TRANSVERSE CRACKING STUDY

of

ASPHALT PAVEMENT

Iowa Final Report

DEPARTMENT OF TRANSPORTATION
IOWA

Highway Division

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TRANSVERSE CRACKING STUDY
OF
ASPHALT PAVEMENT

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BACKGROUND

Transverse cracking of asphalt pavements has been a problem which has been in existence since asphalt was first used as a pavement material. The suggested causes for this phenomenon consists of, but are not limited to, ambient temperature changes, temperature susceptibility of the asphalt, grade of asphalt, mix stiffness, subgrade, etc. Maintenance of these cracks has likewise been a problem in that, because of other work interferences such as snow storms, crack filling and sealing efforts range from very extensive to none at all. Cracks which are not sealed at an appropriate time tend to deteriorate much more rapidly and cause an unsatisfactory riding quality. This, in turn, accelerates the need for more extensive repairs and resurfacing or rehabilitation.

Through the years, there has been much research and many reports have been written on the subject of eliminating or reducing the amount of transverse cracking in asphalt pavements. Most of these have indicated that transverse cracking can be reduced through mix design procedures and asphalt grade and quality controls. There does not seem to be any follow-up reports which allude to any significant success in the use of any of these procedures.

At a pavement management study meeting in Omaha, Nebraska, September 12 and 13, 1979, the states of Iowa, Kansas and Nebraska agreed on the need for an in-depth engineering study of thermal cracking of bituminous pavement. In addition, the states of Oklahoma and North Dakota agreed to participate in the study.

The scope of the study was to analyze all functions relating to the thermal cracking problem to determine how different uses of preventative materials, mix design measures, maintenance repairs, and design of bituminous pavements and overlays might be contributing to the problem and to determine what improvements might be made in these procedures to reduce the problem of thermal cracking.

STUDY APPROACH

The Iowa Department of Transportation entered into a contract with the Federal Highway Administration to work on a "Pavement Management Study - Thermal Cracking", in February, 1980. The study was Task Order No. 11 of the Federal Highway Administration Basic Agreement DOT-FH-8559. The states of Kansas, Nebraska, North Dakota and Oklahoma also participated in the study.

The study was sponsored by the Office of Contracts and Procurement, Federal Highway Administration, located in Washington, D.C. The contract time period began with the initial meeting of the five states in February, 1980 and was scheduled to end on or before May 31, 1981.

The initial meeting of the five states and representatives of the FHWA and the Asphalt Institute was held in Oklahoma City, Oklahoma, on February 5-6, 1980. The states of Kansas, Nebraska, North Dakota and Oklahoma were represented by three member teams. Iowa was represented by two members of a four member team.

The efforts of the first meeting were directed towards a review of the fundamentals of value engineering and how it could be used to address the problem of thermal cracking in asphalt pavements. Each state made a presentation outlining the problem in their state and how cracking may be related to climate conditions, geological make-up, mix design, asphalt quality, maintenance practices, etc. Discussion and comprehension of these differences helped greatly in identifying common parameters for the study area and in setting objectives for study for the second meeting.

One element that stood out in the first meeting was the reluctance on the part of most of the team members to refer to the problem as "Thermal Cracking". After much discussion, it was agreed that the term transverse cracking might be a more appropriate title for this study.

During the discussion period, it also became evident that there were very mixed attitudes and opinions with regard to what results might be expected from this study. These feelings seemed to be predicated by the many research reports which have dealt with the problem and their failure to produce bonafide answers or solutions.

Objectives established for completion prior to the second meeting were established as:

1. An inventory of asphalt pavements and a review of pavement conditions and methods of maintenance crack repair.
2. Methods of 3R crack repair and/or membrane treatment and overlay.
3. Methods of mix design.

The second meeting was held in Kansas City, Missouri, on April 23-24, 1980. Each state made a presentation on their present mix design method and procedure. In addition, James Burton, Senior District Engineer for the Asphalt Institute made a very interesting presentation covering the Asphalt Institute recommended mix design procedure and control methods. The noted differences in mix design methods and modifications of the standard procedures generated considerable discussion.

Each state also made a presentation with regard to the information gathered since the last meeting. There was a noted variance in the presentations, however, they dealt mostly with mileage inventories, crack data and pavement performance history.

The study group was divided into 3 sections to speculate and evaluate alternatives which might be considered in developing and/or improving current practices in the following 3 areas.

1. Methods of maintenance crack repair.
2. Methods of 3R crack repair and/or membrane treatment or overlay.
3. Methods of mix design.

Objectives set for the third meeting were:

1. A maintenance presentation addressing some phase of bituminous pavement maintenance.
2. A review of each states in-depth evaluation of the various study alternatives.

The third meeting of the study group was held in Bismarck, North Dakota on July 16-17, 1980. The workshop groups convened again to discuss and determine any changes or modifications which were needed in the alternatives which were set at the April meeting. Very few changes were made in any of the three areas even though there was considerable disagreement as to how many of these alternatives could be addressed in the final reports.

The study presentations made by the states were quite varied but, for the most part, dealt with the present practice in each state with respect to each of the study alternatives in each of the three areas of study.

The maintenance presentations addressed a specific practice in each state. Some of the subjects addressed were pot hole patching, seal coating, crack sealing, surface milling and fog sealing. The discussion following each of the presentations resulted in a good exchange of ideas even though there was no specific conclusion with regard to a "best method" approach.

Objectives set for the fourth meeting which was held in Des Moines, Iowa on October 22-23, 1980 were:

1. A presentation by each state which should address all phases of the study.
2. Development of group recommendations.
3. Discussion of the final report.
4. A review of future activity.

Following this fourth meeting, each state will finalize their report and forward it to the Iowa Department of Transportation for consolidation into a final report.

FINDINGS

Iowa is located in what is most often referred to as the North Central Region of the United States. The climate is rated as sub-humid with a large variation. Temperatures range from a mean of 16°F to 74°F with extremes of -30°F to +100°F. Annual precipitation ranges from 27 inches northwest to 34 inches southeast with a yearly mean of 31.5 inches. Snowfall is quite variable ranging from 50 inches in the north to 22 inches in the south. Winds have a composite average of 10-12 MPH with maximum velocities of up to 100 MPH. The frost depth in Iowa is quite variable over the state with depths generally in the range of from 36 to 48 inches.

Iowa is predominately an agricultural state ranging from quite hilly in the extreme northeast to flat and gently rolling over most of the remainder. Soil types range from A-4(6) to A7-6(20) with most areas being classified in the A-6 and A-7 area.

Aggregate deposits in Iowa are quite variable in both quality and availability. Limestone is the most available aggregate with ledges occurring on the surface in the hilly regions of northeast Iowa sloping downward to where they are quite deep in southwest Iowa. Gravel deposits of varying quality are the primary source for aggregate in the northwest 1/4 of the state.

Since the early 1930's when Iowa began a lengthy "get out of the mud" program, portland cement concrete pavement has been the domi nant "all weather" surface. Today, Iowa has in excess of 10,100 miles of hard surfaced primary highways. Of this, 4,200 miles are portland cement concrete; 3,400 miles are portland cement concrete which have been overlayed with asphaltic concrete; 2,100 miles are asphaltic concrete over a variety of flexible bases, i.e. rolled stone, soil cement, cold laid bituminous and asphalt treated; approximately 200 miles are inverted penetration asphalt with and without base structures. The remaining 200 miles are gravel and other miscellaneous surface types. The only roads analyzed as a part of this study were the 2,100 miles of flexible base roadways. The results of this survey are included in the crack maintenance section of this report.

Iowa has developed a crack rating procedure with four classes which are dependent on the degree of deterioration. A type I crack is in good condition while a type 4 crack (figure 1) exhibits severe deterioration.

Figure 1 - A Severely Deteriorated Type 4 Crack

Initially, a transverse crack does not adversely affect the riding quality of a pavement. Water action in the transverse crack causes stripping of the asphalt cement and with time results in a void. (figure 2) This void then allows settlement, sloughing and results in a badly deteriorated type 4 joint.

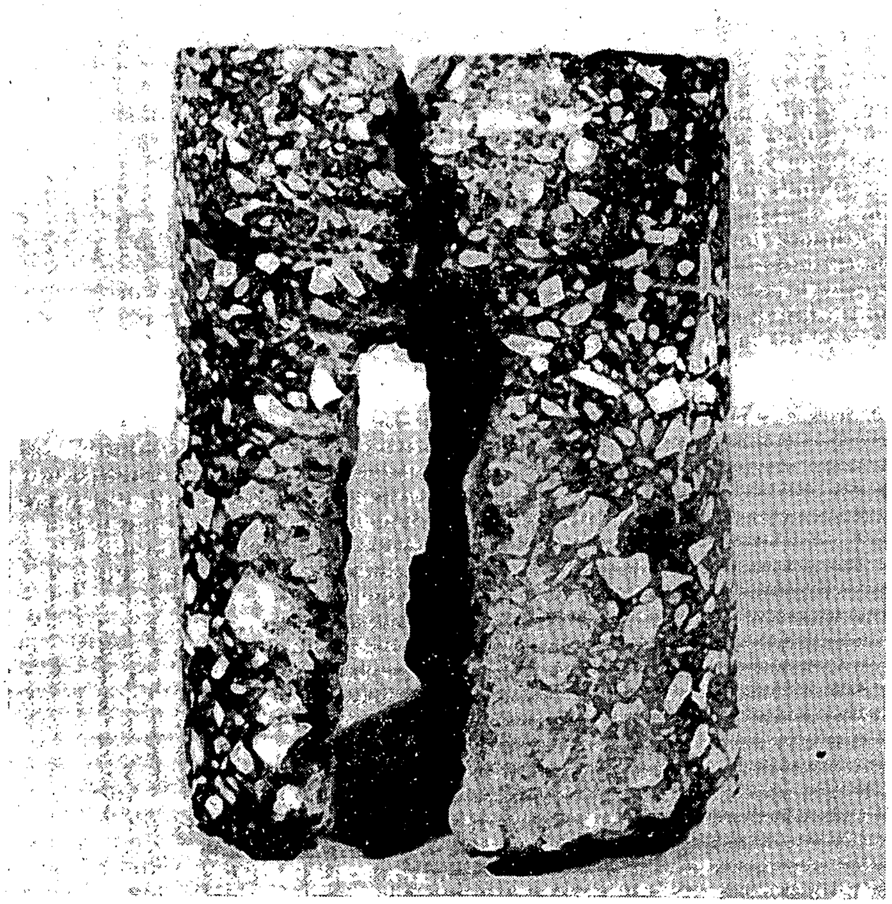


Figure 2 - A Core Showing a Large Void
Under a Transverse Crack

MIX DESIGN

In recent years, there have been numerous studies which have addressed the subject of controlling cold temperature cracking through mix design procedures. Some of the studies have suggested the control of cracking through mix stiffness analysis; some have suggested that cracking can be reduced through the use of softer asphalts while others suggest that cracking can be reduced through the use of asphalt cements that are less temperature susceptible. To date, we have not become aware of any reports which allude to any positive results in eliminating or reducing transverse cracking through the use of any of these procedures.

In analyzing the data we obtained from our survey of the frequency of transverse cracks and the associated job mix and construction reports, we were unable to determine any connection between the job mix design and the crack frequency.

The workshop group which was assigned to evaluate mix design identified a total of fifteen factors which should be considered in designing an asphalt pavement which would be more resistant to transverse cracking. These were discussed in detail at the Bismarck meeting. Following is a brief statement on how Iowa currently addresses these factors:

1. Distress Evaluation

   In determining the appropriate mix type and thickness of required overlay for a resurfacing project, we relay on an "on site" inspection to prioritize projects for a particular year's program. We are currently using a Road Rater to evaluate our flexible pavements and are finding it to be quite reliable in determining the structural value. This will add support to the visual process of determining overlay depths.

2. Voids, Permeability, Compaction

Iowa stresses void content in both it's mix design and in the construction process.

Air voids for mix compacted in the laboratory vary for different mixes with an overall range of 2% to 6%. Particular emphasis is given to the void content of mix compacted on the roadway with a range of 4% to 8% specified.

Iowa requires that asphalt pavements be compacted to 94% of the field laboratory Marshall Density for each particular day production. A statistical formula is applied using a quality index based on a minimum of 80% compliance. Anything not meeting this test is price adjusted.

3. Asphalt Content

Iowa uses standard Marshall procedure in mix design for binder and surface courses, criteria for determining the appropriate asphalt content is (1) void content in a range of from 2%-6%, (2) voids in mineral aggregate in a range of from a minimum of 14% to a minimum of 15.5% depending on mix type and size, (3) a minimum film thickness of 6.5 microns,

(4) Marshall stabilities ranging from minimums of from 1,000 lbs. to 1,750 lbs. depending on traffic and mix type, (5) a maximum filler-bitumen ratio of 1.3.

For asphalt treated bases, the basic specified asphalt content is established at 4.5%. We do, however, apply the Good and Lufsey voids-bitumen index and if the ratio exceeds 6, the asphalt is increased by quarter percent increments to bring the ratio into compliance.

4. Education of Personnel

Iowa has a training coordinator in each of it's six districts. Each year, the training needs of state, county and city inspection staffs are assessed. Depending upon the needs, persons capable and knowledgable in the particular area are selected from the District Materials staff and construction residencies to instruct in the needed training classes. Cross-training of state inspectors is stressed.

Each year the Asphalt Paving Association conducts a two-day workshop which brings together the inspectors and contractor supervisors who will be working together on projects. Specifications, specification changes and construction problems and correction procedures are discussed.

5. <u>Asphalt Quality</u>

Considering all that has been talked about and written about asphalt quality since the 1974 oil embargo, Iowa has not been able to tie any deficiencies or failures to this problem. The one failure we did have which was tied to asphalt quality was traced to an 85-100 penetration asphalt which had a viscosity of about 600 poises. Subsequent to this we have changed to viscosity grading for most of our asphalt. If penetration grade is allowed, a minimum viscosity requirement is stipulated.

6. <u>Traffic Volume</u>

Traffic volumes are an important feature which must be considered in determining pavement thickness and in selection of the appropriate mix type, particularly when traffic exceeds 500 vehicles per day or when trucks exceed 10% of the traffic. Iowa considers traffic volumes in each of these tasks.

7. <u>Antistripping Agents</u>

Iowa has not considered the use of any antistripping agents other than hydrated lime. Lime is only used when the aggregate being used has demonstrated stripping tendencies. It is added at the rate of 1% of the mix by weight.

8. <u>Test Procedures and Methods</u>

Iowa's test procedures and test methods are AASHTO and ASTM procedures with little or no modification. Standard Marshall procedures are used in mix design.

The Abson recovery procedure is used in our Central Laboratory. The vacuum extraction process is used by district laboratories. District laboratories are equipped with Marshall equipment for determining the density requirements of each day's production and for determining asphalt adjustment needs. Densities for each day's run or lot are determined by the use of cores with tests being performed by the project plant inspector.

9. <u>Combined Gradation</u>

Most of the aggregate which is available in Iowa is limestone which in turn requires the use of more than one aggregate for most of our pavement mixtures. By specification, we require a minimum of 65% crushed particles for high type pavements, a minimum of 30% crushed particles is specified for an intermediate and some low traffic type pavements; a pit run type mix is used on some of the low traffic roads in northwest Iowa where material for crushing is not readily available.

Contractors are responsible for selecting the source of materials for each project. They must work closely with materials producers to ensure that aggregates submitted for mix design will comply with the quality and gradation requirements and that future material production will be within the specified limits. Some latitude is afforded which permits minor field adjustment in gradation limits if the quality of mix is not affected. Iowa has placed a limit on the number of mix designs which can be performed for each project. If the limit is exceeded, the contractor is charged for each additional design requested.

10. <u>Cold Mix Design</u>

Iowa has standard specifications for different types of cold mixes. Currently, cold mixes are used very little, but when they are used the mixes are designed by laboratory procedures. Iowa State University has recently completed a research project on the use of foamed asphalt with marginal aggregates. It is quite likely that field research will be undertaken in the near future.

11. <u>Fillers</u>

Iowa has not been faced with the need of adding fillers to it's asphalt mixes. In fact, there are a goodly number of aggregate sources where production results in too many fines unless considerable care is maintained. It was partially for this reason that a fines-bitumen ratio limit was established.

Recent reports that returning baghouse fines directly to the mix could be causing some problems with pavement performance has aroused our interest. We have undertaken a limited evaluation of fines being produced from different aggregate sources. There is evidence that some baghouse fines have a rather high

PI and that some vary in gradation from hour to hour and from day to day. We have not looked into the quantity of fines being produced which will be essential before a final analysis can be made.

12. Aggregate Quality

Aggregate quality varies considerably across Iowa. Aggregate quality limits have been established to permit, for the most part, the use of locally available aggregate. Los Angeles abrasion limits range from 40 for a high type mix to 45 for a lower type mix. The alcohol freeze-thaw limits are 6-10 for a high type mix and 45 for our lower type mix.

13. Crack Relief Layers

Iowa has no experience with crack relief layers. A delegation from Iowa did travel to Arkansas to review their experience and came away very much impressed with the results. We are in the process of developing an experimental project for 1981. It will consist of a 3-1/2" layer of 3" x 3/4" and a 2-1/2" layer of 2" x 1/4" aggregate. We are designing the mix to permit the use of either asphalt cement or emulsion for coating.

14. Membranes, Fabrics

While Iowa has used fabrics in conjunction with resurfacing work, fabrics are not considered in design other than that we require a minimum of 2" of overlay over the fabric. Iowa has not yet used any membrane treatments on asphalt pavements

15. <u>Asphalt Modifiers</u>

Iowa has experimented with two asphalt modifiers currently being marketed in the United States.

A product called "Asphadur", that originated in Austria and is now being marketed by the 3M Company as "Stabilizing additive 5990", was first used in two places in 1978. It has since been incorporated into two more projects where traffic volumes are quite high. The additive "5990" is a mixture of polymers of unsaturated hydrocarbons of varying lengths used with asphaltic concrete to improve its properties. It increases the stability of the mix making it more resistant to rutting and shoving. Because the additive increases the cost of asphaltic concrete by approximately $18 per ton, use has been limited to areas where traffic volumes are high and turning and wearing movements are significant.

"Chem-Crete" is an additive which came on the market this year. It is marketed by the Chem-Crete Corporation of Menlo Park, California. It is claimed that "Chem-Crete" will improve the stability of asphalt concrete significantly and that pavement thickness can be reduced to offset any difference in cost. It is also claimed that "chem-crete" can be used with marginal aggregates making them usable as base materials.

Iowa placed a "Chem-Crete" modified sand surface course on a short section of secondary road this summer as a research project.

16. Research Projects

Iowa has undertaken four research projects in 1980 which are designed to look at both transverse cracking and longitudinal centerline joint reflection and deterioration.

A project on Iowa 64 in Jones County consists of an 8" asphalt treated base with a 3" binder and surface course. Research provides that (1) a high and low temperature susceptible asphalt cement will be evaluated for differences in transverse cracking; (2) the asphalt content in the asphalt treated base be increased from 4.5% to 5.5% to evaluate possible differences in transverse cracking and future base problems; (3) transverse joints be sawed to determine whether or not transverse cracking can be controlled and whether or not maintenance of a controlled crack will result in less maintenance.

At the suggestion of the 3M Company, a research project will be incorporated into the resurfacing of a section of Iowa 44 in Dallas County to evaluate additive "5990" in resisting reflective cracking.

A project on a secondary road in Dubuque County will evaluate the performance of different combinations of dense graded asphalt treated base, emulsion treated and untreated 3/4" x 3" macadam stone bases with combinations of treated and untreated choke courses and bituminous concrete and seal coated surfaces. The research also includes a subgrade fabric treatment to determine whether or not fabric might aid in reducing transverse cracking.

The fourth research project is on Iowa 44 in Guthrie County. It involves different treatments of the longitudinal centerline joint as a means of reducing deterioration which occurs in time.

Involved in this research are (1) a double tacking of the cold joint prior to placing the abutting surface; (2) cutting the cold joint back about 1-1/2" and tacking the vertical face prior to placing the abutting surface; (3) placing the binder and surface courses with the joint in the same vertical plane and (4) using different rolling procedures in placing the abutting surface.

MAINTENANCE

Introduction

To determine the scope of the transverse cracking problem in Iowa, the Resident Maintenance Engineers were requested to make a survey of the Unit 90 roads over 1 mile in length in their areas and submit the following information by road number.

1. Spacing between the transverse cracks in one random 500' section in each mile of the Unit 90 segments.
2. The total length of the Unit 90 segment.
3. The year and thickness of the last resurfacing.

(Unit 90 road is defined as asphalt pavement having an asphalt surface on a flexible base and having a total thickness of 8" or more.)

Review of this information indicated, as we expected, that the majority of the roads had transverse cracks at 30-60' intervals. However, there were some roads that had surprisingly few cracks (less than 5 cracks per 500 feet, including several with no cracks) and some that had an alarmingly close spacing of cracks (over 50 per 500 foot section). It was concluded that perhaps an "in-depth study" of roads exhibiting these extremes in transverse cracking could lead to a possible solution for eliminating or at least minimizing this problem. There were a total of 1992 miles of Unit 90 roads included in this study. There were 208 miles with less than 5 cracks per 500 feet and 113 miles with over 50 cracks per 500 feet. The base and subbase of the roads in the study was determined and compared to the transverse cracking spacing. No overwhelming or decisive patterns were revealed in this comparison except that soil cement base will apparently result in a high frequency of crack spacing; asphalt pavement constructed on rolled stone base or ATB (asphalt treated base) tended to have fewer cracks.

When the location of the Unit 90 roads with the two extremes of cracking were plotted on a state map, it appeared that there may be some correlation between the geological location or climatological influence on transverse cracking since most of the roads in the study with severe cracking problems were in the northeast corner of the state. There was no attempt made to correlate the base type with this regional severity of cracking.

Maintenance of Transverse Cracks

Iowa's maintenance standards state, "Cracks will not be filled until they are open 1/4 inch or more." The recommended procedure is to broom or blow out the crack with compressed air to remove foreign material, then fill between a quarter and a half-inch below the surface with an emulsified asphalt. Cut back asphalts are permitted, but their use for crack filling is discouraged. Wide cracks (half-inch or more in width) are to be "choked" with vermiculite, sawdust, or similar material to approximately 1-1/2" below the surface before placing bituminous filler to reduce the amount of bitumen required and to improve the quality of the filler.

Iowa is also in the process of modifying an asphalt distributor to blend ground rubber with penetration grade asphalt cement for use as a crack filler. This is a procedure used by both Oklahoma and South Dakota with good results. South Dakota reported that cracks would not require refilling for three to five years. Successful development of this procedure in Iowa could have significant ramifications in reduced maintenance costs, increased quality of maintenance, and pavement longevity.

The amount of crack filling accomplished each year varies with the type of winter. In Fiscal Year 1979 (July 1978 to June 1979) 45,136 gallons of sealant were used. Total cost including the equipment, materials and labor was $155,938. In Fiscal Year 1980, 166,441 gallons of sealant were used. Total cost was $718,380 for materials, equipment and labor.

The unit cost (cost per gallon of sealant used) increased from $3.45/gallon to $4.32/gallon from Fiscal Year 1979 to Fiscal Year 1980. On one section where a "full circulating wand" rather than "pouring pots" was used and the cost per gallon of sealant used was reduced to $2.41/gallon. This check was made on relatively low traffic roads, but it is anticipated the expanded use of the circulating wand (figures 3 & 4) rather than pouring pots can significantly reduce statewide crack filling costs.

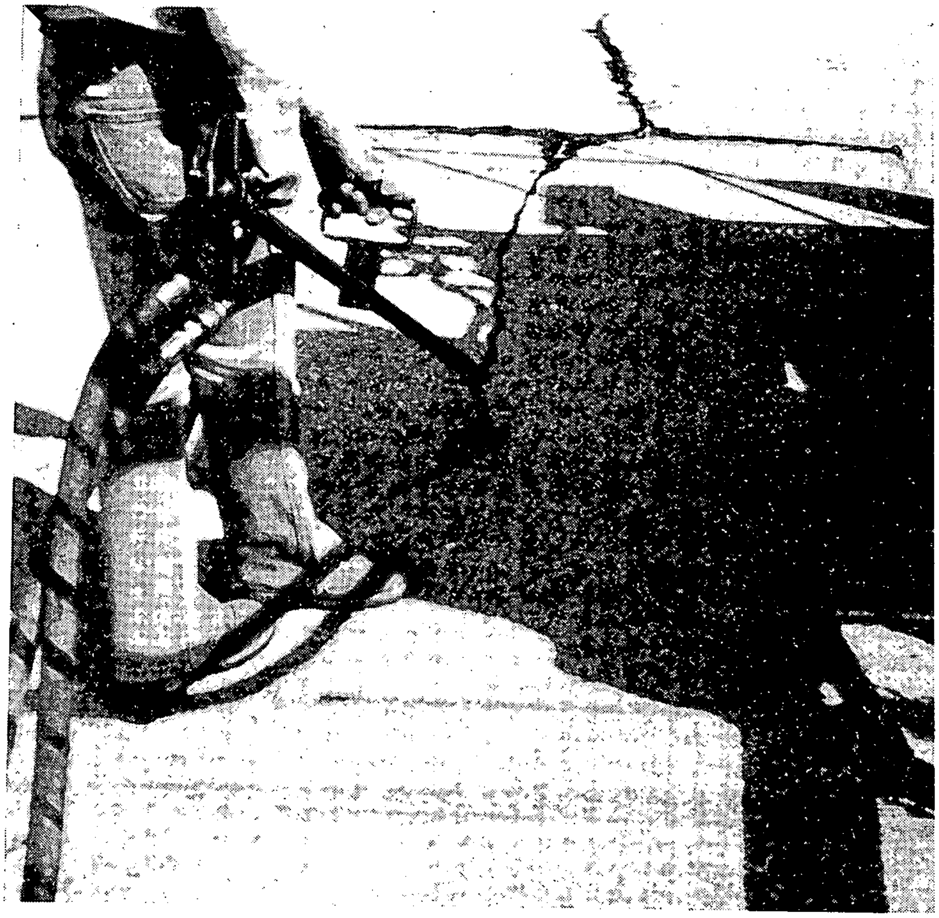


Figure 3 - Recirculating Wand Being Used
to Fill Cracks

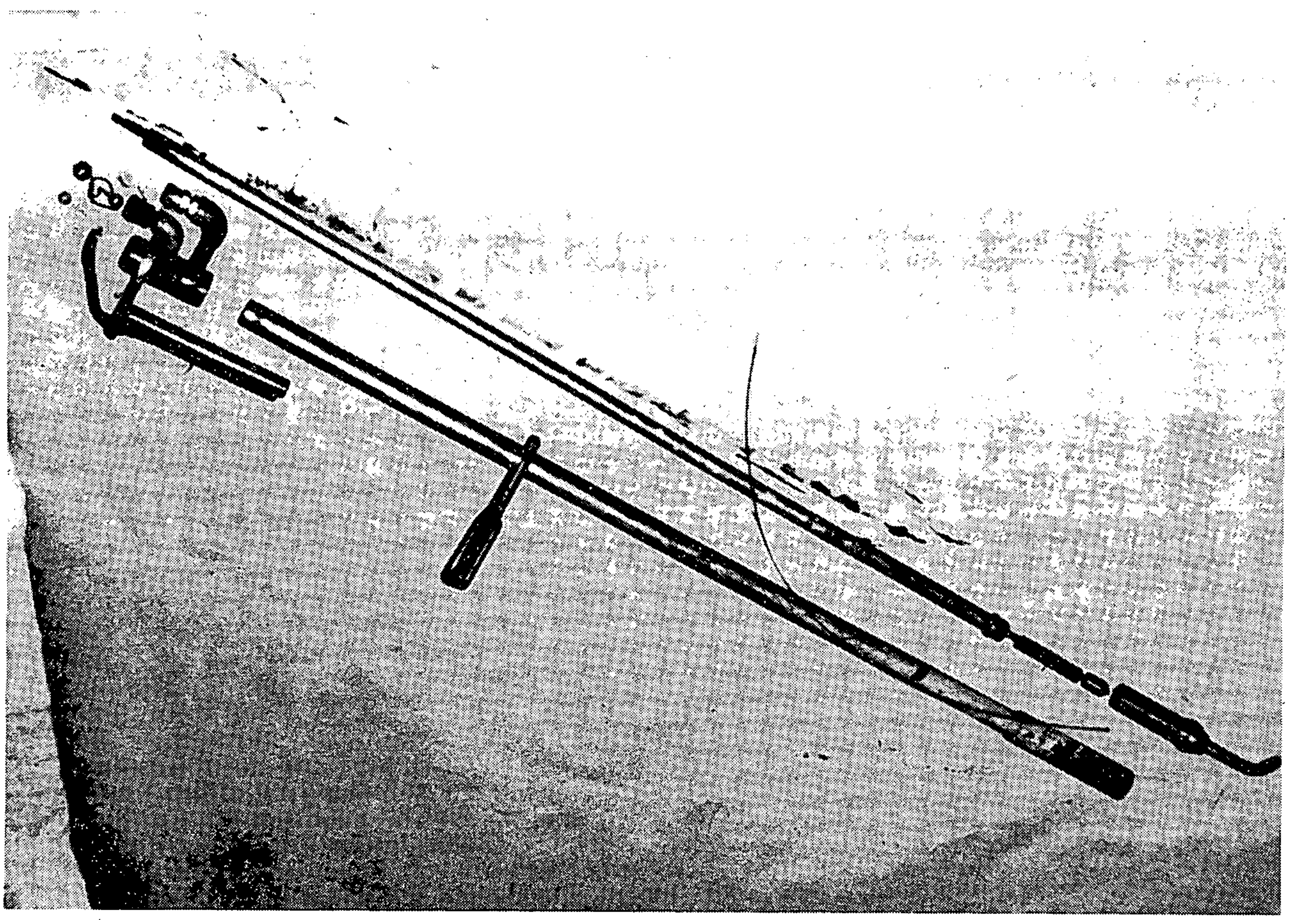


Figure 4 - Component Parts of the Recirculating Wand

Delay or omission of crack filling can result in severe deterioration of the roadway and loss of rideability, thus requiring premature resurfacing. This is usually manifested by a dip or depression adjacent to the transverse crack. These defects have been corrected by two different methods.

1. Blow out the crack with compressed air, then fill the crack and depression with an emulsion slurry, leveling the depressed area using a squeegee.
2. Inject an emulsion slurry into the crack using a pump and leveling the depressed area using a squeegee. (figure 5)

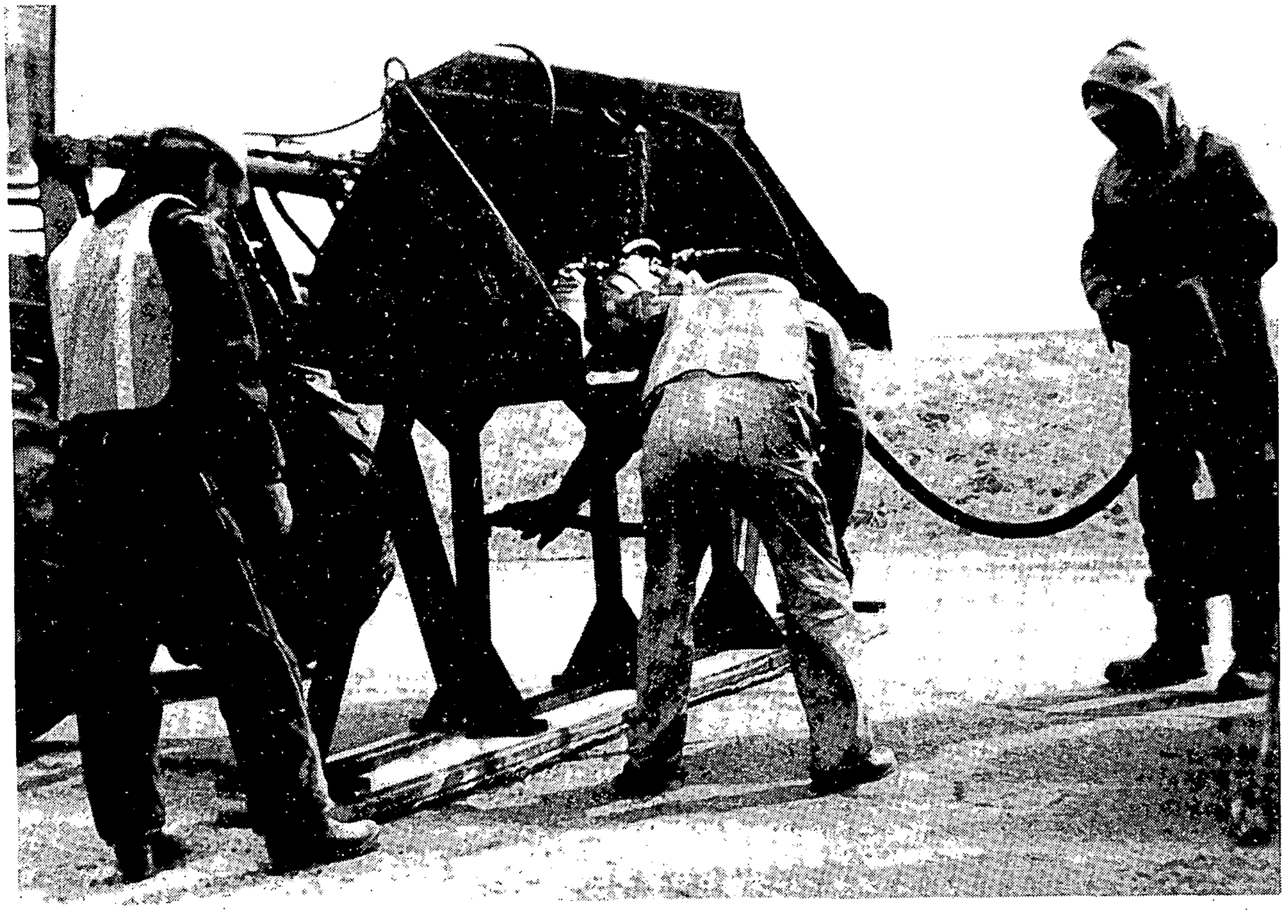


Figure 5 - Pump and Frame for Slurry Injection Filling of Voids Under Transverse Cracks

Both of these methods are expensive; however, 315 12 foot cracks were filled by injection method at a cost of $16.80 per crack. Four hundred twenty-five (425) gallons of emulsion were used.

Surface Failures

In general, surface failures of asphalt paving can be categorized in one of three general types.

1. General raveling
2. Localized raveling
3. Base or structure related failure

General raveling of surface will appear if too dry a mix is used (or an absorbent stone is used in the mix) or the surface becomes oxidized because of long term exposure. These deficiencies have been corrected through the use of fog seals, seal coats, and thin resurfacings. Fog coats and thin (1") resurfacings are usually recommended for high traffic (over 1500 VPD) roads. The general seal coat or chip seal might be used on lower traffic roads.

Local raveling (this is usually load interval segregation) usually becomes evident in 3-5 years after an asphalt mat is placed if it is going to occur. These are usually repaired with local maintenance forces by applying chip seals in these areas.

Base or structure related failures are evidenced by rutting, alligator cracking, and potholes. Temporary elimination of rutting can be accomplished with strip sealing in the wheel tracks and can be accomplished with maintenance forces. Permanent correction of this deficiency will require a substantial overlay and/or sub-surface drainage. Potholing and alligator cracking, depending upon its severity, can usually be repaired by local maintenance forces with patching and chip sealing. In severe areas it may require full depth patching with base repair.

Although this study to date has not resulted in any new design principles or indisputable correlations between base, mix design, and transverse cracking, there is some evidence that perhaps a more in-depth study could be beneficial in at least minimizing transverse cracking, thus reducing maintenance costs and prolonging expected surface life of flexible base pavements.

Maintenance Summary

Investigation of the existing transverse cracking problem on bituminous roads in Iowa revealed a wide variation in transverse crack spacing. It ranged from more than 50 cracks per 500 feet to less than 5 per 500 feet. The majority of the 1992 miles sampled had transverse cracks at 30 to 60 feet intervals.

Comparing transverse crack spacing to base type did not indicate any decisive correlation beyond the fact that soil cement base will apparently result in high crack frequency and pavement constructed on rolled stone or asphalt treated base tends to have fewer cracks.

A good crack filling program by maintenance will prolong the life of a flexible base pavement. Even though a perfect "seal" of cracks may not be accomplished using present procedures of filling cracks with bituminous material, it will help to maintain the pavement rideability and integrity of the existing road structure.

Transverse cracks would not be classed as a "surface failure", however, the maintenance or repair of surface failure was discussed by the study group.

3R CRACK REPAIR AND/OR MEMBRANE TREATMENT AND OVERLAY

1. Reinforcing Fabrics

Various techniques have been tested over the years in an effort to eliminate and/or retard reflective cracking in an asphaltic concrete overlay. The one technique which has shown the most promise in Iowa is the use of a reinforcing fabric. (figure 6)

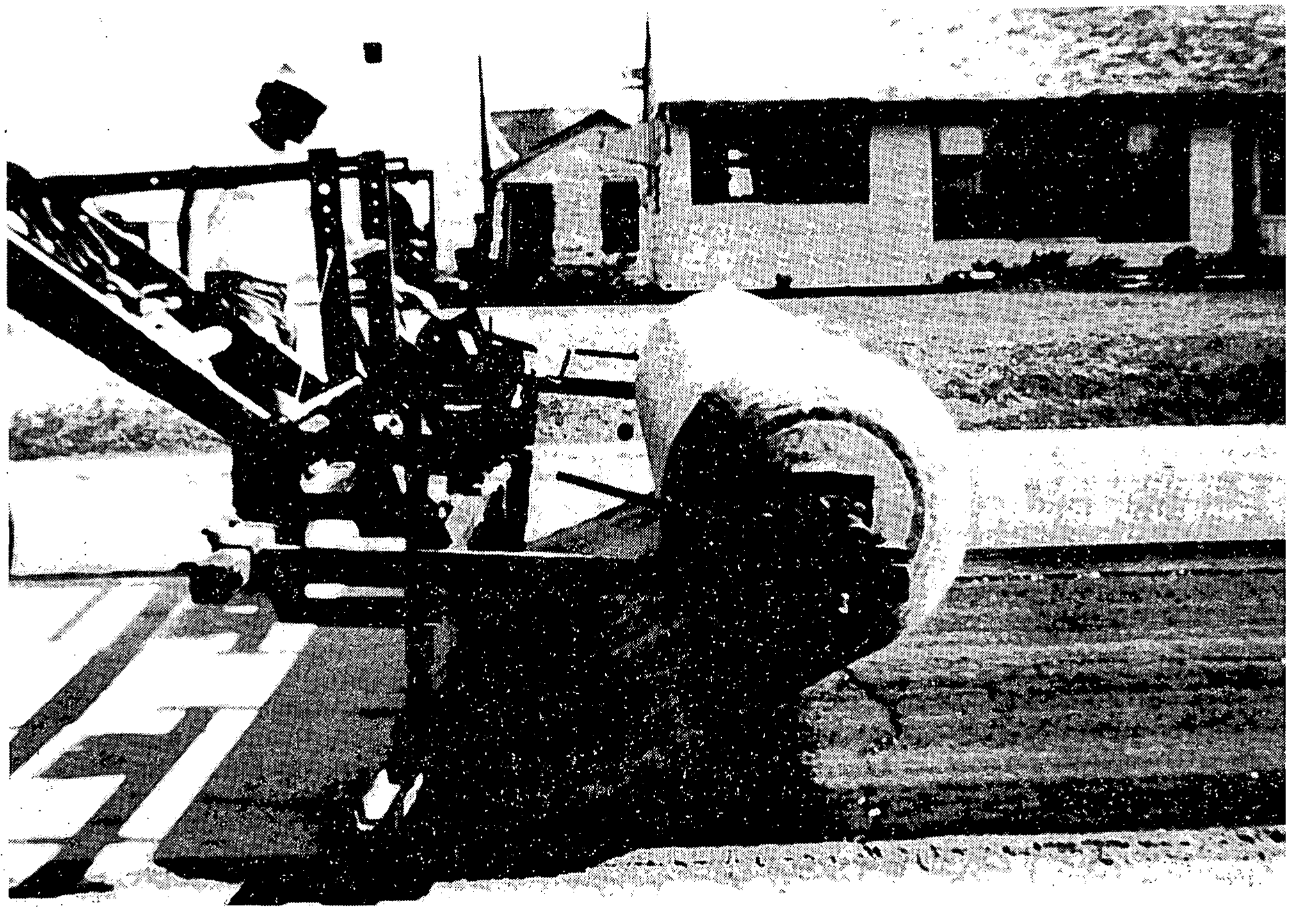


Figure 6 - Placing Reinforcing Fabric
to Prevent Reflection Cracking

Iowa's experience in the use of fabrics for this purpose has been limited to 6 projects, two of which were to be monitored as research installations. Fabric on each of these projects was placed in conjunction with an A.C. overlay placed on an old P.C. pavement section which may or may not have been previously widened and resurfaced. The cracking pattern included transverse joints, longitudinal widening cracks, and meandering cracks. Fabrics were used as a strip or bandaid application, and full width of the pavement.

The first experimental use of a fabric to prevent reflective cracking was on Iowa 89 near the town of Woodward in central Iowa. The three different materials evaluated were Cerex, a spunbonded nylon manufactured by Monsanto Chemical Co.; Petromat, a non-woven polypropylene manufactured by Phillips Petroleum Company; and Structofors, a polyester fiber manufactured in Holland. This project was constructed in 1971 and evaluated over a 5 year period.

The fabrics were placed full width directly over the portland cement concrete surface. Prior to placement, the surface was cleaned, cracks were filled with an asphalt mix, and an emulsion tack was applied at 0.30 gal./sq.yd. A 3" asphaltic concrete overlay was placed over the experimental fabrics.

All three fabrics proved to be effective in reducing reflective cracking. After 5 years, only 1/3 as many transverse cracks were evident in the Petromat section as the non-reinforced control sections, and 1/2 on the Cerex and Structofors reinforced sections. The reflective cracking between the original P.C.C. pavement and the asphalt widening was nearly eliminated where reinforcing fabrics were placed. Fabric reinforcement was least effective over meandering cracks.

Encouraged by these results, the Iowa DOT has since used fabrics on selected areas of 5 projects. The supplemental specification for this work identifies those materials certified for use as determined by laboratory testing. Approved are two polyester materials Bidim C-28, manufactured by Monsanto, and True-Tex MG-75, manufactured by True-Temper, and one polypropylene, manufactured by Phillips Petroleum.

Critical to the performance of these products is the base preparation. All cracks wider than 1/2" must be cleaned and sealed, or filled with asphalt concrete. A uniform A.C. tack is to be applied at 0.25 to 0.30 gal./sq.yd. The bid prices for the fabric installed over the last two years have ranged from $1.25 to $2.00/sq.yd. Where used full width, the installed price of fabric is approximately equal to one additional inch of overlay.

2. Heater Scarification

Iowa has used the heater scarification-overlay process as a maintenance technique for the last 5 to 6 years. On the primary system, approximately 40 miles of 2-lane roadway are heater scarified annually, while another 30 to 40 miles are being done by the cities and counties in the state.

In this treatment, the existing asphalt surface is heated by a commercial heater unit to temperatures not in excess of 475°F and then scarified to depths of up to 1". The surface is then leveled with augers and screed, or special drag assembly. Prior to the temperature dropping below 220°F, hot asphalt mixture is added at the rate of 100 lb/sq.yd. and the combined material compacted.

This process offers several important benefits, namely: correction of surface distortion or wheel rutting; elimination of minor surface cracking related to oxidation or aging of the pavement surface; reduction in the overlay depth thereby saving material and retaining drainage capacities along existing curb and gutter sections; and temporarily sealing off the surface to the elements.

This treatment is now being used on a limited number of construction projects in conjunction with 2" to 3" overlays for some of the same reasons stated above. It is no substitute for proper preparation of thermal cracks open 1/4" or more, and should not be used to correct structural problems, or in lieu of surface patching, or crack sealing. This is another technique available for use on 3R repair projects and should be used selectively.

3. <u>Asphalt Rubber (SAMI or SAM)</u>

The Iowa Department of Transportation has not constructed any asphalt rubber stress absorbing layers and therefore has no experience on this subject.

4. <u>Roto Mill Scarification</u>

There may be some potential benefits for cold milling recycling in the 3R program. The Iowa Department of Transportation has favored heater scarification over cold recycling as the bitumen in the recycled material is heated and the benefits of the asphalt cement are reactivated. Substantial cold milling has been done in Iowa; not for 3R crack repair purposes, but for profile restoration. Substantial Rotomill scarification has been utilized for asphalt concrete salvage but not as a surface restoration process.

5. Crack Filling Material

The Iowa DOT recognizes the benefit of crack and joint maintenance in view of an increasing emphasis on system preservation. Joint and crack maintenance by the Iowa DOT is normally conducted as described in Maintenance Standard 612 (Appendix A). In general, this crack filling is aimed at general maintenance and not preparation prior to an asphalt overlay but "maintenance projects" are an exception. Most asphalt resurfacing is financed through the Primary Road Fund and the surface preparation is one item in the contract. The Iowa DOT lets a few "maintenance projects" each year where the surface preparation is completed by maintenance personnel prior to the overlay by the contractor.

The basic reason for crack sealing is to prevent the intrusion of foreign materials and reduce the infiltration of surface water. Filling of cracks prior to an overlay should be aimed at adding strength and protection to the critically weakened cross-sections. It will also reduce the potential for moisture related deterioration or stripping. Insufficient filling of cracks and joints prior to an overlay allows rapid development of cracks and subsequent accelerated deterioration of the crack through stripping.

There is special emphasis placed on filling cracks during the winter when cracks are at maximum width. The scheduling guide of Maintenance Standard 612 recommends 65% of the program be completed from January through March. Penetration grade A.C. (120-150), cutback (MC-800), and emulsion (CRS-2) are the commonly used liquid crack filling materials. Based on use during the 1979-80 winter, the distribution was 13% A.C., 34% emulsion and 53% cutback. The trend is to increase the use of emulsions for this purpose.

At the present time, there is no statewide policy as to which liquid filler to use. Type of crack, terrain, weather conditions and individual preference are factors considered in selection. Energy conservation is a major factor in the trend to emulsions, but there are other advantages. It has less tendency to bleed and track. Improvements in the emulsion, storage and handling have yielded better performance of the sealing characteristics. Even though many problems have been alleviated, winter storage and limitation of the operation due to freezing conditions continue to hamper the use of emulsions. In overlays, the emulsion has less tendency to adversely affect the resurfacing than would a cutback.

The main advantage of the A.C. and cutbacks is the freedom to seal during freezing weather. There may also be better penetration and/or adherence to the face of asphalt cracks.

The evaluation of crack sealing would indicate very little difference in performance when comparing emulsions, penetration grade A.C. and cutbacks.

There has been relatively limited use of asphalt emulsion slurry seals as a crack filler in Iowa. Of the two recent applications, neither has been used in preparation for an overlay. Slurries have been used successfully in filling severely deteriorated cracks where the opening is relatively wide (3/8") and stripping and loss of material have resulted in an objectionable dip (1/4" to 3/4"). The slurry mix to fill the crack is much more fluid than the mix used to fill the dip. The other recent use is the pumping of badly deteriorated cracks with special probes.

Until three years ago, a rubber asphalt produced from recycled rubber was the standard sealant material for new Iowa P.C.C. pavement. Due to poor performance, the specification was changed to require an upgraded rubber asphalt produced from virgin rubber. With this background and renewed promotion of recycled rubber asphalt for crack filling, a research application of rubber asphalt crack filling was placed prior to an overlay. The old roadway was originally a P.C.C. pavement with subsequent A.C. resurfacing totaling 5 inches. The rubber asphalt sealant material had very poor flowing characteristics and difficulty was encountered in "filling" the cracks. Squeegees were used in an effort to force the material into the cracks with limited success. All except two sections left for comparison within the five mile project were sealed with rubber asphalt. Visual observations and inspection of drilled cores indicated no significant benefit of the special sealant.

6. Drainage

In the past, even as early as the late 1920's, the state of Iowa had utilized transverse and longitudinal drainage under pavement. The use of special drainage systems had declined until 1978. With the realization that many problems of the 1970's were water related, there has been considerable emphasis on longitudinal subdrains. Initially, the edge drains were used for rehabilitation or preservation of jointed and continuous reinforced P.C.C. pavement. The revised drainage program is now being used both for additional improvement in asphalt overlay projects and as a design for new asphalt construction.

A current design standard (Appendix B) has been developed for edge drain construction. Consideration is still given to the cost effectiveness and on that basis edge drains are not a standard item on all Iowa projects. If prior to an overlay or new construction, pavement or soil conditions indicated instability, edge drains are included for those particular areas.

The long term benefit of these edge drains will require additional time, but based on short term evaluations, their use exhibits significant benefit. There is continual flow from the outlets indicating a drainage of both surface water and subgrade water which will result in improved stability. On P.C.C. pavement, there has been reduced pumping and a stabilizing of the pavement slabs.

Transverse drainage is used as a standard practice where porous backfill material is used. These are selected areas where water problems are expected. The transverse drainage is shallow to allow outlet into the roadway ditch.

7. Crack Repair

Iowa specifications require crack cleaning prior to overlaying. Due to the wide variety of conditions encountered, it is difficult to be specific as to minimum level of preparation for all cases.

Performance evaluations of asphalt overlay projects would indicate that insufficient crack cleaning has contributed to premature crack development and deterioration in the overlay. The standard cleaning procedure prior to an overlay is briefly:

1. Remove unsound or unstable material
2. Surface brooming
3. Compressed air jet routing of cracks

There has been a special effort to educate our inspectors about the importance of surface preparation and specifically crack cleaning. The emphasis was to improve the crack cleaning and thereby gain longevity of the overlay. Unfortunately, in too many cases, the cleaning and filling of the cracks are inadequate. Cracks open 3/4" or more are to be filled with asphalt mix.

Where the joint failure has advanced to the point where crack sealing and surface patching will not satisfactorily repair the crack, consideration is given to removing the damaged asphalt material adjacent to the crack. Iowa has in the recent past, specified the width of a patch to be a minimum of 2 feet. We are now looking at a 4 foot minimum trench width to gain production and allow use of motorized removal and compaction equipment. The normal production on a road being repaired under traffic is 150-200 sq. yds. a day. In 1980, full depth patches in A.C.C. pavement cost an average of $62 a sq. yd. This is a very expensive repair technique. Partial depth patches have been tried but the cost savings were insignificant. Possibly, a 4"-12" wide patch could be constructed using a "Ditch Witch" type saw for excavation, which might reduce the cost. This treatment has not been used to any extent in the state.

A research project was initiated to investigate improved procedures for crack cleaning. A waterblaster (figure 7) capable of delivering 10 gallons per minute at 2000 psi pressure was purchased in 1980.

Figure 7 - Waterblast Routing of a Transverse Crack

Comparative sections of air jet cleaning and waterblast cleaning prior to crack sealing have been established. It is too early for performance data, but visual observations of the waterblast cleaning are impressive. The waterblast cleaning appears substantially superior to air jet cleaning. Anticipated modifications in the waterblaster wand should further improve the routing capabilities.

8. Overlay

Thin lift overlays have normally been considered to be less than 1" in thickness and consist of hot-mixed, hot-laid asphalt mixtures placed on structurally sound asphalt pavement surfaced.

Their use in Iowa has been as a part of our maintenance program to temporarily seal off the pavement surface. They can also improve skid resistance, improve ride, and eliminate minor wheel rutting or other surface distortions.

Surfaces most improved by this treatment contain rather tight shallow transverse and/or longitudinal cracks. Normally, on a more severely cracked section, 100% of the cracks would reappear within 1 to 2 years.

In Iowa, most thin overlays are hot sand mixtures containing up to 7% A.C. This material provides good skid resistance and the higher A.C. content adds to durability while producing good stabilities.

Thick overlays are normally considered to be 2" to 4-1/2" in total lift thickness, but may be up to 6". Their application may be as a part of a planned stage construction with full depth asphalt concrete, or as an overlay over P.C.C. pavement. The thicker overlay provides increased structure to the pavement and seals off the surface while retarding further spalling of joints. Experience has shown the thicker the overlay, the more the reflection cracking can be eliminated or delayed.

The main concern with thick overlays is cost, and cost effectiveness in managing a pavement system.

Due to budget limitations and increased inflation, Iowa has had to resort to using 2" overlays which some may classify as a thin overlay. Increased emphasis has been placed on base preparation and joint repair. With proper base preparation, the thinner-thick overlay (2"-3") may be expected to perform satisfactorily for 10 to 15 years, depending on traffic volume and structural conditions.

CONCLUSIONS

The scope of this study addresses the possibility of improved mix design procedures as a means of reducing the amount of transverse cracking and the problems associated with it. The study also addresses the use of maintenance procedures as a means of reducing crack deterioration, thus extending pavement life and special crack treatments which might be used at the time pavements are rehabilitated as a means of reducing crack reflection and further crack deterioration. The study does not address what we believe to be the major contributor to transverse cracking which is the subgrade and subbase.

In preparing for the meetings which were held to discuss the many problems associated with this study, considerable investigation and review of prior work was necessary. Much of this work and information is not discussed in this report but rather was contained in handouts and minutes of the meetings.

Conclusions which can be derived from the total study are as follows:

1. It does not appear that current mix design practices can be expected to do little more than minimize transverse cracking.
2. Iowa's current mix design procedures for binder and surface courses are in line with those recommended through various research reports.
3. Most of the deterioration stripping at transverse cracks occurs in the base course indicating a need for more concern in design of asphalt treated bases.
4. Transverse cracking is more severe when placed on subbases or bases containing portland cement or lime.
5. Cracks which have been effectively sealed are not as badly deteriorated as those which have not been sealed.
6. Improved crack cleaning prior to sealing is necessary to permit effective sealing. High pressure water-blast cleaning exhibits potential as an improved method of crack preparation.
7. An improved crack sealant material is needed both for maintenance and crack repair prior to resurfacing.

8. There are no treatments currently available which will effectively reduce transverse crack reflection, particularly if the crack is temperature related.

9. The use of fabrics in conjunction with overlays can eliminate, or substantially retard longitudinal and some fatigue type cracking. Fabrics will not prevent reflective cracking of a moving or working joint or crack.

10. Heater scarification can economically correct minor surface distortion and shallow surface cracking (1" or less).

11. Control of reflection cracking with an overlay is directly related to the thickness of the overlay.

12. Full depth patching is a very costly repair technique. In the future, some savings might be realized by the use of the new milling equipment and development of special compaction equipment.

13. Pavement design should be modified to provide better underslab drainage.

RECOMMENDATIONS

Transverse cracking is a phenomenon which has been with us since asphalt was first used as a paving material. There has been a lot of research, a lot of reports have been written and there has been a lot of discussion of the subject. While some reports have suggested ways in which transverse cracking can be reduced, none have offered a positive suggestion for stopping it. Recommendations which arise from these reports generally suggest a need for further research.

From the results of our participation in this study, we too would recommend the need for further research. During the interim period, there is a need for concerted efforts in minimizing cracking through mix design, reducing deterioration through better maintenance and reducing reflection cracking through improved surface preparation procedures. The following recommendations are offered for consideration:

1. Continue to seek ways of improving the quality of asphalt treated bases without significant increase in cost.
2. Continue to evaluate the results of recently adopted changes in requirements for binder and surface courses.
3. Adopt a positive procedure requiring timely sealing of cracks.
4. Continue research designed to evaluate procedures which will reduce cracking and crack deterioration.
5. Strengthen specifications for preparing pavement surfaces for overlays.

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 Sealing 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:

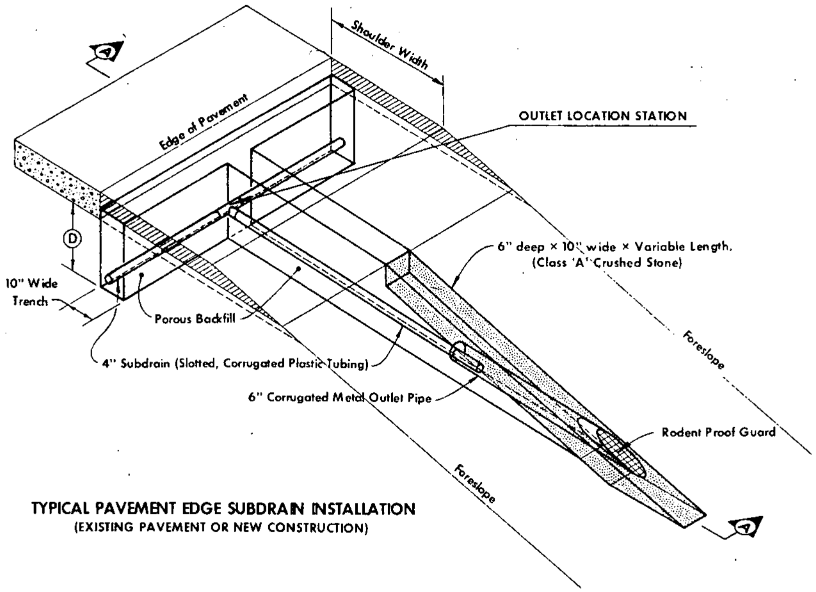
2 - Dump Trucks
1 - Air Compressor
1 - Tar Kettle
2 - Pouring Pots
1 - Portable Generator
1 - Barrel Heater
Hand Tools as Needed

ACCOMPLISHMENT

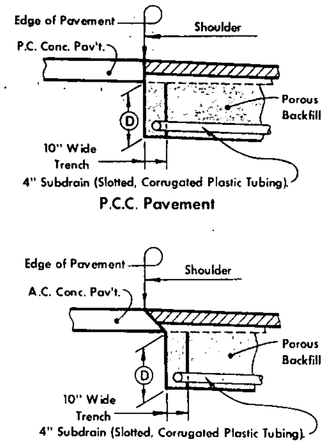
Unit: Gal. of Sealant

Standard Rate: 3.0 Gal. Per MH

Daily Production: 84 - 120 - 156



TYPICAL PAVEMENT EDGE SUBDRAIN INSTALLATION
(EXISTING PAVEMENT OR NEW CONSTRUCTION)



SECTION A-A
TYPICAL SUBDRAIN OUTLET
(NEW CONSTRUCTION)

GENERAL NOTES:

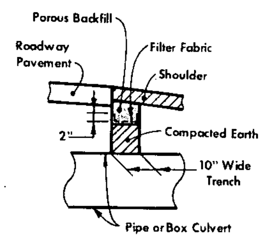
Details indicated hereon are for the construction of pavement edge subdrains and outlets. All work and materials used in the installation shall be in conformance with applicable Standard Road Plans, current Standard and Supplemental Specifications. Refer to "Tabulation Of Pavement Edge Subdrain" for details of individual subdrain and installations.

Each outlet shall be covered with ½" mesh galvanized screen or an approved commercial rodent guard. The guard shall be securely fastened to the outlet pipe end by means approved by the engineer.

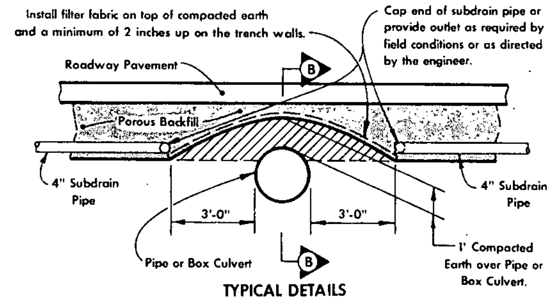
Subdrain trench shall be located adjacent to edge of roadway pavement. On new construction projects, the subdrain shall be placed after the mainline paving and prior to shoulder placement. On new projects with tied P.C.C. Shoulders, trench location shall be as determined by the engineer. On existing roadways, the trench shall be capped with material per current Standard and Supplemental Specifications.

Price bid for "Subdrain, As Per Plan" (in lin. ft.) shall be considered full compensation for all installation work and materials necessary as detailed hereon, included in current Standard and Supplemental Specifications and as required by project plans.

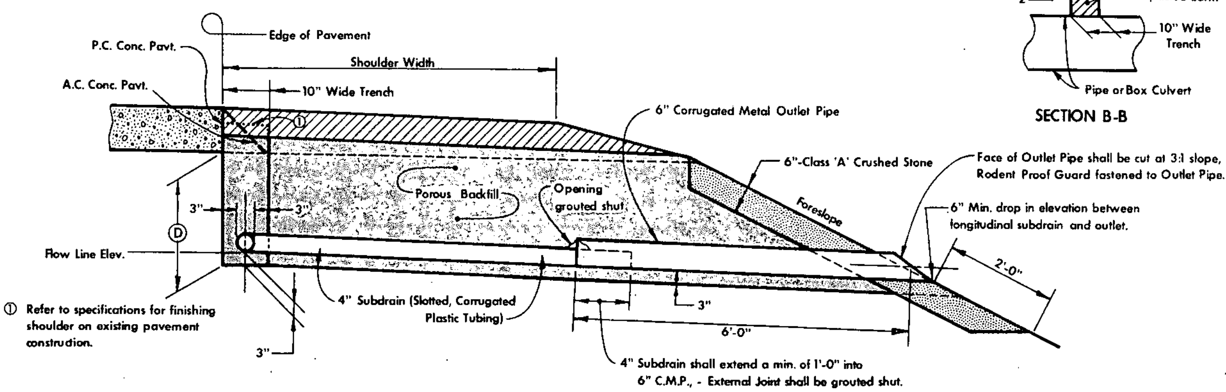
Project quantities includes length for both the subdrain at the edge of pavement and the subdrain in the outlet.



SECTION B-B



TYPICAL DETAILS
SUBDRAIN INSTALLATION AT
R.C.B. CULVERTS OR RF-1 CONCRETE PIPE CULVERTS
(If culvert is 1 ft. or more below trench bottom, no subdrain outlets should be provided. Carry subdrain over culvert.)



① Refer to specifications for finishing shoulder on existing pavement construction.

SECTION A-A
TYPICAL SUBDRAIN OUTLET
(EXISTING PAVEMENT)

DETAIL SHEET	500-7
Revision Date NEW ISSUE 4-18-80	
DETAILS OF PAVEMENT EDGE SUBDRAIN	