserve the original filler. Joints or cracks are required to be cleaned as needed in order to remove foreign material and provide a better bond.

The objective of sealing in Pennsylvania "is to perform cost effective joint and crack maintenance which will prevent more serious failure such as blowups or potholes" (*17*). The policy for filling cracks contains details pertaining to resealing joints and cracks in reinforced concrete pavements, flexible base bituminous pavements, joints between reinforced concrete pavements and shoulders, and rigid bases overlayed with bituminous surface course. The types of materials and the procedures to be used are specified by the policy.

Oregon's policy directs that joints and cracks be sealed to keep surface water from passing through the slab, to prevent debris from collecting in the joint, and to save the original filler (*18*). All cracks that have opened ¼ in. (6 mm) or more must be sealed.

The most common thread among the policies reported is for the specification of the width of the crack opening as the basis for sealing or resealing. Few states or agencies reported not sealing cracks or joints, and there appear to be no written policies to that effect.

BENEFITS

The agencies responding to the questionnaire identified a number of benefits from sealing and resealing of cracks and joints in both rigid and flexible pavements. The most common benefit listed for both pavement types was extended pavement life and reduced or retarded deterioration. The benefit most frequently listed for the joint or crack itself was preventing or retarding raveling or spalling of the joint or crack.

The responses by the various agencies regarding benefits of resealing are summarized in Table 3 for flexible pavements and in Table 4 for rigid pavements.

McKerall (*19*), in discussing the joint sealing techniques used by the Air Training Command, stated:

Joint resealing or joint maintenance is probably one of the most neglected facets of pavement maintenance. Resealing joints at the proper time and using the proper materials and methods will reduce the overall maintenance cost and prolong the life of the pavement.

To establish a good joint-maintenance program, it is first necessary to be able to evaluate the existing sealer. It must be kept in mind that the joint sealer performs three functions: (a) it maintains a water barrier, (b) it keeps incompressibles out of the joint, and (c) it reduces the potential damage from fallen objects.

The first two functions correspond with the benefits of sealing or resealing joints in rigid pavements as reported by the agencies responding to the questionnaire.

With respect to not sealing joints, Wolters (*20*) stated:

There are several different types of pavement deterioration which can result from unsealed joints. Probably the most no-

TABLE 3
IDENTIFIED BENEFITS OF SEALING OR RESEALING CRACKS IN FLEXIBLE PAVEMENTS

Benefit	Number of Agencies
Benefits Related to the Pavement	
Extends pavement life	16
Retards pavement deterioration	8
Keeps water from base	8
Reduces potholes or depressions	6
Reduces freeze damage	3
Maintains rideability	3
Reduces reflection of cracks into overlay	2
Reduces major base repair	2
Improves pavement structural strength in wet weather	2
Minimizes stresses in pavement structure	1
Prevents or retards pumping	1
Prevents or retards faulting	1
None	3
Benefits Related to the Crack	
Helps prevent or retard spalling of cracks	6
Prevents tenting of cracks	2
Helps prevent spread of cracking	2

ticeable of these is joint spalling caused by the infiltration of water and incompressibles into the joints. Foreign material builds up in the joint and when it closes as the temperature rises, tremendous pressures build up and cause pavement growth which can induce blow ups and joint spalling. This type of deterioration is very evident in Minnesota where there are large annual temperature differentials and consequently relatively large joint movements. Large spall failures normally need immediate repair, even if only temporary, and the cost is quite high.

Other types of deterioration usually associated with unsealed joints are dowel bar corrosion, strength loss due to softening of the embankment and loss in slab support at the joint during pumping. All of these forms of structural deficiencies can be attributed to the entrance of water, and each can often decrease the service-life of a roadway substantially, making some type of repair necessary.

It is obvious, then, that there is a definite need for a sealing and resealing program if we expect to keep our concrete pavements at an adequate serviceability level.

FAILURES

In response to the questionnaire, the agencies identified failures that had been observed in the pavement as well as in the sealant or in the joint or crack and the probable causes of the failures. The agency responses are summarized in Table 5 for rigid pavements and in Table 6 for flexible pavements.

When the sealant fails, for whatever reason, to perform its intended function, the probability of some pavement failure increases. For example, when the sealant allows incompressibles to enter the joint in a rigid pavement, the chance of a blow-up increases. Water entering through the joint increases the likelihood of pumping and faulting of the joints. Water entering the pavement system through a joint or crack increases the chances of subgrade weakening and failure. Improper or untimely maintenance may result in failure of the pavement system. Generally, the longer maintenance is delayed, the more serious the deficiencies become. Some agencies have observed that sealing of joints or cracks is not effective if the pavement has already deteriorated or if the base is already weakened. Thus, joint or crack sealing or resealing appears to be effective as preventive maintenance in preventing or delaying failures but not as corrective maintenance in a system that has already failed.

PAVEMENT EVALUATION

Several agencies responding to the questionnaire stated that they base the need for crack or joint resealing on some form of evaluation or inspection of pavement condition. There are various systems for evaluating pavement condition and, in particular, the condition of joints and cracks. Texas A & M University prepared a training manual for establishing priorities for street maintenance, which was subsequently published by the U.S. Department of Transportation (*3*). The manual

TABLE 4
IDENTIFIED BENEFITS OF SEALING OR RESEALING CRACKS OR JOINTS IN RIGID PAVEMENTS

Benefit	Number of Agencies
Benefits Related to the Pavement	
Extends pavement life (reduces deterioration)	13
Prevents water infiltration to the base (protects base)	7
Prevents, retards, or decreases pumping	6
Decreases cracking	3
Prevents or reduces pavement blow-ups	4
Prevents or reduces freeze or frost damage	3
Prevents or retards faulting	1
Reduces chloride infiltration	1
Helps control D cracking	1
Prevents reflection of cracks into overlay	1
Reduces heaving	1
None	3
Benefits Related to the Joint or Crack	
Prevents, retards, or reduces raveling or spalling at joints	10
Keeps incompressibles out of the joints and cracks	5

TABLE 5
FAILURES OBSERVED IN RIGID PAVEMENTS AND PROBABLE CAUSES

Type of Failure	No. of Agencies Identifying	Probable Causes: Design: Improper material	Wrong shape factor	Joint or Crack Preparation: Width and depth wrong	Dirt not removed	Not dry	Installation: Poor weather	Poor procedure by workers	Failure to seal	Mainte-nance: Poor quality	Too late	Operation: Air temp. changes	Freeze-thaw	Water in joint or crack	Particle infiltration in joint or crack	Excessive pavement movement	Poor subgrade	Poor load transfer	Settlement	Time
Failures in the Pavement																				
Blow-ups	3				X				X	X	X	X		X	X	X				
Faulting	3								X	X	X		X	X			X	X	X	
Spalling	3								X				X	X	X					
Pumping	2								X	X	X			X			X			
Slab	1								X							X	X	X	X	
Subbase	1								X					X						
Cracking	1								X				X	X	X					
Failures in the Joint or Crack																				
Adhesion or bond	8	X	X	X	X	X	X	X				X		X	X					
Nonretention of filler	3	X			X	X	X	X												
Loss of seal	3			X	X	X	X	X								X				
Brittle sealant (oxidation)	5	X										X								X
Tracking or bleeding of sealant	2	X						X												
Filler runs through crack	1	X						X												
Loss of elasticity of sealant	1	X										X								
Compression	1											X			X					
Crack expansion	1	X		X					X				X	X	X	X				
Joint mechanism failure	1								X					X	X					
Sealant failure	2	X	X	X	X	X	X	X				X				X				

TABLE 6
FAILURES OBSERVED IN FLEXIBLE PAVEMENTS AND PROBABLE CAUSES

Type of Failure	No. of Agencies Identifying	Probable Causes: Design: Improper material	Wrong shape factor	Crack Preparation: Width and depth wrong	Crack not clean	Crack not dry	Installation: Poor weather	Poor material	Poor procedure by workers	Overfilling	Failure to seal	Mainte-nance: Poor quality	Untimely	Operation: Air temp. changes	Freeze-thaw	Water penetration	Particle infiltration in crack	Excessive pavement movement	Heavy loads	Poor subgrade	Time
Failures in the Pavement																					
Base	2										X	X	X			X			X	X	
Pot holes	2										X				X	X					
Pumping	1										X					X					
Faulting	1										X					X	X				
Spalling	1										X				X	X	X				
Alligator cracking	1																		X	X	
Random cracking	1													X							
Longitudinal and transverse cracking	1													X							
Block cracking	1													X					X	X	
Failures in the Sealant																					
Loss of bond	7	X		X	X	X	X	X	X						X	X	X	X			
Loss of seal	4		X		X	X						X	X					X			
Tracking, bleeding	3	X					X	X	X	X											
Brittle sealant (oxidation)	4	X						X						X		X					X
Materials drop in crack	2		X	X				X	X												
Material flows	1	X					X	X													
Material doesn't expand with pavement movement	1	X						X										X			

contains much information on the various types of cracks and the severity levels for those cracks. Three levels of severity for each crack type are described in the manual, and a section is included on methods of measuring each type of distress. The California Department of Transportation has a similar procedure (*4*); but, in addition, the field performance information is coded for the computer and printout is generated. Ontario's system (*5*) includes the density and the severity for each distress type.

A simple or minimal evaluation or inspection procedure may be nothing more than just a decision made by the maintenance foreman on the action to be taken based on a personal assessment of the situation. For example, the foreman may be aware that if a certain type of maintenance is not performed in a timely manner, more serious problems may occur in the future. Pavement evaluation procedures are discussed in greater detail in *NCHRP Synthesis 76* (*21*) and in *NCHRP Synthesis 77* (*22*).

UNIT COSTS

The average unit costs for crack and joint resealing were difficult to determine due to the manner in which the information was reported. Agencies generally do not obtain or report cost per lineal ft of crack or joint. Production is usually reported in gallons of sealant or in lane-miles per day. The responses to the questionnaires were in dollars per yr and lane-miles per yr.

The cost per lane-mile for crack and joint resealing was calculated using the cost per yr and the number of lane-miles per yr as obtained from the responses to the questionnaire. The weighted average cost per lane-mile of pavement for joint resealing was approximately $700 ($440/km). The weighted average was used because of the variation in lane-miles of pavement resealed per yr by the different states. With this method, the states with a large resealing program are given more weight than those resealing a smaller number of lane-miles. It was found that the states with small resealing programs generally reported higher unit costs than those resealing a greater number of miles. The weighted average cost per lane-mile was $414 ($260/km) for rigid pavement crack resealing and $147 ($91/km) for flexible pavement crack resealing. Because these unit costs are based on cost per lane-mile, they may be somewhat misleading; therefore, costs per lineal ft would be more appropriate because the joint spacing or cracking frequency may vary from state to state. However, this information was not generally available.

The expected joint or crack resealing frequency was used to calculate the annual cost for resealing the joints or cracks in a section of pavement. The average cost per yr per lane-mile was calculated by dividing the weighted average cost of resealing 1 lane-mile of pavement by the reported frequency for resealing. The annual cost of resealing joints in rigid pavements was calculated to be $142 per lane-mile ($88/km). The annual costs of crack resealing in rigid pavements and flexible pavements were $58 per lane-mile ($36/km), and $57 per lane-mile ($35/km), respectively.

The costs per lineal ft for crack or joint preparation and resealing are more difficult to determine because of the manner in which data are obtained and reported by the various agencies. Because it was not possible to obtain cost per lineal ft of crack or joint resealing from the questionnaire responses, the cost was determined from data provided in various agency reports. In a 1973 report by CERL (*6*), unit costs for cleaning and sealing were given. Cleaning costs ranged from $0.15 to $0.25 per ft ($0.49 to $0.82/m). Crack filling costs were reported to be $5 per gal ($1.30/L). Assuming that 1 gal (3.8 L) can seal 150 lineal ft (46 m), the cost of sealing is $0.03 per ft ($0.10/m). Thus the total cost of crack sealing is $0.18 to $0.28 per ft ($0.59 to $0.92/m). Assuming a 10 percent increase in costs per yr, the 1981 cost is estimated to be $0.39 to $0.60 per lineal ft ($1.30 to $2.00/m) of crack.

Costs of $537 per 100 gal ($1.42/L) for rubberized liquid asphalt for materials and operation were reported by Arizona (*23*). These costs do not include the cost of crack preparation, which was $0.036 per ft ($0.12/m) in 1976 and $0.058 per ft ($0.19/m) in October 1981.

The cost of resealing a joint in a concrete pavement in 1974 was estimated by Utah to be $0.48 to $0.67 per ft ($1.60 to $2.20/m) (*24*). The higher cost included resizing the joint by sawing. Assuming a 10 percent increase in costs per yr results in 1981 costs of $0.93 to $1.30 per ft ($3.00 to $4.30/m) of joint.

The costs for several products for sealing joints in rigid pavements were reported in 1975 by Pennsylvania (*25*); the costs ranged between $0.062 and $0.438 per lineal ft ($0.20 to $1.44/m) of joint depending on the material used. In another report (*13*) unit prices were reported as ranging between $0.04 and $0.53/ft ($0.13 to $1.70/m) for liquid sealants and $1.01/ft ($3.30/m) for preformed neoprene. In Iowa contractor sealant materials costs were reported as ranging between $0.015 and $0.149 per ft ($0.05 to $0.50/m) in 1979 for sealing joints in concrete pavements (*26*). [The joint was ¼ in. wide by ½ in. deep (6 by 12 mm)].

A 1981 bid abstract provided by Minnesota included an item for preparing and resealing concrete pavement joints and cracks (*27*). The bid price for cleaning and sawing concrete pavement joints was $0.85 per ft ($2.80/m) of joint. The bid price for cleaning concrete pavement cracks was $0.75 per lineal ft ($2.50/m) of crack. The bid price for routing and cleaning concrete pavement cracks was $0.90 per lineal ft ($3.00/m). Materials costs were $1.85 per lb ($4.10/kg) of sealant installed excluding crack or joint preparation. The unit cost of sealant materials equals approximately $0.50 per lineal ft ($1.60/m) of joint or routed crack. The pavement joint is ¾ in. by ¾ in. (19 by 19 mm). At $20,000 traffic control costs for the 7.5-mile (12-km) project were significant.

Crack or joint preparation costs can include more than just the cost of the sealant materials. When traffic-control costs are added, it becomes more important to utilize materials and techniques that will assure long life. When a poor-quality material fails in half the time, costs can multiply rapidly.

CHAPTER THREE

MATERIALS AND TECHNIQUES

Various materials and techniques have been used with different degrees of success. Some have been adopted as standard practice by various agencies. However, material that may prove successful for one agency may be a failure for another due to different conditions or techniques. Climatic variations can contribute to failure as can differences in the shape of the installed sealant. Performance data, which can be helpful in evaluating sealants over a period of time, have been accumulated by some agencies.

In response to questions on the materials and techniques used for sealing and resealing cracks and joints in pavements, effectiveness ratings ranging from very good to very poor were reported by the various agencies. In addition, information was obtained on the performance of different materials and on techniques from published reports.

The performance of a given sealing material is not only a function of the characteristics of the material, but also of the condition of the crack or joint at the time of resealing. Local conditions, such as climate, traffic, and subgrade condition, are also important factors. The installation technique plays an important part in the ability of a given sealant to perform in accordance with its design expectations.

CLIMATIC EFFECTS

Climatic factors, such as temperature and moisture, affect the performance of the pavement and the joint and crack sealants. Temperature changes can cause expansion and contraction of both rigid and flexible pavements, resulting in the opening and closing of the joints and cracks. Changes in moisture content in the pavement can also lead to some expansion and contraction of the pavement.

As pavement joints or cracks open and close, stress is applied to the sealant. If the sealant is not able to withstand the movement and stress, adhesive or cohesive failure is likely to occur; either the sealant will separate from the face of the joint or crack or it will fail internally and separate. Adhesion or bond failures occur more frequently than do cohesive failures.

When the sealant fails, incompressibles or water or both can enter the joint or crack. Incompressibles in the crack or joint can cause spalling of the cracks in rigid or flexible pavements and of the joints in rigid pavements. Incompressibles in the joints may ultimately cause blow-ups of rigid pavements. Water in the system may result in freeze-thaw damage to the joint or crack and to the pavement in the colder regions of the country. Water and cold temperatures can cause frost-heave damage to both rigid and flexible pavements. Water in the pavement system combined with traffic loads causes pumping and, ultimately, faulting of the joint or crack. Unsealed joints or cracks can provide an avenue for water to enter the system. Water entering the base materials leads to a weakening of the subgrade and a reduction of the pavement's structural strength or load-carrying capacity. This loss of strength contributes significantly to rapid deterioration of the pavement system and a shorter pavement life. Repetition of axle loads in combination with water adversely affects the performance of the pavement.

SHAPE FACTOR

The shape of the sealant reservoir is an important factor in the success or failure of a sealant. The shape factor is defined as the ratio between the width and depth of the sealant [see Figure 4 (*11*)]. If the ratio is too small because of a narrow and deep reservoir, many of the sealants can be stressed beyond their extensibility limits.

Tons (*28*), who was one of the first researchers to examine the influence of the shape factor on the performance of the sealant, found that the shape factor contributes significantly to the effectiveness of a sealant. Various materials have different physical characteristics and therefore can tolerate different shape factors; what may be adequate for one material may be entirely inadequate for another. Tons developed a method for determining the strain along the parabolic curve of the sealant surface as the sealant is extended. The strain is determined from the width and depth of the sealant, the amount of joint or crack movement, and minimum joint or crack opening. A narrow and deep sealant has much higher strains for a given movement than a wide and shallow sealant and would therefore fail more rapidly.

The effect of the shape factor on the performance of sealants in concrete pavements was studied in Utah (*24, 29*). Utah had been sealing transverse joints that were saw cut ⅛ in. wide by 2½ in. deep (3 by 64 mm). The joints were sealed with a hot-poured material meeting federal specification FSS-SS-S-164. Adhesion (bonding) failures started as early as 1½ years after installation. The strains generated from this set of conditions were approximately 1780 percent, as calculated by Tons' procedure, which was the primary reason for the universal failure of the sealants in Utah. The shape factor was modified in 1975

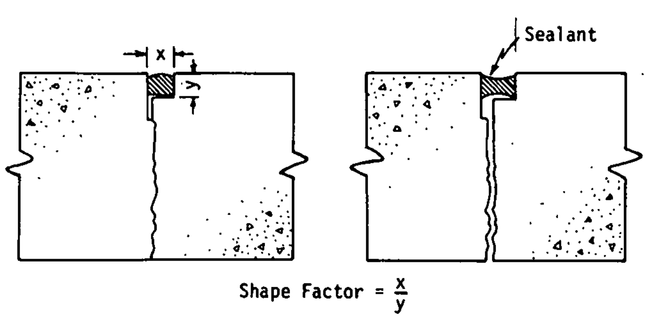

FIGURE 4 Concept of shape factor and effect on sealant elongation (*11*).

to reduce the strain on the sealants as they were extended when the pavement contracted. The new shape of the sealant reservoir was ⅜ in. wide by 1 in. deep (10 by 25 mm). This size and shape resulted in a strain along the parabolic curve of the sealant surface of about 50 percent, which was a considerable reduction from 1780 percent. An evaluation in 1979 of the sealants installed using the new shape showed that 90 to 95 percent of sealants installed 3 yr before were performing in an excellent manner. The signs of distress in the remaining 5 to 10 percent appeared to be caused by poor joint preparation (improper cleaning of joint faces, sawing too early, etc.) and the depth of sealant placement.

Schutz (*30*) pointed out that the shape factor of the pavement joint has a critical effect on the ability of the sealant to withstand extension and compression. A 5-yr study of joints that had failed revealed three basic causes for the failures (*30*):

1. *Poor Joint Design.* Some joints are doomed to failure regardless of the sealants that may be used.
2. *Use of an Inappropriate Sealant.* For the service conditions to be encountered. Physical properties of sealants cannot be exceeded without some degree of joint failure.
3. *Poor Workmanship* in preparing surfaces or applying sealants.

The Federal Highway Administration recommended shape factors for certain classes of materials used for field-molded (poured) sealants (*31*). The following list summarizes the recommendation:

Material	*Recommendation*
Rubberized and bituminous sealants	Shape factor (width to depth) around 1:1 (minimum 1:2). Minimum depth ⅜ in. If contraction joint, minimum depth ½ in., extension no greater than 20 percent.
Elastomers (polysulfides, polyurethanes, urethanes, etc.)	Shape factor around 1:1 (minimum 1:2). Minimum depth ⅜ in.
Polyvinyl chloride (PVC)	If tape used, minimum joint size ⅜ in. wide by 1¼ in. deep. If cord used, minimum joint size ⅜ in. wide by 1⅜ in. deep.
Silicone	Width-to-depth ratio 2:1 (depth of ¼ to ½ in.)

The shape factor for sealants has been studied by several other agencies and reported in the literature (*13, 26, 32–34*). These reports all verify the need for a proper shape factor in order to assure good performance of the sealant and the pavement. Proper shape factor is important for flexible as well as rigid pavements.

PERFORMANCE HISTORY

All transportation agencies experiment from time to time with new products or techniques. Often these may be tested under actual field conditions in comparison with other products or techniques that are designed to perform similar functions. The field trial may be a direct comparison of a new product with an existing standard product or a test of the same material in several different areas to determine its performance under varying climatic and traffic conditions. Unfortunately, many of the field trials are conducted informally and the results are not published or disseminated. Frequently, the data are not even made available within the agency that conducted the experiment, causing a great loss of information that could be beneficial to others within the agency and to other agencies. Information on failures is often as useful as information on successes and is generally less available.

Most pavement evaluation systems do not include details on the condition of the joint or crack. They generally cover a broader base of the types and quantity of cracking. The Ontario pavement evaluation system (*5*) and the California system (*35*) include the severity of the cracking in addition to quantity. Utah's pavement evaluation system (*36*) includes crack width and whether it is sealed or unsealed. Pavement evaluation should include the cracks and joints as a part of an overall pavement management program.

Several agencies have experimented with different joint or crack sealing products and/or techniques to determine how they perform under local conditions. Ontario experimented with 13 crack sealing materials for asphalt materials and evaluated their performance (*37*). Various techniques for preparing and sealing the crack were tested (see discussion under Techniques in this chapter). Iowa evaluated six different sealants for use in rigid pavement joints (*26*). Three different joint-cleaning techniques were tested and five different saw cuts were used to create different joint shapes. Based on Iowa's visual rating scheme, joints with shallower depths performed better. The ¼-in. (6-mm) wide saw cut, which was the narrowest, yielded the poorest elongation capabilities. The Poly-Jet Highway sealant from W. R. Meadows and the Dow Corning 888 sealant exhibited no visible failures in the Iowa experiment after about 1 yr of service. Pennsylvania experimented with a number of sealant products over a span of several years (*13, 25, 38–43*). Arizona experimented with rubber mixed with liquid asphalt (*23*). Georgia evaluated low-modulus silicone rubber as a joint sealant material in a rigid pavement restoration program (*2*). The AASHTO-FHWA Special Product Evaluation List (SPEL) includes many references to joint sealants and fillers that have been tried with varying degrees of success by the states (*44*).

The results of various experiments, research, and operational experience covering a wide range of materials and techniques are discussed in greater detail below.

MATERIALS

Based on the information obtained from the questionnaire, several categories of various sealant materials were classified in order to simplify comparisons; e.g., all of the asphalt cements were grouped in one category and all of the hot-applied rubberized asphalts were grouped in another. The effectiveness ratings for each type of material were averaged in order to obtain a composite number or rating. A rating of very good was given a numerical rating of 5.00, good, 4.00, fair, 3.00, poor, 2.00, and very poor, 1.00. Thus a composite or average rating of 3.5 would be considered to be fair to good. The materials used to reseal cracks and joints in rigid pavements are listed in Table 7 and those used to seal and reseal cracks in flexible pavements

TABLE 7
MATERIALS USED TO RESEAL CRACKS AND JOINTS IN RIGID PAVEMENTS

Material Type	Number Listings by Agencies	Effectiveness Rating Range	Average Effectiveness Rating[a]	Comments
Asphalt Cement	11	Poor-Good	3.15	Does not penetrate; must be resealed often.
Cutback Asphalt	17	Very Poor-Good	2.29	Generally requires blotter; relatively short life.
Emulsion	10	Very Poor-Good	3.22	Seasonal. Generally must be resealed often.
Rubberized Asphalt, Cold Applied	1	Good	4.00	Labor intensive.
Rubberized Asphalt, Hot Applied	36	Very Poor-Very Good	4.12	Relatively long life.
Cutback Asphalt with Rubber	2	Good-Very Good	4.75	Limited data; good performance.
Asphalt Emulsion with Rubber	1	Good-Very Good	4.50	Limited data; good performance.
Preformed Filler	2	Fair-Good	3.50	
Silicone Dow 888	7	Good-Very Good	4.60	Relatively limited data but good performance to date.
Preformed Joint Seal	5	Poor-Very Good	3.60	Costly.
Other (PVC, Polyurethane, Vulken)	6	Very Poor-Good	3.25	Vulken rates very poor.
Tar	2	Very Poor	1.00	Short life; too rigid.
Catalytically Blown Asphalt	1	Good	4.00	

[a]Rating Scale Very Good - 5.00
Good - 4.00
Fair - 3.00
Poor - 2.00
Very Poor - 1.00

are listed in Table 8. Some of the materials are used for sealing both rigid and flexible pavements.

It was found that the addition of rubber to asphalt cement, to cutback asphalt, or to an asphalt emulsion increases the effectiveness rating by a significant degree. When rubberized, cutback asphalts showed the biggest improvement. It should be noted, however, that little information was available on rubberized cutback asphalts. The largest amount of information available was on hot-applied rubberized asphalt, which with the addition of rubber increased one effectiveness rating level (from fair-to-good to good-to-very good). Arizona reported that rubberized asphalt in use for 6 to 7 yr was still in good condition. North Dakota reported that after 3 yr rubberized asphalt performed well. Maine reported that hot-poured rubberized asphalt (federal specification SS-S-164) lasted from 4 to 5 yr. Arizona, Michigan, Montana, and North Dakota reported a short life for nonrubberized cutback asphalt; North Dakota reported that annual treatment was required. Various agencies noted that frequent resealing was required for nonrubberized asphalt emulsions.

Pennsylvania reported that using improved rubberized asphalt joint sealants increased costs for sealing joints by 31 percent (*43*). This included the use of an improved joint sealant shape factor. The joint used in the past had a width of ⅜ in. (10 mm) and a depth of 2½ in. (64 mm), which was too deep and narrow for a sealant material. The new recommended shape was ¾ by ¾ in. (19 by 19 mm) or 1 by 1 in. (25 by 25 mm).

Minnesota experimented with five different liquid sealants and seven preformed seals for use in rigid pavement joints and found that one liquid hot-poured sealant (Superseal 444) and two preformed seals (Grace 5041 505A and Acme 13/16) have the greatest potential (*20*). A shape of ⅝ by ⅝ in. (16 by 16 mm) was recommended for joints where the hot-poured sealant is used. Minnesota also did experimental work with crack sealing on flexible pavements (*45*). Of the five hot-poured rubber asphalt sealant materials tested, the fewest failures were reported with the use of Grace 156. A shape of ½ in. wide by 1 in. deep (13 by 25 mm) was recommended for the crack sealant reservoir.

The AASHTO-FHWA Special Product Evaluation List (SPEL) covers a large number of products for joint sealing that are being evaluated by the various states (*44*). The various products are grouped into three status categories: accept, not

TABLE 8
MATERIALS USED TO SEAL AND RESEAL CRACKS IN FLEXIBLE PAVEMENTS

Material Type	Number Listings by Agencies	Effectiveness Rating Range	Average Effectiveness Rating[a]	Comments
Asphalt Cement	10	Fair-Very Good	3.50	
Cutback Asphalt	20	Poor-Good	2.90	Generally requires blotter, relatively short life.
Emulsion	20	Very Poor-Very Good	3.02	Relatively short life, tends to bleed.
Asphalt General Class or Type Specified	5	Poor-Good	3.10	
Rubberized Asphalt, Hot Applied	31	Very Poor-Very Good	4.40	Relatively long life.
Cutback Asphalt with Rubber	2	Good-Very Good	4.50	Limited data. Good performance.
Asphalt Emulsion with Rubber	5	Poor-Very Good	3.40	
Rubberized Asphalt; materials not fully identified	7	Fair-Very Good	4.14	Good performance.
Material Class not identified	11	Very Poor-Very Good	2.61	
Mixture	3	Good-Very Good	4.33	Mixtures of asphalt and sand or aggregate. Used in wide cracks.
Other (Arm-R-Shield, Vulken)	4	Very Poor-Good	3.25	Vulken rates very poor.
Tar	3	Very Poor-Poor	1.33	Too rigid, short life.
Catalytically Blown Asphalt	1	Good	4.00	

[a]Rating Scale Very Good - 5.00
Good - 4.00
Fair - 3.00
Poor - 2.00
Very Poor - 1.00

accept, and pending. Those products that are applicable to this synthesis and their status are listed in Table 9. Products that were only listed once in SPEL are not included in the table. There is no listing in SPEL for crack sealants for use in flexible pavements.

TECHNIQUES

Despite adequacy of the design and effectiveness of the material, unless the sealant is installed properly under satisfactory conditions, the chance of failure is great. The installation technique is a significant factor in the achievement of the design expectations of a sealant. The techniques and some of the equipment used by the various agencies in the process of resealing cracks and joints were identified and rated on effectiveness by the agencies responding to the questionnaire. The equipment and techniques identified are listed in Table 10, along with a description of uses and types of pavement. A particular resealing operation may require using several techniques. For example, the process may require further removal of an existing sealant, sawing or routing the joint or crack, cleaning and drying the joint or crack, and installation of the sealant. Various techniques used in the resealing process are shown in Figures 5–9; other techniques are presented in Appendix A.

Arizona

In response to the questionnaire, Arizona reported the following procedure for sealing cracks:

> Routing with vertical routing machine to a width of approximately ½" and a depth of ¾", then blowing out dust with air compressor and filling with either AR 2000 asphalt mixed with granulated rubber or MC 250 or MC 800 with granulated rubber.

TABLE 9
RIGID PAVEMENT JOINT SEALANT SUMMARY (*44*)

Product Name	Description	Number Agencies Evaluating	Status
Allied Seal	Hot-poured	5	3 accept 2 pending
Dow Corning 888	One-part, low-modulus silicone rubber	8	2 accept 5 pending 1 not accept
Flo Mix; US Rubber Reclaiming	Devulcanized rubber used in hot-poured rubberized asphalt	2	1 pending 1 not accept
Hi-Spec.; W.R. Meadows	Hot-poured rubberized asphalt	5	4 accept 1 pending
Lion D 200; Lion Oil Company	Two-component, cold-applied elastomeric	10	3 accept 3 pending 4 not accept
Para-plastic; W.R. Grace	Hot-poured rubberized asphalt	5	4 accept 1 not accept
Poly-jet Highway; W.R. Meadows		3	2 pending 1 not accept
Pourthane; W.R. Meadows	Cold-applied, two-component polyurethane	2	1 accept 1 not accept
PRC 3105; Products Research and Chemical Corp.	Cold-poured	2	2 accept
Superseal; Superior Products	PVC, hot-applied	6	3 accept 2 pending 1 not accept
Sika Flex 1-A; Sika Chemical Corp.	One-component polyurethane	5	3 accept 1 pending 1 not accept
Sonolastic; Sonneborn - Contech	Two-component polyurethane	3	3 accept
Vulken; Nameco Int.	Cold-poured	2	1 accept 1 pending

Ontario

In a series of field trials on flexible pavements in Ontario, the following procedures were used for the installation of each sealant that was being evaluated (*37*):

1. The cracks were routed with most cracks routed to a width and depth of approximately ¾ inch.
2. The routed grooves were cleaned with a jet of air using mostly back pack blowers.
3. A wire brush was used as an aid in cleaning some of the cracks.
4. The grooves were filled either through hand pouring or by a hose and wand from a low pressure pump attached to the melter.
5. Part of the sections were overfilled and a horseshoe shaped squeegee was used to strike the material off.
6. The hot poured sealants were dusted to prevent tracking.

Based on the study (*37*), it was concluded that sealing of cracks should not be undertaken if the cracks show dampness. It was also concluded that air blowing of the routed cracks should immediately precede the filling operation. Cold-poured sealants were found not to be suitable if they were to be subjected to traffic less than 2 hr after installation. Emulsion-based sealants were not recommended if rain was predicted within 12 hr. The method for crack sealing in Ontario is as follows (*5*):

1. Set up safety devices and signs. . . .
2. Designate the areas requiring repair.
3. (a) Clean out cracks using a stiff bristled broom and/or compressed air. (b) Rout cracks, remove dust and debris with compressed air.
4. Fill cracks with sealant; apply inside the crack to avoid creating a bump.

Note: When using asphalt emulsion, sprinkle the surface of the filled crack with dry sand or stone chips.

Iowa

Iowa conducted a field evaluation project on resealing joints in rigid pavements (*26*). Sealants were placed according to the following general procedures:

1. Joints were cut to the proper size and shape.
2. Joints were cleaned with a sandblaster.
3. Joints were then cleaned with a blast of high-pressure water.

TABLE 10
TECHNIQUES USED FOR RESEALING CRACKS AND JOINTS

Equipment or Technique	Function or Description	Rigid Pavements: Transverse Joint	Rigid Pavements: Transverse Crack	Rigid Pavements: Shoulder Joint[a]	Flexible Pavement Cracks
Concrete Saw	To cut existing joints to a new desired width and/or depth including step joints.	X		X	
Blade on Backhoe	A blade attached to a backhoe; dragged along joints to remove existing sealant.	X			
Cleaning Hook	A hand-operated hook to remove an existing sealant.	X			
Router	To remove loose material and to enlarge and/or shape cracks and joints to desired section.	X	X	X	X
Cutting Wheel on Motor Grader	A disk wheel attached to a motor grader to enlarge and shape joint between rigid pavement and flexible shoulder.			X	
Power Brush	To clean residue in joints before resealing.	X		X	
Wire Brush	Same as power brush.	X		X	
Sand Blaster	To assist in cleaning joints before resealing.	X			
Air Compressor	To provide air to blow out residue in joints and cracks.	X	X	X	X
Back-Pack Blower	Carried on a person's back to clean joints and cracks.	X	X	X	X
High-Pressure Water	To help remove film or residue in joints and cracks.	X	X	X	X
Dryer	To remove moisture from joints and cracks and to provide better bond.	X	X	X	X
Flame Cleaning	To dry joints and cracks.	X	X	X	X
Tafa Burner	To dry joints and cracks.	X	X	X	X
Sweeper	To remove residue in and around joints and cracks.	X	X	X	X
Distributor	To transport, store, and distribute liquid asphalt joint and crack sealants. May be heated.	X	X	X	X
Melting Kettle	To melt and/or heat solid or semi-solid joint-sealing materials to required temperature for use.	X	X	X	X
Tar Pot	Same as melting kettle.	X	X	X	X
Wand (from Distributor, Tar Pot, etc.)	Attached by hose to allow application of sealant directly into joints and cracks.	X	X	X	X
Hand Snivey	Same as wand.	X	X	X	X
Pour Bucket, Pot, or Kettle	Hand-held container with a spout to apply sealing material directly into joints and cracks.	X	X	X	X
Mechanical Squeegee	A mechanically operated squeegee to force sealing material into joints and cracks and leave a smooth surface.	X	X	X	X
Hand-Held Squeegee	Same as mechanical squeegee except hand held and operated.	X	X	X	X
Sand Bucket or Container	To spread sand or sawdust on sealants that tend to bleed and track.	X	X	X	X
Preformed Joint Sealant Installer	To install preformed joint sealants into prepared joints.	X			
Backer Rod or Tape	Installed at the base of sawed joints to control the depth of the finished sealant.	X			

[a]Flexible shoulder.

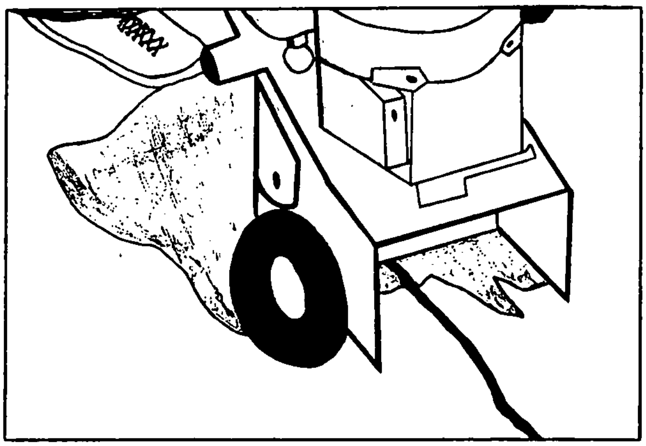

FIGURE 5 Router.

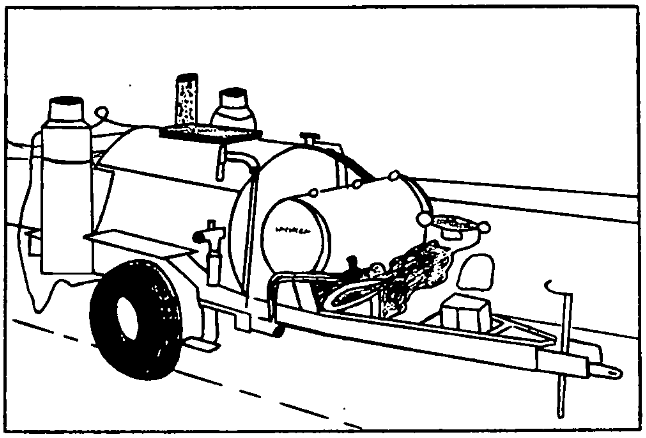

FIGURE 6 Melting kettle.

FIGURE 7 Cleaning joint with air.

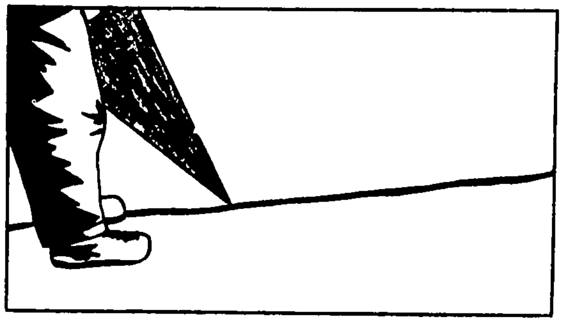

FIGURE 8 Sealing the joint.

4. Backing rod was placed in the joints to the control depth for the sealer.
5. Joint sealer was installed in accordance with the manufacturer's recommendations.

Florida

Florida's procedure for resealing joints in rigid pavements using silicone sealants (as reported in the response to the questionnaire sent to the agencies) is as follows:

- Plow out old sealant.
- Saw joint.
- Flush with water (if water cooled saw blades are used).
- Blow out with air.
- Install backer rod.
- Install sealant.

South Dakota

South Dakota's procedure for the removal and the replacement of a sealant in a rigid pavement is as follows (*46*):

> 1. A power driven rotary cutter or grooving tool will be used for removing old joint sealer thus cutting a clean new groove prior to resealing.
> 2. The concrete should be dry and the joints thoroughly cleaned by use of compressed air, brooms, steel brushes or other means.
> 3. Fill the joint level full with an approved joint filler.
> 4. Unless traffic is kept off the pavement, the newly filled joint should be covered with paper tape or dusted with fine sand or rock dust to prevent the sealant from being picked by the tires.

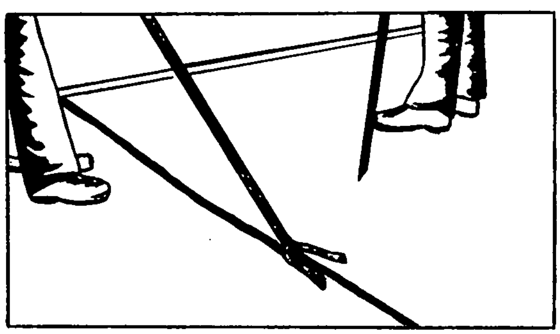

FIGURE 9 Squeegeeing the joint.

5. Excess material should be trimmed off when the joint material is cool to provide a neat appearing joint.

Minnesota

Minnesota has established the following procedures for concrete joint resealing (*47*):

1. Remove old joint seal materials using manual or mechanical methods.
2. Saw cut at a depth ¼ in. greater than original cut and width of the blade.
3. Saw cut ¾ by ¾ in. using two blades with adequate spacers and adjusted to the proper depth.
4. Flush joint with water to remove cement-water slurry and other debris.
5. Lightly sandblast joints and follow with air blast and inspection for cleanliness.
6. Place backer rod or tape to prevent joint sealant from flowing down through joint.
7. Place joint sealant flush to not more than ⅛ in. above the pavement surface. After placing sealant, dust surface of sealer with talc or cover with tissue paper to keep small incompressibles from bonding to surface.

Minnesota seals random cracks (classified as "working cracks") in rigid pavements. Open random cracks are routed to an approximate shape of ½ by ⅝ in. (13 by 16 mm). After routing, the random crack is treated the same as a joint.

Minnesota's procedure for filling cracks in flexible pavements is described as follows (*47*):

> It has not been determined conclusively that crack filling is cost effective. There is a consensus, however, among maintenance engineers and superintendents that we should crack fill because it does extend the life of the pavement. Cracks that are not treated with one of the acceptable materials described below tend to ravel (become wider). When they become an inch or more wide, a fine mix must be placed to maintain reasonable rideability. An alternate is to place an overlay or surface recycling. Placing a fine mix, an overlay or some form of recycling is costly. Also, these activities are dependent upon time of the year and equipment as the hot mix plants are open in the Spring after the snow and ice season. Recycling procedures are also limited to the construction season.
>
> Crack filling can be performed between storms during the snow and ice control season when the pavement is dry.
>
> The intent of crack filling is to coat the sides of the crack and not fill them prior to significant crack deterioration. By coating the sides of the crack with the right amount of bitumen, the crack does not ravel as quickly as it would be left unprotected. The top corner of the mat, adjacent to the crack needs the most protection. However, small cracks (¼" –) may be filled because of the small amount of material required.

The following materials are acceptable in Minnesota for crack filling in flexible pavements: AC3; MC250 or 800; RC250 or 800; or an emulsion.

Indiana

Indiana conducted an evaluation of work methods under field conditions during actual maintenance operations (*48*). It was found that maintenance crews were not following exactly the maintenance procedures as directed in their training programs. For example, it was learned that the crews apparently did not believe that there was a need to clean cracks before sealing. Also a narrow squeegee had been recommended, but a wider one was being used. As shown by the Indiana evaluation, recommended procedures may not always be followed. However, this does not mean that the actual practice is incorrect just because it deviates from recommended procedures; actual practice may be based on available equipment or materials or it may be the best practice for particular site conditions.

Desirable Techniques

Based on a review of the techniques and procedures obtained from the responses to the questionnaire sent to the agencies, it appears that certain procedures are desirable for each pavement type. Using the proper sealing materials in combination with proper techniques should provide a completed activity that will achieve its design purpose and extend the pavement life.

Rigid Pavements

Joint Resealing

1. Remove the remnants of the existing sealing material using some type of mechanical equipment or manual method; e.g., a blade on a backhoe to pull through the joint to remove the existing material or a cleaning hook to manually remove the material.
2. Reshape the joint to the desired cross-section by sawing. This can be accomplished through a single or two-stage process depending on the existing joint size and the desired new shape. The proper shape factor, considering the material to be used and the amount of pavement movement, should be the end result. A router can also be used to reshape the joint.
3. Clean the joint using one or more techniques, such as high-pressure water, power brush, sandblasting, and air blowing.
4. Dry the joint, if required, using a suitable dryer or flame cleaner.
5. Install backing material at the bottom of the joint to control the depth of penetration of the sealant and to assure a proper shape factor.
6. Install the sealing material to the proper depth, making certain that it does not protrude above the pavement.
7. Dust the sealant, if necessary, to prevent tracking.

Crack Sealing or Resealing

1. Remove the existing crack sealant if the crack was previously sealed.
2. Rout the crack to the proper depth and width using the appropriate equipment.
3. Clean the crack using one or more of the following: power brush, sandblaster, high-pressure water, or compressed air.
4. Dry the crack to remove any moisture.
5. Place a backing material in the bottom of the routed crack, if necessary, to control the depth of the completed sealant.

6. Place the sealant in the completed reservoir, making sure not to overfill.

Flexible Pavements

Two general procedures were identified for flexible pavements: crack sealing and crack filling. The first is more effective as a sealant and has a longer life.

Crack Sealing

1. Rout the crack to the desired cross-sectional shape.
2. Clean the crack to remove loose material and debris and to provide a clean crack face to enhance bonding of the sealant. Techniques used include sandblasting, high-pressure water, compressed air, etc.
3. Dry the crack area to remove all moisture.
4. Place backing material in routed crack to prevent excessive penetration and maintain proper shape factor.
5. Fill the crack with a suitable sealant, but do not overfill.
6. Dust, if necessary, to prevent tracking.

Crack Filling

The second procedure for flexible pavements helps to preserve the integrity of the crack interface.

1. Clean out cracks using a stiff bristled broom, compressed air, or other techniques.
2. Dry the crack area to remove moisture.
3. Fill the crack with sealant, allowing it to penetrate the crack depth.
4. Squeegee the pavement surface over crack area.
5. Dust sealant, as necessary, to prevent tracking.

CHAPTER FOUR

CRITERIA FOR RESEALING AND MAINTENANCE PERFORMANCE STANDARDS

The decision to be made first is whether or not the cracks or joints in a pavement should be resealed. This determination should be based on the condition of the pavement and on the condition of the joints and cracks. The potential for moisture-related pavement damage must also be evaluated to help establish both the need and urgency for resealing. Once the decision is made that resealing is required, then the selection of the proper procedures including preparation, sealant materials, and sealing techniques, is undertaken. A number of factors must be reviewed in selecting the procedures. Many agencies have developed maintenance performance standards to assure quality, uniformity, and timeliness of the final product.

FACTORS AFFECTING THE DECISION TO RESEAL

The factors that should be considered in determining whether the cracks or joints should be sealed or resealed in a section of pavement include:

1. Highway classification (secondary, primary, Interstate, etc.).
2. Traffic volumes and type of traffic.
3. Climatic conditions (precipitation, temperature, etc.).
4. Pavement type.
5. Pavement condition (general).
6. Subgrade type.
7. Subgrade characteristics (permeable, impermeable).
8. Joint or crack type(s).
9. Joint or crack condition (width, spalling, etc.).
10. Crack density (frequency, multiplicity).

The costs of traffic control and safety are greater for the higher classifications of highways. High-traffic-volume freeways are much more difficult to repair than low-volume farm-to-market roads. Thus it is desirable to use more durable materials on the higher volume roads to reduce the repair frequency. Due to increased traffic-control costs, more expensive and durable materials become cost-effective.

Crack and joint resealing can be considered either preventive or corrective in nature. If crack or joint resealing is done in a timely manner and helps to prevent other more severe pavement defects, then it is preventive and thus timing is critical. High-traffic-volume roads deteriorate more rapidly after distress first develops; therefore early repairs are essential to prevent more costly corrective maintenance at a later time.

Climatic conditions are critical. Temperature variations result in contraction and expansion of the pavement and thus the opening and closing of joints and cracks. Joints and cracks that are not properly sealed allow the entrance of water and incompressible materials, causing spalling or blow-ups as the pavement expands. Water entering the pavement can significantly affect the performance of the pavement due to changing subgrade support. In addition, water contributes to pumping in rigid pavements and ultimate joint faulting and slab cracking.

A knowledge of the pavement condition is necessary to determine the type and extent of treatment required. Crack sealing or filling may not be the best solution if the pavement has other deficiencies, if the pavement is badly deteriorated, or if there is multiplicity of cracking. In some cases, crack sealing in combination with other treatments, such as surface sealing or overlaying, may be the optimal solution. Pavement performance data are essential in making the proper choice of a treatment.

Information on the characteristics of the subgrade and the effect of moisture is beneficial in determining whether the joints or cracks need to be sealed to keep out water. If the material is susceptible to water damage when combined with traffic loads, then sealing in a timely manner is necessary to maintain the pavement integrity.

Knowledge of the type of joint or crack and its condition is necessary to determine if and when resealing should be done. The questionnaire responses indicated that cracks ¼ in. (6 mm) or more in width were the ones generally being sealed. Some agencies indicated no width criteria for resealing. Spalling of the joint or crack and other joint or crack problems also affects the decision on when resealing should be done.

FACTORS TO BE CONSIDERED IN THE SELECTION OF THE TYPE OF RESEALING

The proper resealing of a particular joint or crack requires knowledge about the characteristics of the pavement, the joint or the crack, and the materials to be used for resealing. Once the decision has been made to reseal, information on the items listed below is needed in making the final design or selection.

Rigid Pavement Joints

1. Slab lengths (these control the amount of movement and therefore the sealant shape factor).
2. Joint movement (opening and closing).
3. Temperature and season at time of resealing.
4. Width and depth of sealant to be used, based on sealant material characteristics (shape factor).
5. Type and size of backing rod or tape to be used (if needed).
6. Materials and physical characteristics of sealant.
7. Techniques to be used in preparing joint and installing sealant (the technique should be matched to the sealant to be used).
8. Traffic control and safety.

Rigid Pavement Cracks

1. Crack type (longitudinal, transverse, corner, etc.).
2. Amount of crack movement and whether it is a working or nonworking crack.
3. Temperature and season at time of sealing.
4. Width of crack opening.
5. Crack condition.
6. Proposed shape of crack sealant (width and depth).
7. Material and physical characteristics of sealant.
8. Techniques to be used in preparing crack (routing, cleaning, etc.) and installing sealant. Techniques selected may be influenced by sealant material used.
9. Traffic control and safety.

Flexible Pavement Cracks

1. Crack type (longitudinal, transverse, etc.).
2. Amount of crack movement.
3. Width of crack opening.
4. Temperature and season at time of resealing.
5. Crack condition (spalling, multiplicity, etc.).
6. Proposed shape of crack sealant (width and depth).
7. Material and physical characteristics of sealant.
8. Techniques to be used in preparing crack (routing, cleaning, drying, etc.) and installing sealant. Techniques selected may be influenced by sealant properties.
9. Traffic control and safety.

MAINTENANCE PERFORMANCE STANDARDS

Many agencies have developed standards for maintenance activities to help assure uniformity of the work product. The maintenance performance standards also provide some measure of expected production or quantity of work for a given amount of effort to assure efficiency and minimize costs. A typical performance standard will usually contain the following items:

1. Narrative description of the activity.
2. Purpose of the activity.
3. Type of road or pavement or both.
4. Manpower requirements required to accomplish the activity.
5. Equipment requirements.
6. Material types and amounts.
7. Traffic control.
8. Workmanship expected during the accomplishment of the activity and quality of the completed work product; desired end product.
9. Productivity or accomplishment measurements to be used. This may be the estimated manhours required to perform a unit of work or the expected quantity of work to be performed by a crew in 1 day. For the measurement of productivity, some agencies use gallons of sealant per day, whereas others use ft or miles of cracks or joints sealed per day. Some agencies use lane-miles per day.
10. Recommended procedure to complete the activity (this is usually presented in a step-by-step manner).

The performance standard not only describes the sequence of operations, but also provides a measure of performance both in the quality of the end product and in the quantity of work expected to be accomplished. Examples of the maintenance performance standards used by several agencies are presented in Appendix B.

EXAMPLES OF AGENCY PRACTICE

Ontario

Ontario has developed pavement maintenance guidelines covering various types of distress, maintenance alternatives, and performance standards (*5*). The guidelines include: (a) photographs of the different types of pavement distress and the various stages of development; (b) a method for classifying each distress according to severity and extent; (c) lists of suitable treatments or maintenance alternatives including expected service life; (d) performance standards for each type of treatment; and (e) a method for determining the most cost-effective maintenance alternative through the use of a calculated value called equivalent annual cost. Equivalent annual cost was developed to take into account the differences in service life between treatment alternatives and to determine the average cost of a repair throughout service life.

$$\text{EQUIVALENT ANNUAL COST} = \frac{\text{UNIT COST}}{\text{EXPECTED LIFE OF ALTERNATIVE (YR)}}$$

where

EXPECTED LIFE OF ALTERNATIVE (YR) is obtained from experience and is as reported in the distress treatment tables (*5*).

$$\text{UNIT COST} = \frac{\text{MANPOWER} + \text{EQUIPMENT} + \text{MATERIALS}}{\text{ACCOMPLISHMENT PER DAY}}$$

where

MANPOWER, EQUIPMENT, AND MATERIALS required to perform the activity are as reported in the Maintenance Performance Standards (*5*), and
ACCOMPLISHMENT PER DAY is the amount of work that can be done in 1 day on a particular activity as reported in the Maintenance Performance Standards (*5*). (Crack sealing accomplishment is measured in volume of crack sealing material used per day.)

The treatment alternative having the lowest equivalent annual cost is considered to be the most cost-effective.

The Ontario manual (*5*) describes each form of cracking for both flexible and rigid pavements. The possible causes of the cracking, the levels of severity, the density of cracking, and the expected effective service life in years are provided. Maintenance performance standards are given for each maintenance treatment alternative. The performance standard contains information on crew size, equipment requirements, materials, accomplishment units of measure (volume, weight), manhours required per accomplishment, and accomplishment per day. This information is used to calculate the equivalent annual cost and to determine the most cost-effective procedure through comparison of different treatment alternatives.

California

California's pavement management system (*4, 35*) is somewhat similar to the Ontario system in that both include severity and extent in the field measurements. In California, a computer is used to help identify appropriate repair strategies for the distress mode in question. The cost-effective strategies are identified along with reasonable alternatives. Alternative repair procedures for cracking include crack sealing and other treatments, such as seal coats, thin blankets, and overlays. A report by Bartell and Kampe (*35*) contains the following information for crack filling on flexible pavements:

1. Repair strategy—crack filling
2. Function (objective)—waterproof pavement
3. Proper use—A. Clean crack > ¼″
   B. Appropriate sealant
4. Improper use—A. Dirty cracks
   B. < ¼″ wide cracks
5. Service life—1 to 2 years
6. 1976–77 cost per lane-mile—$200.00
7. California experience—extensive.

Sawed joints in rigid pavements are not generally filled unless excessive spalling occurs. Random cracks in rigid pavements are filled following the same general guidelines described for flexible pavements.

MOISTURE ACCELERATED DISTRESS (MAD)

Research was conducted by the University of Illinois at Urbana-Champaign on a pavement moisture accelerated distress (MAD) identification system for the Federal Highway Administration (*49–51*). Because moisture is a major contributor to the development of pavement distress, the study was conducted to gain a better understanding of moisture damage and to develop a tool to predict the potential for moisture damage.

The moisture accelerated distress index and the moisture distress index (MDI) are potential tools for determining the need for joint and crack sealing. The lower MAD indices indicate situations where the need to keep moisture out of the pavement system is critical. High MDIs indicate that a high ratio of moisture distress exists and that there is a critical need to control it.

> Distress can be directly related to the presence of moisture, but more importantly, it is accelerated by moisture at varying rates. The need to be able to examine moisture accelerated distress and predict the future behavior of the pavement has led to the development of the methodology presented in this report. *M*oisture *a*ccelerated *d*istress, given the acronym MAD, either already exists, or has a level of potential development in all pavements (*49*).
>
> The MAD Index indicates the relative potential for moisture to cause or accelerate distress. It also shows the engineer which materials are most likely responsible. The MAD Index serves as an indicator of where potential problems may be expected to develop most readily. It can be used as a design tool for new construction as well as for investigating rehabilitation needs (*50*).
>
> The *m*oisture *a*ccelerated *d*istress index (MAD Index) is a ranking procedure designed to separate pavements based on their potential to exhibit drainage problems which could lead to premature deterioration of the pavement structure. The MAD Index is formed by considering the climate of the area and the properties of the pavement foundation materials (*50*).

The MAD index is determined through a combination of climatic zones, granular material acceptability, and subgrade drainability. Figure 10 is a map showing the climatic zones in the United States. The roman numerals indicate the moisture region and the alphabet letters indicate the temperature region. The three classifications of granular material acceptability (ac-

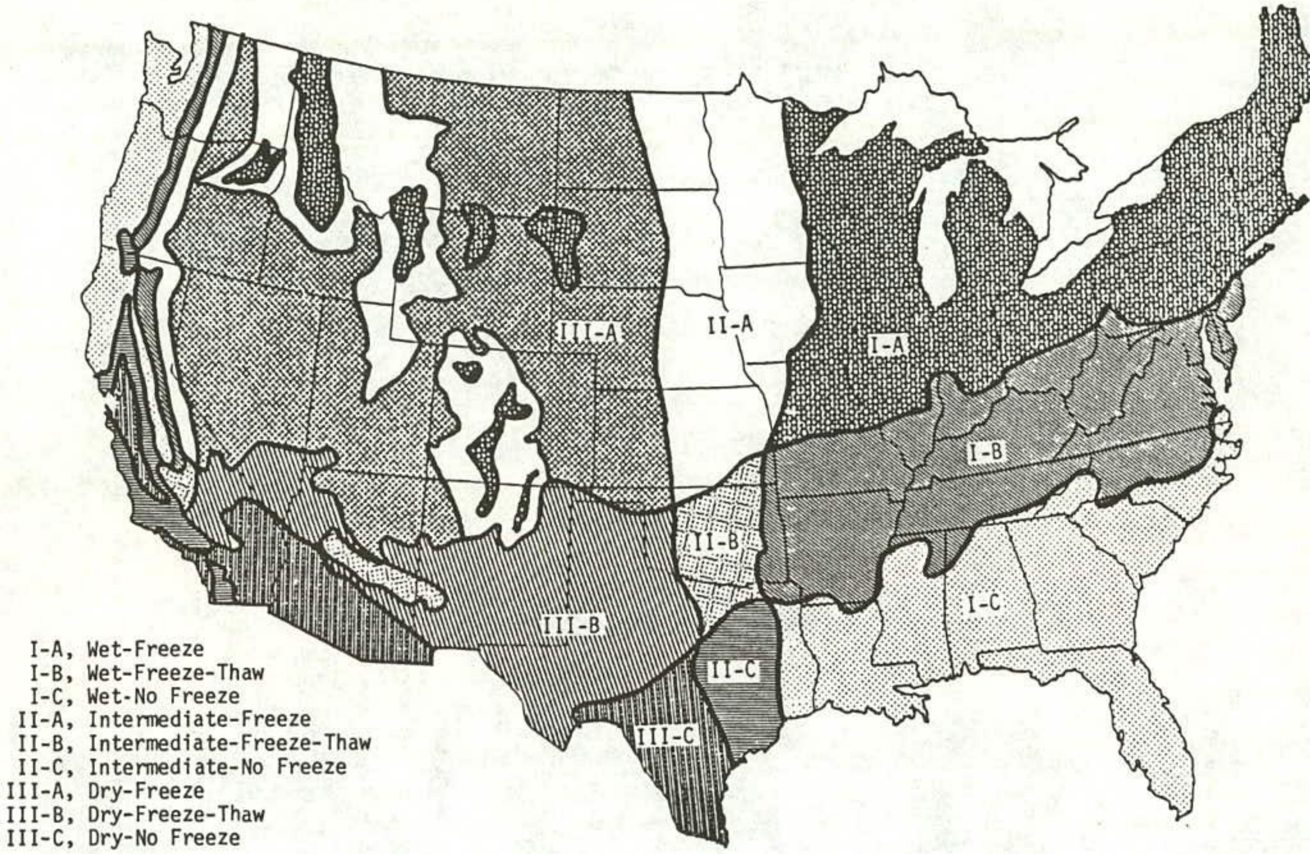

FIGURE 10 U.S. climatic zones (*50*).

ceptable, marginal, unsatisfactory) are shown in Figure 11. The three levels of subgrade drainability (k, j, i), based on the AASHTO classification, and the position of the material in the topography are shown in Figure 12. The ranking of material combinations using the MAD index is shown in Figure 13. The moisture damage potential for various MAD indices is shown in the figure corresponding with various climatic and materials combinations. The damage potential for various MAD indices is shown in Figure 14 along with a narrative description for each damage potential term.

Distress data are obtained for pavement sections in the field and tabulated. The distress data containing the specific distress type, severity (low, medium, high), and amount (or density) are then used to determine deduct values. The pavement condition index (PCI) is then calculated:

$$\text{PCI} = 100 - \text{CDV}$$

where

PCI = Pavement condition index, and
CDV = Corrected deduct value.

A distress identification manual is included in a report for the FHWA by Carpenter et al. (*50*). Each distress type description contains a section titled "Acceleration of . . . by Moisture." The moisture distress index (MDI) is determined as follows:

$$\text{Moisture distress index (MDI)} = \frac{\text{Sum of deduct values of moisture related distress and severity} \times 100}{\text{Sum of all deduct values}}$$

The moisture accelerated distress (MAD) index and the moisture distress index (MDI) can be evaluated together to see if what was predicted is actually occurring. The MAD index is indicative of the potential for moisture damage and the MDI is a measure of the distress damage that is actually occurring. Various distress manifestations for flexible pavements and rigid pavements are shown in Figures 15 and 16, respectively, along with various causes (moisture, climatic conditions, material problems, or load associated).

A design philosophy for water in pavement systems was developed and recommended in the study for the FHWA by Dempsey et al. (*51*). This design philosophy is based on the concepts for predicting water conditions and the methods for controlling water content. Three methods of controlling the water content in the design were identified (see Figure 17):

- Protection of the roadway.
- Rendering materials insensitive to water.
- Evacuation of water from the pavement system.

Protection of the roadway includes waterproofing the roadway, which includes the use of joint and crack sealants. Methods of protecting the roadway are shown in Figure 18.

Acceptable:	(a):	Will readily pass water to the down slope. Free draining. Load Related granular moisture performance will be excellent and will not be influenced by the subgrade.
Marginal:	(m):	May let load related moisture damage accumulate in the granular layer. Drainage is an absolute necessity for this material. The moisture related performance may be improved by the subgrade.
Unsatisfactory:	(u):	Granular layer will absorb moisture and remain above the critical saturation level even with drainage. Moisture damage will be excessive in the granular layer and the subgrade cannot alter it.

FIGURE 11 Performance of granular layer defined by the quality level (representing the best situation attainable) (*50*).

AASHTO Class. \ Position in Topography.	Top of Hills	Sides of Hills	Depressions
A-1 A-3	K	K	K
A-2-4 A-2-5	K	K	J
A-2-6 A-2-7	K	K	J
A-4	K	J	J
A-5	J	J	i
A-6	J	i	i
A-7-5 A-7-6	i	i	i

A group index above 20 will alter the NDI rating, K → J, J → i.

A group index below 5 will alter the NDI rating, i → J, J → K.

FIGURE 12 Approximate relationships for obtaining the natural drainage index from soil classification data (*50*).

Moisture Region → Temperature Region → Granular Material acceptability → Subgrade Drainability

MAD Index	Damage Potential	Combinations
100	NEGLIGIBLE	
99		
98		
97		
96		
95		
94		
93		
92		III Cak
91		
90		
89		III Cmk
88		
87		
86		
85		III Caj III Bak
84	LOW	
83		
82		III Bmk
81		
80		
79		
78		III Caj III Cmj III Baj III Cuk III Aak
77		
76		
75		III Amk
74		II Cak
73		
72		
71		III Cuk III Bmj III Aaj III Buk II Cmk
70		III Cmi III Bai
69	NORMAL	
68		
67		II Caj II Bak
66		
65		
64		III Buk III Amj III Auk II Bmk
63		III Cui III Bmi III Aai
62		
61		
60		II Cmj II Baj II Cuk II Auk
59		II Cai
58		
57		III Auk II Amk
56		III Bui III Ami
55		
54	MODERATE	I Cak
53		II Cmi II Bai II Cuk II Bmj II Auj II Buk
52		
51		I Cmk
50		
49		III Aui
48		
47		I Caj I Bak
46		II Buk II Amj II Auk
45		II Cui II Bmi II Aui
44		I Bmk
43		
42		
41		
40		I Cmj I Bai I Cuk I Aak
39		II Auk I Cai
38		II Bui II Ami
37		I Amk
36		
35		
34	HIGH	
33		I Cuj I Bmj I Aaj I Buk
32		I Cmi I Bai
31		II Aui
30		
29		
28		
27		
26		I Buj I Amj I Auk
25		I Cui I Bmi I Aai
24		
23		
22		
21		
20		
19		I Aui
18		I Bui I Ami
17		
16		
15		
14	EXCESSIVE	
13		
12		
11		I Aui
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		

FIGURE 13 Ranking of material combinations, the MAD index (*50*).

MAD Index	
Negligible: (85-100)	This pavement would not show any moisture-related problems during its lifetime - Drainage not needed.
Low: (70-85)	This pavement contains a combination of properties that make it moisture insensitive, but climatic influences and maintenance must be carefully watched to maintain the good performance.
Normal: (55-70)	This pavement is composed of average materials exposed to average situations. Moisture damage is likely unless adequate drainage and maintenance are kept at a high level.
Moderate: (35-55)	Lower quality materials and a slightly inferior climate will produce large amounts of moisture damage unless extensive care is given to drainage considerations and routine maintenance.
High: (15-35)	Even with adequate drainage moisture damage will appear due to variability in materials. Without drainage there would be excessive moisture damage.
Excessive: (0-15)	The combination of climate and materials precludes any effectiveness of drainage in reducing moisture damage. Severe problems will develop, excessive maintenance should be planned for.

FIGURE 14 Potential for moisture-accelerated problems in a pavement as indicated by the MAD index (*50*).

TYPE	DISTRESS MANIFESTATION	MOISTURE PROBLEM	CLIMATIC PROBLEM	MATERIAL PROBLEM	LOAD ASSOCIATED	STRUCTURAL DEFECT BEGINS IN		
						ASPHALT	BASE	SUBGRADE
SURFACE DEFECT	ABRASION	NO	NO	AGGREGATE	NO	YES	NO	NO
	BLEEDING	NO	ACCENTUATED BY HIGH TEMP	BITUMEN	NO	YES	NO	NO
	STRIPPING	YES	YES	BOTH	YES	YES	NO	NO
	RAVELLING	NO	NO	AGGREGATE	SLIGHTLY	YES	NO	NO
	WEATHERING	NO	HUMIDITY AND LIGHT-DRIED BITUMEN	BITUMEN	NO	YES	NO	NO
SURFACE DEFORMATION	BUMP OR DISTORTION	EXCESS MOISTURE	FROST HEAVE	STRENGTH-MOISTURE	YES	NO	YES	YES
	CORRUGATION OR RIPPLING	SLIGHT	CLIMATIC & SUCTION RELATIONS	UNSTABLE MIX	YES	YES	YES	YES
	SHOVING	NO		UNSTABLE MIX LOSS OF BOND	YES	YES	NO	NO
	RUTTING	EXCESS IN GRANULAR LAYERS	SUCTION & MATERIAL	COMPACTION PROPERTIES	YES	YES	YES	YES
	WAVES	EXCESS	SUCTION & MATERIALS	EXP. CLAY FROST. SUSC.	NO	NOT INITIALLY	NO	YES
	DEPRESSION	EXCESS	SUCTION & MATERIALS	SETTLEMENT, FILL MATERIAL	YES	NO	NO	YES
	POTHOLES	EXCESS	FROST HEAVE	STRENGTH-MOISTURE	YES	NO	YES	YES
CRACKING	LONGITUDINAL	YES	SPRING-THAW STRENGTH LOSS		YES	FAULTY CONSTRUCTION	YES	YES
	ALLIGATOR	YES DRAINAGE		POSSIBLE MIX PROBLEMS	YES	YES MIX	YES	YES
	TRANSVERSE	YES	LOW-TEMP., F-T CYCLES	THERMAL PROPERTIES	NO	YES, TEMP. SUSCEPTIBLE	YES	YES
	SHRINKAGE	YES	SUCTION, MOISTURE LOSS	MOISTURE SENSITIVE	NO	YES, HARDENING	YES	YES
	SLIPPAGE	YES	NO	LOSS OF BOND	YES	YES-BOND	NO	NO

FIGURE 15 Distress manifestations for flexible pavements (*50*).

TYPE	DISTRESS MANIFESTATION	MOISTURE PROBLEM	CLIMATIC PROBLEM	MATERIAL PROBLEM	LOAD ASSOCIATED	STRUCTURAL DEFECT BEGINS IN SURFACE	BASE	SUBGRADE
SURFACE DEFECTS	SPALLING	POSSIBLE	NO	CHEMICAL INFLUENCE	NO	YES - FINISHING	NO	NO
	SCALING	YES	F-T CYCLING		NO	YES	NO	NO
	D-CRACKING	YES	F-T CYCLING	AGGREGATE	NO	YES	NO	NO
	CRAZING	NO	NO	RICH MORTAR	NO	YES - WEAK SURFACE	NO	NO
SURFACE DEFORMATION	BLOW-UP	NO	TEMPERATURE	THERMAL PROPERTIES	NO	YES	NO	NO
	PUMPING	YES	MOISTURE	FINES IN BASE MOISTURE SENSITIVE	YES	NO	YES	YES
	FAULTING	YES	MOISTURE-SUCTION	SETTLEMENT DEFORMATION	YES	NO	YES	YES
	CURLING	POSSIBLE	MOISTURE AND TEMP.		NO	YES	NO	NO
CRACKING	CORNER	YES	YES	FOLLOWS PUMPING	YES	NO	YES	YES
	DIAGONAL TRANSVERSE LONGITUDINAL	YES	POSSIBLE	CRACKING FOLLOWS MOISTURE BUILDUP	YES	NO	YES	YES
	PUNCH OUT	YES	YES	DEFORMATION FOLLOWING CRACKING	YES	NO	YES	YES
	JOINT	PRODUCES DAMAGE LATER	POSSIBLE	PROPER FILLER AND CLEAN JOINTS	NO	JOINT	NO	NO

FIGURE 16 Distress manifestations for rigid pavements (*50*).

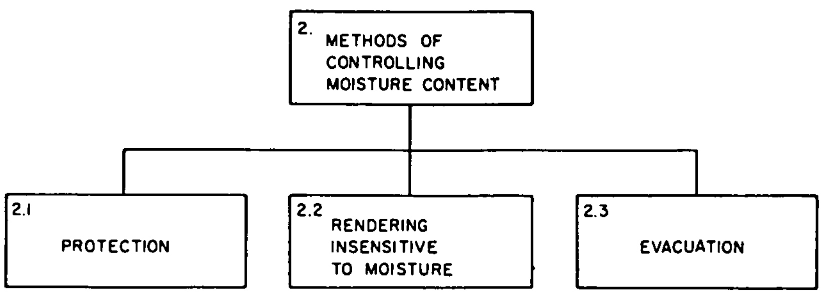

FIGURE 17 Controlling moisture content in the pavement system (*51*).

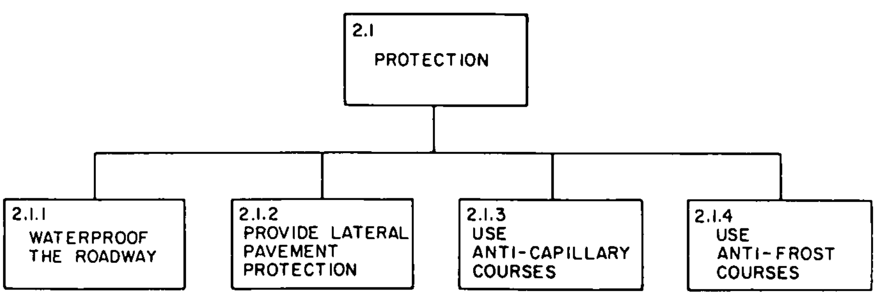

FIGURE 18 Protection of the roadway (*51*).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions are based on the information gathered and evaluated during the preparation of this synthesis:

1. The consensus of most states is that crack and joint resealing is beneficial and should be performed. The cost effectiveness of the procedures has not been documented.
2. Crack and joint resealing is considered effective for extending pavement life and reducing pavement deterioration. Pavement deterioration is accelerated by water entering the pavement and incompressibles filling unsealed joints and cracks. Resealing at the proper time will reduce overall maintenance costs and prolong the life of the pavement.
3. The average frequency for resealing joints and cracks in rigid pavements is 5 yr; the average frequency for resealing cracks in flexible pavements is 3.6 yr. The frequency is not necessarily related to sealant life but may be due to availability of funds and manpower.
4. Adhesion (or bond) failure is the most frequent cause of sealant failure, and is caused by poor materials, improper shape factor, inadequate joint or crack preparation, incorrect installation procedures, or a combination. Sealant failures contribute to pavement failures, such as blow-ups, faulting, pumping, and subgrade weakening. Joint or crack resealing is effective as a maintenance tool in preventing or delaying failures in the pavement system. Sealing is not considered an effective measure if the pavement is badly deteriorated.
5. Joint or crack sealing or resealing prevents or retards spalling of the face of the joint or crack by keeping out the incompressibles.
6. The most common criterion for sealing cracks is the width of the crack. Conventional sealing equipment can be used to install sealants in wide cracks. The resealing of narrow cracks requires routing. The size of the crack width generally used as the criterion in the decision to reseal is about ¼ in. (6 mm); some agencies use ⅛ in. (3 mm).
7. Few cost data are available and are difficult to obtain on a lineal-ft basis. Most agencies use lane-miles as the basis for costs. As reported by the agencies, costs per lane-mile per yr of service averaged $142 for rigid pavement joints, $58 for rigid pavement cracks, and $57 for flexible pavement cracks.
8. The cost of proper preparation of the joint or crack is generally more than the cost of the sealant material. However, preformed seals may cost more than joint preparation. Sealant costs range from a few cents per lineal ft for unmodified liquid asphalt to as much as $1 per ft for the preformed joint seals. Durability is important in order to reduce sealing frequency and annual costs. Traffic-control costs may be high during the resealing process.
9. Utilization of a proper shape factor (ratio of width to depth of the in-place sealant) is considered essential to poured sealant longevity. When the ratio is small (a narrow width and large depth), the stress on the sealant will be high. Generally under these conditions adhesion failure will occur. Shape factor is critical in the ability of the sealant to withstand extension as the pavement contracts. The recommended shape factor is generally 1:1 (with a minimum of 1:2) width to depth.
10. The addition of rubber to asphalt sealants enhances the properties of the sealants and increases their effectiveness rating. It was reported that the ratings generally increased one full effectiveness rating; e.g., from fair to good. Several states reported longer sealant life through the use of rubberized asphalt.
11. Proper joint and crack preparation and sealing techniques are essential to assure long sealant life. Effective joint and crack sealing techniques include removal of the existing failed sealant, sizing the joint or crack through routing or sawing, cleaning, drying as needed, using backing material to control depth if needed, and proper installation of the sealant.
12. Climatic conditions at the site are an important factor in the decision to seal. If the potential for moisture damage is high, sealing is critical in reducing or preventing pavement damage due to water. Because certain distresses are accelerated by the presence of moisture in the system, the reduction of water will slow or stop stress development.
13. The three methods of controlling moisture in a pavement system are: protecting the roadway, rendering the materials insensitive to moisture, and evacuating water from the system. Crack resealing and joint resealing are effective methods of protecting the roadway by preventing water from entering the system through the pavement surface.
14. Maintenance performance standards based on sound principles and documented experience are essential in assuring uniformity of the final product and long performance. Standards should include the following: (a) narrative description, (b) purpose, (c) pavement and road type, (d) manpower needs, (e) equipment requirements, (f) materials, (g) traffic control, (h) workmanship, (i) productivity or accomplishment measures, and (j) recommended procedure in a step-by-step format.

RECOMMENDATIONS

The following recommendations are based on the need for further information and work in order to better understand the effectiveness of sealing programs and to enhance their performance:

1. More experimental work is needed under a wide range of conditions, including varied climate conditions, to further un-

derstand and document the effectiveness of sealing cracks and joints. Control sections should be left unsealed to document the benefits of sealing under the full range of conditions. Sealed sections should be adequately maintained throughout the evaluation period.

2. Information is needed on sealing costs in terms of sealing materials, joint or crack preparation, and traffic control. The costs should be per lineal ft of joint or crack, rather than lane-mile, because of the variation in joint and crack spacing.

3. More information is needed on the effective life of various sealing materials and on the effects of various placement techniques on sealant life. This information, along with the unit costs, is needed in determining the cost-effectiveness of a sealant. A definition for point or time of failure is needed.

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APPENDIX A

EXAMPLES OF TECHNIQUES AND PROCEDURES FOR SEALING AND RESEALING JOINTS AND CRACKS

Guidelines for Silicone Sealing

PURPOSE

These guidelines are to provide information on the installation of silicone sealants on maintenance and new construction that will be useful in the installation and inspection of silicone sealing.

INTRODUCTION

This information has been compiled to establish methods that have been successful as the accepted procedure for installation of silicone seal. These guidelines are not intended to establish the only methods by which the desired results can be obtained. Innovations that result in a more efficient operation are encouraged, but they must result in a well sized joint, uncontaminated with sawing latence (concrete dust), old sealant, dirt mud or moisture sealed with silicone well bonded to both faces of the joint, with a properly designed sealant cross-section in street conformance with the plan detail. Study of sealing operations indicates that effective sealing is possible and that uniform sealant depth, recess, and joint width can be obtained within reasonable limits. The methods by which the desired results can be achieved and evaluated are outlined.

I. SAWING

Many factors contribute to sawing efficiency. The following are listed:

(1) Blade combination. Blades may be ganged together to achieve the necessary width. This is usually more economical than expensive wide blades.

(2) Blade diameter. The blade diameter influences the following: 1) horsepower of the saw and 2) the cost of sawing. Larger diameter blades cost more. Generally, the blade diameter should be no more than necessary to cut the required depth.

(3) The water supply must be adequate to cool blades and a jet of water should be directed to both sides of the blade.

(4) Sawing RPM determined by blade diameter; normally surface speed should be 9,000 - 10,000 ft/min.

(5) Maneuverability of the saw. The more maneuverable saws can more accurately follow initial cut or old joint centerlines.

(6) Cutting pressure which is also a function of forward travel saw should be operated so that the saw does not try to ride out of joint. Also crowding of saw may cause the saw to lead to left or right. Warping or dishing of blades may also result.

(7) Orientation of saw, such as change of position at shoulders, change of direction, etc.

(8) Accurate operation of the saw is essential. The minimum width is desirable and to follow the joint accurately enough to cut 1/16 inch or less on each face requires very accurate sawing. Small saws have relatively great maneuverability.

(9) Wheel wear. Uneven wearing of drive wheels will cause a saw to lead to left or right and control is difficult.

(10) A guide should be used to insure accurate alignment of the saw in the joint.

II. CHECKING THE SAWED JOINT

The following checks should be made when the final saw cut is complete:

1) The joint width should be checked for uniformity. The cause for non-uniformity should be determined and corrections made early if the best results are to be obtained. When a cut is made with one pass with a blade width approximately the desired joint width or gauging blades of similar width a uniform joint width usually results. However, when a joint is not followed accurately or when a cut is made down each joint face to remove old sealant or unitube in wide joints a groove varying width is often produced. When joint width varies the force required to insert the backup material and the amount the backup material rebounds also varies. If the maximum control of sealant depth is to be obtained, it is necessary that the joint width be uniform. A non-uniform joint will cause the depth of the backup material to vary unless special attention is given subsequent to rolling it in place. When the depth of the backup rod varies, the depth of sealant or the depth of recess or both must vary and maintaining the required tolerance is not possible. Varying joint width also requires that the nozzle travel through the joint vary if constant sealant depth is maintained. When the joint narrows, the speed must increase. When the joint widens the rate of travel through the joint must decrease. Large variations in joint widths require 2 sizes of backup material and special attention to installation. Old sealant not completely removed to sufficient depth or old sealant and debris left in joints prevents installation of backup material to the proper depth and a deficient sealant depth recess is the result.

2) The joint must be checked for cleanliness. The most common cleaning deficiency on resealing work is old sealant left on joint faces. When old rubber-asphalt sealant is left on joint faces it is difficult if not impossible to remove by scrapping or sandblasting. It can be removed by water blaster which can also utilize sand in the water. Sandblasting will also remove a film of old sealant but sand and air does not readily cut rubber like materials.

The following precautions should be taken to prevent the presence of old sealant on the faces of a joint prepared for sealing:

a) The saw blade or blade combination should be of adequate width to cut concrete on both joint faces.

b) The saw must be guided very accurately through the joint. When the saw is permitted to deviate from the joint centerline concrete on only one face is cut and a varying width joint with old sealant on one face results. Initial misalignment when the saw is started in the joint leaving old sealant at the beginning of the joint is common.

c) Wheels on self-propelled saws wear unevenly causing saws to lead to the left or right because of different wheel diameter. Accurate sawing is difficult when drive wheels are not properly maintained.

3) Unsound or fractured concrete indicating potential spalls should be removed and the large ones repaired prior to sealing.

III. CLEANING

Sawing residue of concrete and old sealant on resealing work must be removed from the joint. Normally a well directed, concentrated jet of water of sufficient pressure will wash the joint faces clean with very little difficulty if sawing residue is not allowed to dry. However, often water is trapped in joints and contaminated water will deposit a film of dust on joint faces which must be removed. A jet of high pressure air immediately ahead of sealant installation but prior to installation of backup material is usually adequate. One solution is to use an excess of water to wash the joint clean so that only clean water is left to dry from the joints. A final cleaning with air immediately ahead of sealant installation is usually beneficial but care should be taken that the air does not displace the backup rod.

The following cleaning methods have been successfully used:

Sandblasting

Sawing residue that has been permitted to dry and harden on joint faces can be readily removed by sandblasting. However, rubber asphalt hot pour left on joint faces is very difficult to remove even by sandblast cleaning. Often the sand will cut the concrete adjacent to the rubber asphalt before the old sealant is removed. Some old sealant can be removed by sandblasting if it is in a deteriorated, oxidized condition but this is usually a very slow process. Often soil will be splashed on joint faces that cannot be easily removed with high pressure air alone.

Compressed Air

Check for oil. The air compressor should have a trap capable of removing excess moisture and oil. Oil and moisture when present can be detected by simply passing a piece of cleaning tissue through the air jet. Air compressors in poor condition sometime produce air containing oil. This inhibits the ability of the sealant to adhere. Excessive moisture is also undesirable.

An air jet when directed into a wet joint will usually splash mud on joint faces and result in a worse condition than if it was not used. The joints can be blown completely dry after which the dry contaminant is readily removed with compressed air.

Water Jet

Joints freshly sawed or joint resawed to remove old sealant can usually be cleaned with a well directed water jet when the water is not trapped in the joint. Unless an excess of water is used sawing residue suspended in the water will redeposit on joint faces. A well directed jet of water can be used to force sawing residue and old sealant from and away from the joints to that it does not return.

Wire Brushing

Wire brushes used in conjunction with compressed air are the most effective method of cleaning joints. Joints cleaned in this manner are usually dry and can be sealed immediately after cleaning. When joints are cut the minimum width, some wire brushes will not go into the joints because they are too wide. Brushes are available that will do an effective job. These brushes have bristles that are limber enough to be concentrated by the centrifugal force. Bristles enter the joint and contact the faces. The contamination is moved from joint faces readily when brushes are used in conjunction with air. The cost of brushes and the addition of the operation is probably justified.

IV. BACKUP MATERIAL

Purpose

The purpose of the backup material is only to (1) support the sealant until it cures, (2) provide a means to control the depth of the sealant section, and (3) provide a surface to which the sealant will not bond.

Material

Closed cell polyethylene foam backup material is used almost exclusively when backup material is required for cold applied polymeric sealants. Masking tape, silicone coated foil tape, upholstery welt cord, butyl rubber have been used for bond release, backup material or both, but for low modulus silicone seal backup material will be closed cell polyethylene foam road of a circular cross-section. A rule of thumb for the size of the backup material is to use material with a diameter 1/8 inch greater than the saw cut width. Widths other than the rule of thumb width may be used if the purpose can be accomplished. Backup rod too small will not remain in position until the seal cures but will (1) curl out of the joint, (2) fall to the bottom of the joint, or (3) be forced down by the sealant as it is extruded into the joint. The backup rod which is too large will be evidenced by the following: (1) it will rupture during installation, and (2) it will be more difficult to position at the proper depth and frayed portions of rod will be found protruding through the sealant section. A backup rod that is larger than necessary can sometimes be used by stretching the rod to cause the diameter of the cross-section to reduce enough to permit it to be inserted into the joint. This practice does not appear to cause adverse results if it is not stretched to the breaking point.

Installation of Backup Material

A roller with a flange slightly narrower than the narrowest joint width is used. The depth of the flange must be greater than the depth of recess desired plus the sealant depth desired because the backup material is very resilient and will rebound. It is important that the depth of the final position of the backup material be checked to insure that the final position of the backup material be checked to insure that the desired cross-section and recess will result. Old sealant left in the joints will sometimes remelt and accumulate in the bottom of the joint often although the saw was run at adequate depth accumulation of old sealant will prevent the backup material being installed at proper depth.

INSTALLATION OF SEALANT

The manner of installation of silicone sealant must be such that the sealant is forced to the bottom of the joint and is preferably in contact with the joint faces. Normally full contact with the joint face will not be accomplished unless it is forced to contact the joint faces by the tooling operation. Sealant extruded into a joint and not forced against the joint faces will not adhere properly. The nozzle should be such that it can (1) fit into the joint, (2) have a flange that will ride on top of the slab, protrude into the joint enough to insure that sealant is forced to the bottom of the joint but not far enough to displace the backup material or to cause the force of the sealant to displace the backup rod. The rate of speed that the nozzle is passed through the joint should be constant.

The major fault observed with silicone sealant installation is the varying depth from too thick to too thin. With reasonable precaution the desired depth can be consistently maintained. However, the preparation prior to sealing must be adequate.

When a unit of material is put on the pump, air can be trapped under the plunger with proper care not to trap air and by bleeding off trapped air. Otherwise the sealant should be extruded from the nozzle until the the trapped air is expelled. Empty cartridges or guns should be kept on hand to be filled at this time. Filled cartridges can then be used on hand caulking guns to touch up joints and repair inspection plugs.

Silicone sealant bonds to cured sealant very readily and failures such as spalls, ruptures, and adhesion loss can be repaired so that the repair will not be detectable after a short period of time. The object is to seal the pavement. Therefore any saw cut extended into the shoulder, ruptures of previously sealed lanes at the juncture, must be prepared and sealed:

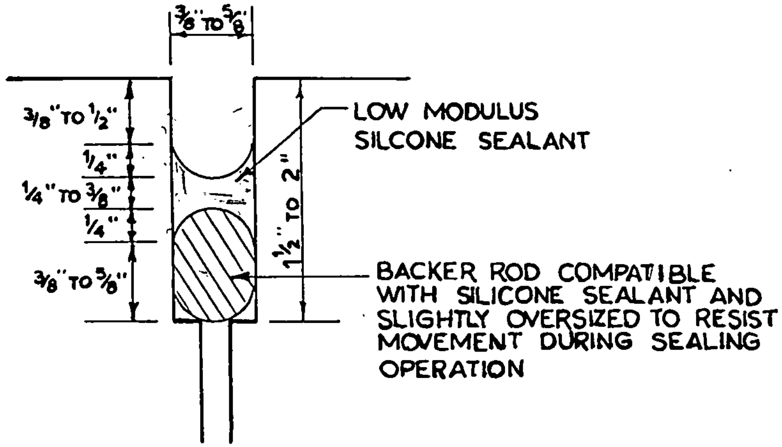
1) When one lane or partial joints are sealed the previously installed sealant must be cut or brushed so that the skin is removed and fresh uncontaminated material is present where bond is desired. Silicone sealant bonds readily to cured silicone with a freshly cut surface.

2) Cuts extended into the shoulder should be cleaned and sealed. Usually enough excess sealant is accumulated in the strikeoff process to seal these cuts.

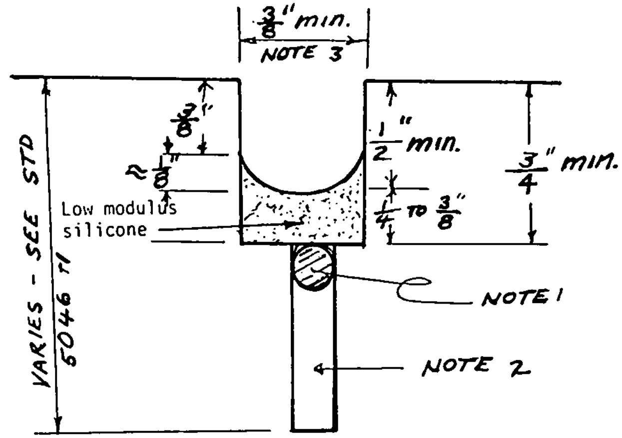
<u>Checking the Depth of Sealant</u>

The depth of sealant in the uncured state can be checked by sticking a blunt probe into the sealant. A small screw driver, blunt rod 1/16 - 3/32" diameter or other suitable items can be used if not sharp pointed. Care is needed to sense contact with the backup rod because it is easily depressed or forced downward causing sealant depth readings greater than the actual depth. Sharp instruments puncture the backup rod so easily that it is not possible to determine when initial contact is made. When the probe is withdrawn from the sealant the end is not visible and sealant extends past the end. If the probe is jammed against a firm block or object the depth can be measured. Another method is to measure the depth of recess and the depth of the backup material with a depth gage. The depth of sealant is the difference between the two readings.

The depth of cured sealant can be determined by cutting a plug about one inch long from the joint, repairing the hole with a caulking tube size unit of silicone. The depth of the sealant can be measured directly from the plug and the plug can be numbered or labeled and saved if desired. Examination of the plug will reveal old sealant or other contamination if the plug is cut as close as possible to the concrete. Also, other deficiencies will be evident such as sealant not forced to the bottom or sides of the joint, bubbles in sealant and faulty cure. The depth of the cured sealant should be checked against the specification requirement.



DETAIL FOR SEALING JOINTS PRIOR TO GRINDING PAVEMENT



ALTERNATE DETAIL
MAY BE USED FOR CENTERLINE JOINT ONLY
IN LIEU OF OTHER DETAILS

NOTES:

1. Use backup rod only as desired to conserve sealant.
2. This area is filled with old sealant on resealing project. It may be necessary to place backup rod in the initial cut on new construction projects.
3. The final cut is to be such that some cut will be made on both sides of the joint. The initial cut will be followed as nearly as possible. On reseal projects originally constructed with unitube, the cut will be as wide as necessary to remove the unitube.

5-791.074 PROCEDURES FOR CONCRETE JOINT SEALING

A. Remove Old Joint Seal Materials

Concrete joint seal materials placed during the construction of the pavement consist of two types: preformed neoprene (Spec. 3721) and hot poured elastic (Spec. 3723). Prior to sawing and resealing the joints, the preformed and hot pour joint materials must be removed by manual or mechanical methods. Manual removal works best during the cool part of the day. A mechanical hook or claw welded to a blade or bucket can also be utilized successfully.

B. First Saw Cut

After the joint materials have been removed, each joint should be sawed 1/4" deeper than the original depth of the joint the width of the blade. This cut is made to remove the incompressibles which collect at the bottom of the joint. (See Figs. 1 and 2 5-791.074)

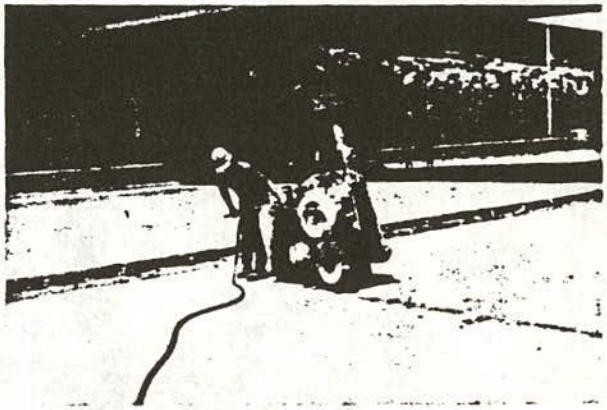


Fig. 2 5-791.074 - First saw cut. Saw needs to be adjusted to the proper depth 1/4" below bottom of original joint to remove incompressibles.

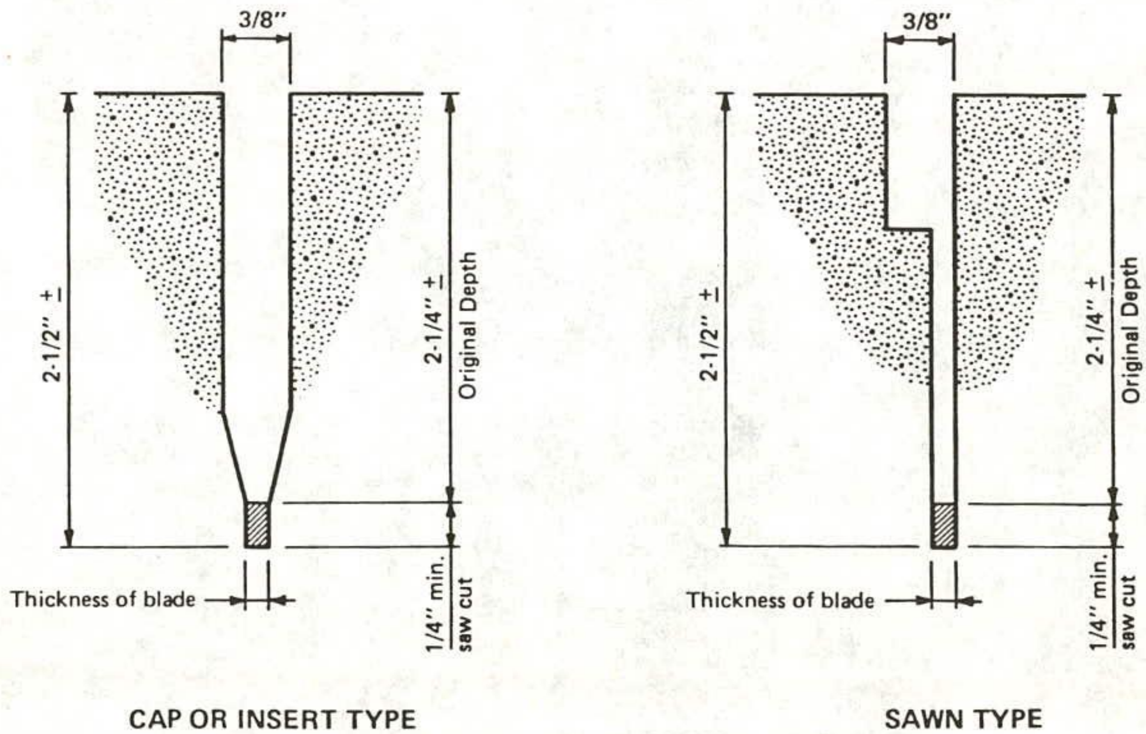
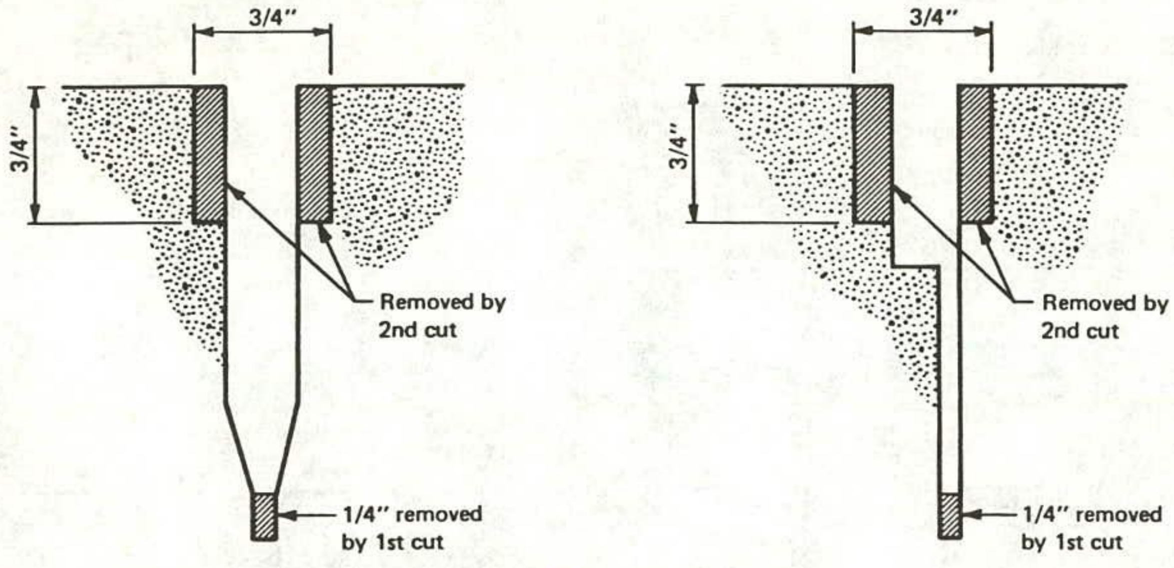


Fig. 1 5-791.074 - Joint after joint material is removed and first saw cut is made using 14" blade.

C. Saw Joint 3/4" x 3/4"

Each joint is sawed a second time to a width and depth of 3/4" (Fig. 3 5-791.074). Two 12" diamond blades with adequate spacers to cut 3/4" wide are bolted together (Fig. 4 5-791.074). Saw must be adjusted for proper depth of 3/4".



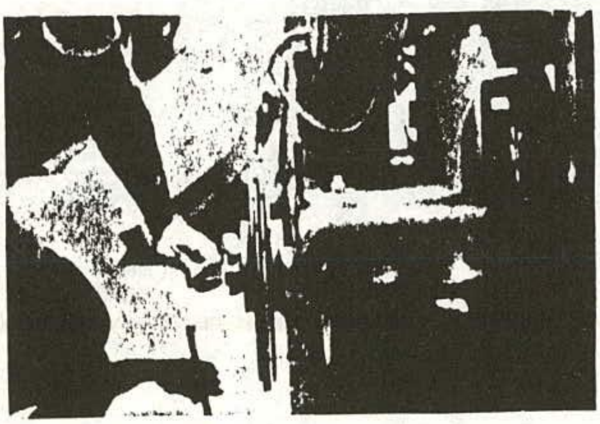


Fig. 4 5-791.074 - Blades are bolted together with spacers between them to provide proper width and permit water to cool each blade. Cutting edge of blade is thicker than center of blade. Provide proper spacer thickness to give 3/4" wide cut.

D. Flush Joint

After the second saw cut is made the joint shall be flushed with water. This is done to remove the cement-water slurry and other debris from the joint while it is still wet from the sawing operation. Water may be provided from same hose that furnishes the second saw.

E. Light Sandblast

The joints shall be cleaned by a light sandblast. The joints shall then be cleaned by air blast, inspected for cleanliness and any foreign material removed just before sealing, see Figure 5 5-791.074.

F. Place Backer Rod or Tape

Purpose of backer rod or backrolled masking tape is to prevent the joint sealant from flowing down through joint. (See Fig. 6 5-791.074).

Fig. 5 5-791.074 - Blow joint with air after sandblasting. Note hook on end of air hose pipe; this is used to aid in removal of rocks stuck in joint. If sliver of concrete is present, remove at this time.

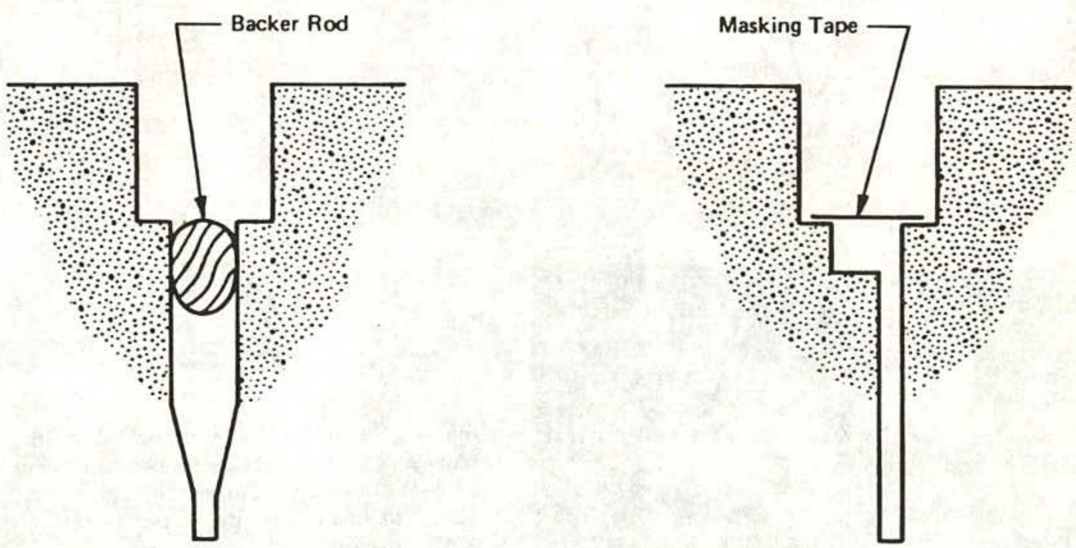


Fig. 6 5-791.074 - Joint with backer rod or backrolled masking tape inplace.

G. Place Joint Sealer

The joint sealer shall meet the requirements specified. Contact Concrete Engineering Section for the appropriate Specification). The joints shall be filled flush to not more than 1/8" above the pavement surface. In any location where, after a time interval of not less than 24 hours nor more than 48 hours, the joint sealer is more than 1/8" below the pavement surface, the joint shall be filled flush to the surface, see Fig. 7 5-791.074.

Shortly after placing, the surface of the sealer will be dusted with talc or covered with a single layer of tissue paper to prevent small incompressibles from bonding to the exposed tacky surface, see Fig. 8 5-791.074.

H. Random Cracks

Random or midpanel cracks that are tight do not require sealing. Only random cracks that are "working" require sealing.

A "working" crack is open and often will have "step-off"; "step-off" is when two sides of the joint are not in the same horizontal plane. Usually the depressed side is in the direction of the traffic flow. Open random cracks shall be routed to an approximate shape of 1/2" by 5/8". After routing, the random crack shall be treated the same as a joint.

I. Joint Spall Treatment

Often joints will exhibit small spalls along the face and at the corners. All fractured concrete, or unsound concrete at the joint must be removed prior to sealing.

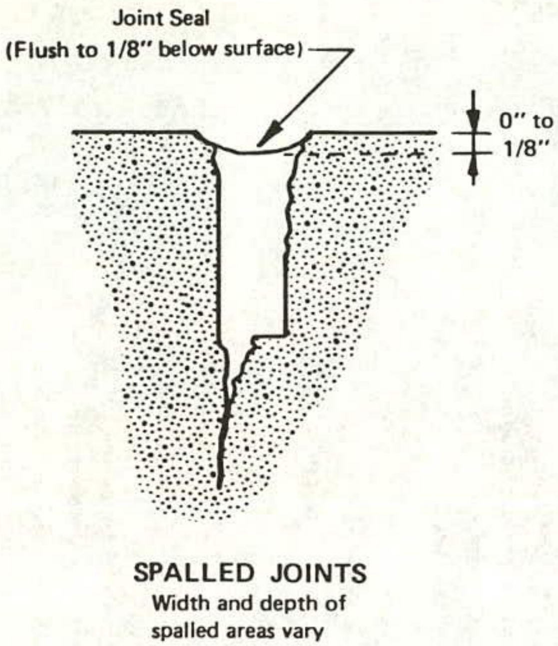


Fig. 7 5-791.074

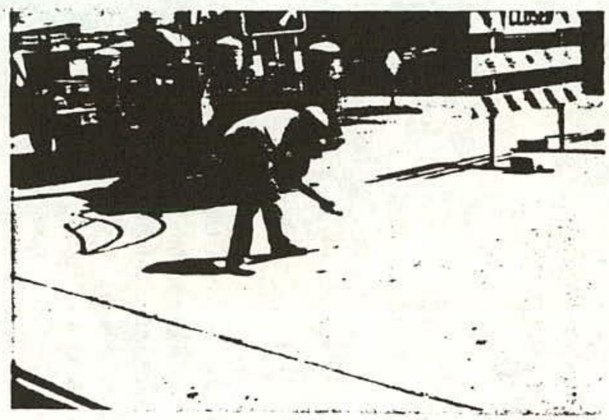


Fig. 8 5-791.074 - Placing talc

CONSTRUCTION

A summary of trial installations and individual installation notes may be found in Appendix IV. One cold pour sealant (RS-1 & sand) was dropped from the trials (see section 10 Appendix IV), causing the trials to end in section 19 instead of 20.

Routing

All the manufacturers of the sealing compounds required the cracks to be routed. Tennant and Crafco routers were used for most of the work with vertical routers of various manufacture being employed for the more meandering cracks. Even though this was a demonstration project and one would expect to see above average workmanship, there were numerous examples of cracks being missed in the routing operation. This problem was most severe where the Tennant router was employed, for it seems best suited to straight line cracks. The Crafco router could follow meandering cracks far better than the Tennant. The Crafco routers could be used alone but whenever the Tennant router was used alone many meandering cracks were missed. All the routers produced grooves with semi-vertical sides and rounded bottoms. Most routing was to a width and depth about 19 mm but some were deliberately less. (See Individual Installation notes Appendix IV).

The productivity of the routers was determined by Mr. F. Jewer of M.T.C. Maintenance Management Section who observed all the trials. (See Appendix V).

Tennant Router with carbide tip cutting wheels	-	15.2 m/min.
Crafco Router with steel cutting wheels	-	8.1 m/min.
Vertical Router with carbide cutter	-	0.72 m/min.

Unfortunately, the weather was not too favourable during the trials and rain caused several delays and some less than desirable installations. After a rain and subsequent drying of the pavement surface, the cracks would still show moisture for up to a day. When the damp cracks were routed, the moisture caused the finer fraction of the cuttings to form a slurry in the groove which would subsequently resist removal by either brushing or blowing.

Cleaning Grooves

The routed grooves were all cleaned with a jet of air, mostly from back pack blowers with air velocity of up to 320 km/hr. A rented compressor was at first used in Section 7 at the manufacturer's request but was given up in favour of a back pack blower after a very short time. The compressor is bulky and must be constantly moved and so is not nearly as convenient as the back pack blower which is free of hose length and other logistic problems. The back pack blowers were found to be in conditions from poor to good with some on the trials not fit for the job at all. The problems encountered with these units included:

- engine hard to start.
- engine would not run at full speed.
- engine would not keep running.
- hoses and nozzles in poor repair.

The back pack blowers would appear to be a high maintenance piece of equipment. Only the back pack blowers in top working condition did a satisfactory job of cleaning out the grooves. A Crafco wire brush/blower was used for short periods in Sections 16, 17 and 18, and this equipment did a superior job of cleaning the groove. The Crafco wire brush/blower is much more convenient than a compressor but still much slower in operation than a back pack blower.

In routed grooves that were damp neither back pack blowers nor the Crafco wire brush/blower would remove the fine slurry deposit.

Air blowing of the grooves had to immediately precede the filling operation or traffic would blow dirt back into the grooves. Whenever the blowing of the grooves got more than about 30 meters ahead of the pouring of the sealant, the grooves were observed to be dirty.

Filling the Grooves

The sealant was placed in the routed grooves with either a hand pouring cone or by hose and application wand from a low pressure pump on the melter.

The hand pouring cones are equipped with replaceable nozzles (standard 3/4 inch iron pipe thread) and with some of the more viscous sealants, these had to be removed to allow sufficient flow of material.

All but four of the materials were poured flush with the pavement surface. The other four sealants, three hot applied and one cold applied, were installed by overfilling the routed groove and then striking the material off with a squeegee. Trial Sections 17 and 18 employed a special designed horseshoe-shaped steel squeegee which limited the width of the spread.

Hot poured sealants placed in damp grooves did not develop much of a bond within the groove. In Section 8, the north 171 meters of the section was placed in a damp condition but since the surface was dry and the material overfilled and levelled, a good bond was achieved on the surface. Section 9 installed at the same time was poured flush in a damp groove and a poor bond was observed. Six days later an examination of Section 9 revealed some increase in bond of the sealant. The south 49 meters of Section 15 were also placed in a damp groove.

The hot poured sealants, when dusted with an appropriate material, could be exposed to traffic within 15 minutes. All the cold applied sealants were skinned over but still liquid under the skin after an hour and subject to damage and tracking if exposed to traffic.

In Section 10, the cold applied material was washed out of the grooves during an overnight and next morning's rain. This section was subsequently repaired with a hot pour material the same as in Section 15 and removed from the evaluation.

In two of the hot applied trials the manufacturers' recommended temperature range for application was not followed; Section 14 was above and Section 16 below recommended range.

Sampling and Testing

A sample of each sealing product used in the trials was obtained for laboratory testing. At the time of writing, the laboratory work is not complete and thus is not reported. The object of the laboratory work is to try to find a correlation between specific tests and actual field performance. The tests at this point are not for decisioning the materials but if correlations between performance and tests can be identified, they could be used as an acceptance criteria in the future.

OBSERVATIONS

- The Tennant Router had the highest production rate of all the routers used on the trials but was not effective in routing meandering cracks.
- The Crafco Router, although less productive than the Tennant Router, with care, could rout meandering cracks.
- The vertical routers are the least productive but most effective in treating the meandering cracks.
- Many cracks were missed during routing in spite of the trials being a demonstration project.
- If the cracks showed dampness when routed, the grooves would have a muddy slurry deposited within the groove which could not be removed by back pack blowing.
- Back pack blowers had to be in first class condition to do a satisfactory job.
- The cleaning of the grooves too far in advance of the filling operation allowed traffic to blow debris back into the groove.
- Hot poured sealants placed in a damp groove would not bond properly.
- The cold poured sealants did not set up quickly enough to be used in typical highway crack sealing operations where the seals are exposed to traffic in less than one-half hour.
- Emulsion type cold pour sealants are prone to wash out if rain occurs within a few hours of installation.
- Cold pour sealants are more subject to tracking than hot pour sealants for the first day after installation.

CONCLUSIONS

- Tennant Routers alone are not suitable for routing and sealing work with meandering cracks.
- Careful inspection of routing work will be required if all cracks are to be treated.
- Routing and sealing work should not be undertaken if the cracks are showing dampness.
- Only back pack blowers in proper operating condition with suitable hose and nozzle were successful in cleaning routed grooves.
- Air blowing of the routed groove should immediately precede the filling operation.
- The cold pour sealants in these trials are not suitable for use where they would be subjected to traffic in less than two hours after installation.
- Emulsion based sealants should not be placed if rain is forecast in the next 12 hours.
- Placing a hot pour sealant in a damp groove will lead to premature failure.

RECOMMENDATIONS

- Continue to appraise the surviving seals on a quarterly basis.

ALABAMA HIGHWAY DEPARTMENT
MAINTENANCE
PERFORMANCE STANDARD

ACTIVITY	CRACK SEALING (Asphalt, rubberized or polymeric sealer)	ACTIVITY CODE
		605
	EFFECTIVE	10/1/80

DESCRIPTION AND PURPOSE

Cleaning and sealing random cracks in concrete pavement and including the edge crack between concrete pavement and asphalt pavement or asphalt shoulder. Also included are any nonfunctioning joints or cracks. (See activities 611 and 612 for sealing contraction and expansion joints).

AUTHORIZATION AND SCHEDULING

The Division Maintenance Engineer should authorize and schedule this work after field inspection indicates that the existing crack sealers are no longer effective or that random cracking has developed which would allow water to damage the base material.

CREW SIZE

9 MEN

No. - Description			
1	MT	II	Crew Leader
2	MT	I	Cleaning
3	MT	I	Sealing
1	MT	I	Truck Driver
2	MT	I	Flagman

OPTION: Add 1 - MT III if Motor Patrol used to clean and open crack.

EQUIPMENT

No. - Code/Description		
2	4	Pickup
1	12	Flat Truck/Flat Dump
1	41	Air Compressor
1	99	Motor Patrol (Optional)
1	100000	Hot Pot
1	180000	Early Warner
1	220000	Router
1	230000	Brush/Blower

MATERIALS

Code - Description	
1365	Rubberized Asphalt/Joint Filler (or asphaltic or polymeric)

WORK METHOD

1. Place signs and safety devices.
2. Rout, sand blast, high pressure, or appropriate method to clean crack.
3. Use compressed air to remove debris and moisture from cleaned crack.
4. Inject asphaltic, rubberized, or polymeric sealer.
5. Form sealer with template.
6. Allow curing time.
7. Remove signs and safety devices.

AVERAGE DAILY PRODUCTION: 7,500 Linear Ft.

ALABAMA HIGHWAY DEPARTMENT
MAINTENANCE
PERFORMANCE STANDARD

ACTIVITY: CLEANING CONCRETE JOINTS

ACTIVITY CODE: 611

EFFECTIVE: 10/1/80

DESCRIPTION AND PURPOSE

Cleaning designed joints in concrete pavement. Includes re-sawing and cleaning expansion and contraction joints with concrete saw.

NOTE: This work to be done before activity 612.

AUTHORIZATION AND SCHEDULING

The Division Maintenance Engineer should authorize and schedule this work after field inspection indicates that existing joint sealers are no longer effective and prior to joint sealing operations.

CREW SIZE

5 MEN

No.	Description	
1	MT II	Operator (Crew Leader)
1	MT I	Operator
2	MT I	Laborer

EQUIPMENT

No.	Code	Description
2	4	Pickup
1	1017	Water Truck
1	180000	Early Warner
2	240000	Concrete Saw SP

MATERIALS

Code	Description
4399	Water

WORK METHOD

1. Place signs and safety devices.
2. Saw or appropriate method to clean joint.
3. Remove debris from joint with water spray.
4. Remove signs and safety devices.

AVERAGE DAILY PRODUCTION: 3,300 Linear Ft.

ALABAMA HIGHWAY DEPARTMENT MAINTENANCE PERFORMANCE STANDARD

ACTIVITY	JOINT SEALING (Silicone Sealer)	ACTIVITY CODE
		612
		EFFECTIVE 10/1/80

DESCRIPTION AND PURPOSE

Sealing designed joints (expansion and contraction) in concrete pavement. Includes longitudinal and transverse joints. Does not include sealing crack between concrete pavement and asphalt pavement or asphalt shoulder. (See activity 605 for sealing edge crack).
NOTE: This work to be performed after activity 611.

AUTHORIZATION AND SCHEDULING

The Division Maintenance Engineer should authorize and schedule this work after field inspection indicates that existing joint sealers are no longer effective.

CREW SIZE

9 MEN

No.			Description
1	MT	II	Crew Leader
1	MT	I	Cleaning
2	MT	I	Backer Rod
3	MT	I	Sealing
1	MT	I	Truck Driver
1	MT	I	Flagman

EQUIPMENT

No.	Code	Description
1	4	Pickup/Crew Cab
1	12	Flat Truck/Flat Dump
1	41	Air Compressor
1	180000	Early Warner
1	250000	Silicone Pump

MATERIALS

Code	Description
2365	Silicone Sealer
3365	Backer Rod

WORK METHOD

1. Place signs and safety devices.
2. Use compressed air to remove debris and moisture from the previously cleaned joint.
3. Install and gauge backer rod.
4. Inject silicone sealer.
5. Form sealer with template.
6. Allow curing time.
7. Remove signs and safety devices.

AVERAGE DAILY PRODUCTION

5,000 Linear Ft.

ARIZONA DEPARTMENT OF TRANSPORTATION
HIGHWAYS DIVISION - MAINTENANCE SECTION
PERFORMANCE STANDARD

ACTIVITY: Fill Cracks NUMBER: 103** EFFECTIVE: 7/1/80

DESCRIPTION & PURPOSE

The cleaning and filling of cracks in bituminous pavements to prevent passage of water through the pavement and into the base or subgrade.

PERFORMANCE CRITERIA

SCHEDULING CATEGORY	AUTHORIZATION REQUIRED	QUANTITY OF WORK
Seasonal	District	Limited

Only cracks 3/8" (Pencil width) or greater are to be cleaned and filled. Perform if possible when cracks are open widest.

JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
			x	xxx	xxx	x	x	xxx	xxx	xxx	

TYPICAL CREW SIZE

2 Truck Drivers/Workers
1 Compressor Operator

1 Distributor Operator
*1 Flagman
5 Crew Total

*Add or delete flagmen as required.

WORK METHOD

1. Place safety devices and signs.
2. Blow cracks clean with air compressor.
3. Fill crack with filler to within 1/4" of the top of the surface to allow for pavement expansion.
4. Cover crack lightly with sand to prevent tracking.

EQUIPMENT

NO.	CLASS CODE	DESCRIPTION
1	01	Pickup
1	03	Truck, 2 axle
1	62	Distributor Truck*
1	71	Compressor

MATERIAL

M-5 Produced Sand
M-6 Purchased Sand
M-50 Liquid Asphalt
M-51 Emulsified Asphalt

DAILY PRODUCTION RANGE

100 to 180 Gallons

NOTES:

*Substitution of 61 portable distributor is permissible.

**When latex or rubber is being used as part of the filler material designate Activity 103 with the suffix letter "R". (103-R)

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
MAINTENANCE PERFORMANCE STANDARD

CONCRETE PAVEMENT JOINT SEALING

STANDARD	DATE	FUNCTION
423	7 - 1 - 79	X423

DESCRIPTION

Cleaning and sealing joints in concrete pavement and longitudinal joints between concrete pavement and asphaltic concrete shoulders with hot-poured rubberized asphalt.

PURPOSE

To prevent the passage of surface water and roadway debris through concrete pavement and shoulder joints.

SCHEDULING FREQUENCY

Pavement and shoulder joints should be resealed when existing seal is no longer effective.
For planning purposes, an average effective joint seal life of 2 years may be used.

RECOMMENDED PROCEDURE

1. Place work signs and safety equipment in proper location as outlined in the Safety Regulations.
2. Remove old sealant material and score joint walls with pavement saw. Mechanical joint cleaner (plow) may be necessary first, where existing joints are wide (½" or greater).
3. Saw pavement joints as necessary to provide for ½" wide min. joint width and 1" maximum joint depth. Shoulder joints to be sawed at a depth equal to width, no less than ¾".
4. Clean joints with mechanical brush as necessary and blow out with compressed air.
5. Place appropriate type bond breaker in transverse pavement joints that will provide a joint depth equal to width. No bond breaker is to be placed in shoulder joints or center line joints.
6. Place sealant material at temperature recommended by manufacturer. Flush with surrounding pavement.

PREPARED BY:	REVIEWED BY:	APPROVED BY:
M. L. Shrivers	C. R. Miller	Jay W. Brown
ENGINEER OF MAINTENANCE SYSTEMS	STATE MAINTENANCE ENGINEER	DIRECTOR OF ROAD OPERATIONS

STANDARD
423

RECOMMENDED PROCEDURE CONTINUED

PERSONNEL

CLASS CODE	NO. REQ'D	SKILL CLASS
12810	1	HMT III
12801	2	HMT II
12800	4	HMT I
12800	1*	*Safety - HMT I (For Flagmen)*
		**Not Included In Manhours Per Unit.*

EQUIPMENT

FLEET CODE	NO. REQ'D	EQUIPMENT DESCRIPTION
20500	1	Pickup Truck ½ Ton
21002	1	2-Ton Flatbed (LWB)
21100	1	2-Ton Crew Cab
23420	1	Joint Sealing Machine
29111	1	Air Compressor (150 CFM)
23540	3	Concrete Saw
24080	1	Utility Trailer
		Mechanical Joint Cleaner (As Needed)
		Joint Router (As Needed)

SMALL TOOLS

Shovels
Brooms
Mechanical Brush
Sequential Flashing Arrow (Trailer Mtd.)
Work Signs and Other Safety Equipment

MATERIALS

Rubberized Joint Sealant
Bond Breaker

DAILY PRODUCTION

0.54 Joint Miles

STANDARD MAN HOURS PER UNIT

103.704 Man Hours/Mile

INDIANA STATE HIGHWAY COMMISSION
DIVISION OF MAINTENANCE

PERFORMANCE STANDARD

ACTIVITY: Sealing Cracks

CODE: 207

DESCRIPTION AND PURPOSE: Cleaning and sealing open cracks and joints in bituminous and concrete roadways and paved shoulder surfaces to prevent the entry of moisture and debris which leads to surface and base failure. This activity also includes sealing short sections or isolated areas of alligatored, raveled, or spalled bituminous surfaces to prevent entry of moisture and further deterioration of the surface.

AUTHORIZED BY: Subdistrict

WORK CONTROL CATEGORY: Limited

SCHEDULING: Perform on areas where there is loss of seal or cracking or the joint filler is broken, brittle or missing and allowing entry of water and foreign material. This work should be scheduled in the cooler months when contraction has opened the crack or joint.

CREW SIZE: 12 MEN

WORK ASSIGNMENT	QTY.
Supervisor	1
Flagman	2
Pickup or Tractor Operator	2
Air Compressor Operator	1
Tar Kettle Spray Operator	1
Laborer	2
Truck Driver/Laborer	3

EQUIPMENT	QTY.
Pickup or Tractor/Air Compressor	1
Pickup or Tractor/Tar Kettle	1
Dump Truck	2
Pickup Truck	1
Pickup/Crew Cab	1

MATERIALS

Bituminous Material
Cover Aggregate

AVERAGE DAILY PRODUCTION: 2 - 4 Lane Miles

WORK METHOD

1. Place signs and other safety devices.
*2. Clean crack as required.
3. Pour crack.
4. Squeegee material to force into cracks and surface voids.
5. Remove any surplus material.
6. Dust the area lightly with cover aggregate.
7. Remove signs and safety devices.

* When routing of the joint or crack on concrete surfaces is required before sealing, see Activity 219, Other Roadway and Shoulder Maintenance.

APPROVED BY:

K. M. Mellinger
CHIEF, DIVISION OF MAINTENANCE

D. W. Lucas
ASST. CHIEF ENGR. - HIGHWAY OPERATIONS

EFFECTIVE DATE: July 1, 1978

MAINTENANCE STANDARD

IOWA DEPARTMENT OF TRANSPORTATION
Highway Division
Office Of Maintenance

APPROVED BY: Fay O Bloomfield **Maint. Engr. Date:** Rev. 7-1-77

ACTIVITY TITLE: Joint and Crack Filling **ACTIVITY CODE:** 612

FUNCTION CATEGORY: ROADWAY SURFACE

WORK PROGRAM CATEGORY: Routine Limited

DESCRIPTION & PURPOSE:

Filling of cracks and constructed joints in paved surfaces with joint sealing compounds or with emulsified or cutback asphalts to seal cracks against entry of moisture and foeign materials.

Includes transverse and random cracks on paved shoulders.

Does not apply to construction of pavement expansion relief joints or filling the joint between pavement and paved or stabilized shoulder.

LEVEL OF MAINTENANCE(Quality Std.):

The term "cracks" shall include transverse expansion joints, built-in construction joints, natural longitudinal and transverse cracks caused by shrinkage.

Cracks will not be filled until they are open ¼" or more.

Cracks open ½ inch or more will be choked with dry sawdust, vermiculite ground corncobs, etc., to about 1½" below the surface to reduce the amount of sealant required and to improve the quality of the seal.

Cracks should be filled to between ¼ and ½ inch below the surface with sealant.

SCHEDULING GUIDE: Normal monthly accomplishment as a percent of total program.

JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
4	2	2	2	1	4	13	30	22	9	3	8

Accounts for 0.8% of total maintenance manhours

PERFORMANCE STANDARD

ACTIVITY: 612

RECOMMENDED PROCEDURES:

Provide traffic control as necessary (see Activity Code 673)

1. Clean cracks with compressed air or brooming to remove dirt, sand or aggregate.
2. Place filler in crack if required.
3. Pour sealant in cracks being careful not to overfill.
4. If sealant is accidently slopped on to surface blot with lime dust or other fine material.
5. Sand or agg. lime may be used to construct dams to prevent sealant from running out the lower end of cracks.

Provide Safety Equipment needed to comply with Safety Regulations

MATERIALS:

Emulsion
Commercial Seal ing Compound
Vermiculite-Sawdust-Ground Corncobs . . . . . .
Sand or Agg. Lime

RECOMMENDED CREW SIZE:

1 - Air Compressor Truck Driver
1 - Tar pot Truck Driver
2 - Pour Pot Operators
1 - Crack Cleaner

RECOMMENDED EQUIPMENT:

2 - Dump Trucks
1 - Air Compressor
1 - Tar Kettle
2 - Pouring Pots
1 - Portable Generator
1 - Barrel Heater
Hand Tools as Needed

ACCOMPLISHMENT

Unit: Gal. of Sealant

Standard Rate: 3.0 Gal. Per MH

Daily Production: 84 - 120 - 156

MICHIGAN

PERFORMANCE STANDARD

MAINTENANCE MANAGEMENT SYSTEM

ACTIVITY ▶ CRACK FILLING **NO.** 101

DESCRIPTION & PURPOSE

Cleaning and filling of random open cracks with liquid sealant. (See application temperatures for bituminous materials on page 5 of TABLES Section.)

RECOMMENDED CREW SIZE

7 - (2 Flagmen included)

TYPE OF ACTIVITY

Special Authorization (Blue)

MATERIAL

Sealant
Sand or 31C (3/8" stone max.)

EQUIPMENT

Qty.	Group	Description
1	02	Pickup
3	04	Trucks
1	12	Flashing Arrow
1	19	Compressor
1	36	Kettle

AVERAGE DAILY PRODUCTION

125-225 gallons of sealant

RECOMMENDED WORK METHOD

1. Seal cracks and joints when the pavement is contracted and the average temperature is below 50^{0}.
2. Before filling, clean cracks with an air compressor.
3. Apply sealant heated to the specified application temperature. (See table)
4. Fill cracks to within 1/4" of the top of the surface to allow for slab expansion.
5. 3/8" stone may be used in wide cracks on bituminous surfaces.
6. Do not use 3/8" stone when filling cracks on concrete surfaces.
7. Sand may be sprinkled lightly on top to prevent tracking.

CRITERIA:

ONLY CRACKS GREATER THAN 1/4" (diameter of a pencil) WILL BE FILLED.

NEVADA
DEPARTMENT OF TRANSPORTATION
MAINTENANCE DIVISION

PERFORMANCE STANDARDS

ACCOMPLISHMENT UNIT	ACTIVITY	ACTIVITY NO.
Pounds Filler Material	Crack Filling	101.07

ACTIVITY REQUIREMENTS

MEN		EQUIPMENT		MATERIALS	
NO.	CLASS	NO.	TYPE	AMOUNT	DESCRIPTION
6	Maintainers	2	Dump Trucks Single Axle	1 lb.	Crack Filler (pounds)
		1	*Compressor with nozzle to clean cracks		
		1	Maintenance Distributor (Pot Type) or Crafco Rubber Machine		

*Not used in Budget Preparation

PRODUCTIVITY DATA

UNIT/CREW HR.	UNIT/MAN HR.	CREW HR/UNIT	MAN HR./UNIT
210# Filler/CrewHr	35# Filler/Man Hr.	0.0048 CrewHr/#Filler	0.02857 ManHr/#Filler

QUALITY GUIDE

CONDITION: Asphalt surfacing cracked allowing penetration of water. Fill cracks when 60% of the cracks in any 1000 foot section exceed 1/2" in width.

MAINTENANCE LEVEL: Fill cracks and joints to level of travelled surface.

FREQUENCY OF WORKLOAD RATE:

140 pounds of filler per mile or 24' bituminous surface.

METHOD AND PROCEDURE:

Note: Have one man at the station an hour or more ahead of shift time to heat filler material.

1. At site set up traffic control (signs, cones), assign flagmen. Place equipment on shoulder or part of lane.

2. Where necessary, use compressor and air jet to clean cracks that are to be filled.

3. Pour hot filler material into cracks taking care to avoid spill.

4. Pick up signs, etc.

ACTIVITY REPORTING:

1. Report this activity with from-to mileposts.

2. All labor, equipment and materials must be reported.

3. The reported accomplishment will be the total pounds of material used during the work period. If liquid asphalt or bitumuls is used in place of rubberized crack filler, the reported accomplishment must be made in pounds by converting gallons applied into pounds, using 8.25 lbs. per gallon. The quantity in gallons must still be reported under the material columns using class code 12.

Note: Refer to Table on Page 7-15 to convert Liquid Asphalt from gallons to pounds.

PENNSYLVANIA

3.1.31A

M-200L (1-80)

BUREAU OF MAINTENANCE

PERFORMANCE STANDARD

ACTIVITY NUMBER	EFFECTIVE DATE
711-147-01	July 1980

ACTIVITY	PERFORMANCE STANDARD
ROAD PAVED CRACK & JOINT SEALING - CONCRETE ROADS PARAPLASTIC OR EQUIVALENT	0.2571 Man Hours/Gallon

ACTIVITY DESCRIPTION SUMMARY

This activity includes all actions related to joint sealing operations, such as routing and cleaning joints, mechanically applying para-plastic joint sealing material, and cleanup on rigid pavement only. This material is supplied in 50 pound cans. Use Appendix A, Table 33 to convert to gallons.

This activity can only be performed when the temperature is above 40°F. and is best performed between 45° and 55°F. It should be programmed for the spring and fall seasons.

The BMA-100 should only be run by a trained operator. A slide-tape training presentation is available through the District training coordinator.

A properly placed seal should last 4 to 6 years before requireing replacement. However all joints should be checked annually and repaired if badly deteriorated or open.

ACTIVITY REQUIREMENTS

MEN		EQUIPMENT		MATERIAL	
NUMBER	CLASSIFICATION	NUMBER	TYPE	AMOUNT	DESCRIPTION
1	Foreman	1	Crew Cab	250 lbs. Per Hr. (Approx. 35 Gal. Per Hr)	Lbs. - Paraplastic or Equivalent
2	Equip. Opers.	1	Dump Truck		
5	H.M.W.	1	Oil Bath Heating Kettle with Applicator Air Compressor with Hose		
		1	Power Brush		
		1	Vertical Router		

SUPPORT REQUIREMENTS	PRODUCTION UNIT	PROD. UNITS/HOURS	PLANNING UNITS
Add men and equipment for safety	Gallon (Code 5)	35 Gals./Hr.	225 Gals./Day (Approx. 1500 lbs

3.1.31B

METHOD AND PROCEDURE

Give all equipment its general servicing as required by the specific equipment either at the stored location or the county yard.

Attach BMA-100 to dump truck or crew cab (do not use a pickup, clutch damage may result) attach air compressor, load power brush, router and hand tools on crew cab.

Proceed to work site placing traffic control equipment on the way. At the work site foreman gives his daily safety talk and general instructions concerning work for the day.

Operator positions BMA-100 on the side of the road since it will take about 2 hours to heat the sealent.

While operator is heating the sealent in the BMA-100 the remainder of the crew begins cleaning the joints. Joints cleaned in 6 hrs. can be sealed in 4 hrs. so with a little planning the operation can work very smoothly.

Three H.M.W.'S using the router, brush and air compressor thoroughly clean all joints. First with the router, followed by the power brush and finally blown clean with the air compressor.

When the paraplastic reaches a "Safe Heating Temperature" (this temperature can be obtained from the manufacturers shipping container, and in no case shall the material be applied more than 25°F. Below the "Safe Heating Temperature"). Unreel the hose on the BMA-100, taking out no more than is needed. Pulling out extra hose increases the change of material clogging or flowing to slowly.

The operator walks backward sealing the joint, while one man keeps a loop in the hose to aid in keeping the material flowing. (Joints are to be filled to within 1/3" from the top. There is no need to use sand or fines).

If the material will not flow simply reel in the hose and wait five minutes. If at any time sealing is stopped for more than a few minutes, reel the hose in and keep it warm.

At end of day clean all equipment.

South Dakota Department of Transportation

APPROVED BY: [signature]
ENGINEER OF MAINTENANCE

PERFORMANCE STANDARD

DATE: ISSUED 4-2-75
REVISED 10-3-79

APPLICABLE FUNCTION(S) 2111

CRACK TREATING

DESCRIPTION:

Cleaning and treating open cracks in a bituminous surface using liquid asphalt sealant.

PURPOSE:

To prevent surface water from passing through a bituminous surface into the base or subgrade and to minimize spalling along the edges of cracks.

QUALITY and WORKMANSHIP:

1. Cracks of 3/8 inch in width or greater will be treated with liquid asphalt.
2. Cracks less than 3/8 inch in width may be treated.
3. Cracks should be treated during that period of time when the cracks are opened up to a maximum.
4. Cracks should not be overfilled with asphalt material.
5. Bumps created by crack treating will be removed.

SCHEDULING and INSPECTION:

1. Crack treating is normally a low priority item.
2. Crack treating may be scheduled during the period from January through March.
3. Routine daily inspection will identify the proper time to schedule crack treating.

PROCEDURE:

1. Place safety devices and signs.
2. Select only those cracks 3/8 inches in width or larger for treating.

SOUTH DAKOTA
Department of Transportation

PERFORMANCE STANDARD

 APPLICABLE FUNCTION(S) 2111

PROCEDURE continued:

3. Clean material out of the top 1" of the crack with a broom, wire brush or compressed air.

4. Pour hot asphalt into each selected crack.

5. Control the flow of asphalt and use a squeegee so as to treat the surface for about 1" to 3" on each side of the crack.

6. When needed to control tracking by traffic, blot excess asphalt using a light application of sand.

CREW and EQUIPMENT ARRANGEMENT:

MEN

5 - Includes one flagman

EQUIPMENT

1 or 2 - 840 trucks (when needed for sanding)
1 - Air Compressor (081 series - if needed)
1 - Distributor
1 - Loader at Stockpile

Ontario
Ministry of Transportation and Communications

MAINTENANCE PERFORMANCE STANDARD

M-1003

Crack Sealing

DESCRIPTION

The preparation and filling of cracks with emulsified asphalt or rubberized asphalt, and followed by the spreading of stone chips or sand when required. Includes minor spray patching of distressed areas when performed during crack filling operations.

ROAD TYPE	HOT MIX CONCRETE MULTI-LANE		HOT MIX CONCRETE 2-LANE	
CREW SIZE	2-Drivers 1-Sweeper 2-Router/Comp. Air Oprs. 1-Spray Bar Opr. or 2-Pourers 1 to 2-Drivers (Traffic Control)	(or) 2-Drivers 1-Sweeper 2-Router/Comp. Air Oprs. 1-Spray Bar Opr. or 2-Pourers 1 to 2-Drivers (Traffic Control)	2-Drivers 1-Sweeper 2-Router/Comp. Air Oprs. 1-Spray Bar Opr. or 2-Pourers 1 to 3-Flagmen (Traffic Control)	(or) 2-Drivers 1-Sweeper 2-Router/Comp. Air Oprs. 1-Spray Bar Opr. or 2-Pourers 1 to 3-Flagmen (Traffic Control)
EQUIPMENT	1-Crew Carrier 1-Dump Truck 1-Mtce. Kettle 1-Air Comp. 1 or 2-Sign Trucks/ Sign Trailers	1-Crew Carrier 1-Dump Truck 1-Paraplastic Kettle 1-Air Comp. 1-Router 1 or 2-Sign Trucks/ Sign Trailers	1-Crew Carrier 1-Dump Truck 1-Mtce. Kettle 1-Air Comp.	1-Crew Carrier 1-Dump Truck 1-Paraplastic Kettle 1-Air Comp. 1-Router
MATERIALS	Asphalt Sand or Stone Chips	Rubberized Asphalt	Asphalt Sand or Stone Chips	Rubberized Asphalt
ACCOMPLISHMENT	Litres	Litres	Litres	Litres
MANHOURS PER ACCOMPLISHMENT	0.066 - 0.11	-	0.06 - 0.12	-
ACCOMPLISHMENT PER DAY	970 - 600	-	1100 - 550	-

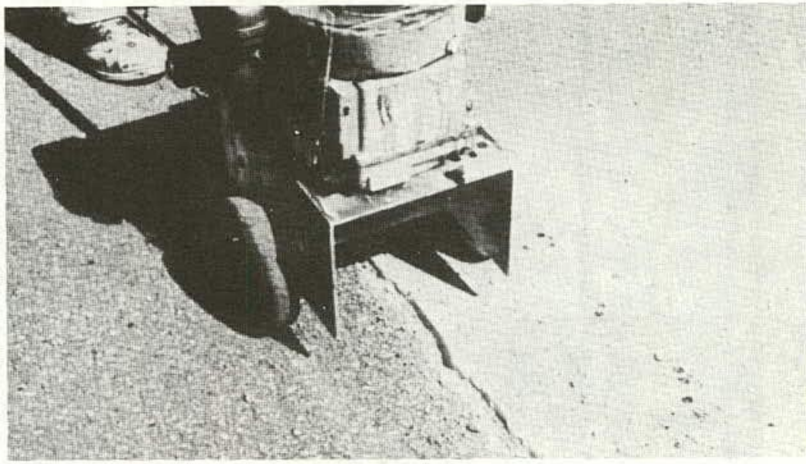
Recommended Method

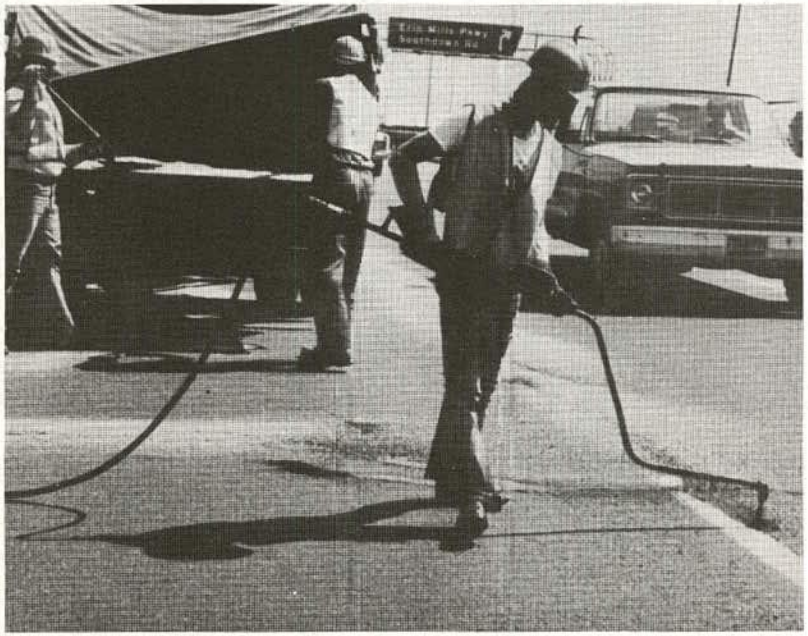
1. Set up safety devices and signs in accordance with "Traffic Control Manual for Highway Work Operations."
2. Designate the areas requiring repair.
3. (a) Clean out cracks using a stiff bristled broom and/or compressed air.

   (b) Rout cracks, remove dust and debris with compressed air.
4. Fill cracks with sealant; app y inside the crack to avoid creating a bump.

   Note: When using asphalt emulsion, sprinkle the surface of the filled crack with dry sand or stone chips.

Procedures for Crack Sealing





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