Current Practices and Research on Controlling Reflection Cracking

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Reflection cracking has become an increasingly important problem as the mileage of bituminous resurfacings over concrete pavements has grown. As yet no wholly satisfactory technique of crack control has been developed.

The methods proposed for controlling reflection cracking are reviewed and discussed. In general they fall into two broad categories: prevention and sealing. Prevention involves eliminating the forces which cause cracking or modifying the resurfacing in the vicinity of joints to enable it to withstand these forces. None of the proposed methods of elimination are in general use, but many have been incorporated in test roads both in this country and abroad. Some have proved to be unworkable; others are being tested but are still too new to provide definite conclusions. Several proposed techniques have yet to be tried or need further development before their worth can be determined.

The sealing of reflection cracks is difficult because of their narrow width and irregular shape. They require techniques and materials differing from those developed for sealing joints in cement concrete pavements. Surveys of technical literature, correspondence, and questionnaires to highway agencies reveal that current practices are far from satisfactory. Most treatments are not effective in keeping out water and dirt and preventing further deterioration. Some research on improved sealing techniques is underway, but much has yet to be learned and applied.

● ONE of the most-widely used ways to prolong the useable life of concrete pavements is to resurface them with a layer of bituminous concrete. This restores the smoothness and improves the riding quality. It also improves the structural strength by adding several inches to the thickness of the pavement. This practice has grown in use since World War II, as part of a general program to catch up with deferred maintenance, and to strengthen pavements to meet the current demands of more and heavier traffic. Resurfacing is also adaptable to widening of pavements and salvaging old pavement on reconstruction projects.

One of the characteristics of these resurfacings which demands repeated maintenance is its tendency to form reflection cracks. These cracks develop directly over the joints and cracks in the underlying slabs, reflecting their pattern into the new surface. There is obviously a connection between the cracks and the underlying joints, and it has been found that cracking can result from either of two causes, differential vertical movements between adjacent slabs or the repeated opeining and closing of the joints due to the thermal expansion and contraction of the concrete (5). While both causes are often present, the horizontal opening and closing is the more difficult to control. Subsealing and mudjacking have been successfully used to restore the support needed to prevent critical differential vertical movements. The techniques for controlling horizontal movements, however, are not so well known and many of them are still experimental. This paper deals primarily with methods of reducing the effects of horizontal movements.

The subject matter for this paper is drawn from published and unpublished reports, from the authors' experience, and from replies received to a questionnaire on sealing methods sent to state highway departments. Where applicable, references are made to the bibliography at the end of the paper.

METHODS OF CRACK CONTROL

There are two approaches to the control of reflection cracking. The first is to attempt to prevent the formation of these cracks by some modification of the current resurfacing practice, and the second is to minimize the harmful effects of the cracks by effectively sealing them after they have formed. Each of these phases will be presented separately.

In discussing crack control methods it should be kept in mind that any method to be of practical application must not only successfully eliminate the undesirable features of cracks, but it also should not: (1) lessen the strength, stability or service life of the resurfacing, (2) add excessively to the cost, (3) unduly delay construction progress, or (4) require special skills or techniques which cannot be handled by the usual labor force.

Reduction of Slab Movement at Joints

One method of reducing cracking is to fill the expansion joints in the concrete with incompressible material so that the movement of the slabs is reduced to an amount which the resurfacing can absorb without cracking. Such a process eliminates the expansion space which was provided in the original design and will cause compression in the slabs when they expand with temperature rise. While some compression can be taken by the slabs, not all of the movement can be eliminated without danger of blow-ups or compression failures. For this reason, it would not be advisable to fill too many consecutive joints. In one state where joints 60 feet apart were plugged with grout blow-ups occurred at about every fifth joint.

In practice, it is difficult to thoroughly clean out the old filler material and to completely plug the joints. The presence of dowel bars in the joints restricts the depth to which they can be cleaned out by mechanical means. Hand methods, used on the Revere Test Road in Massachusetts, proved very inefficient (6).

The experimental joints plugged with cement grout and with soil mix on the Revere Test Road proved ineffective in eliminating very much of the movement and in preventing reflection cracking (7).

Breaking Concrete Slabs into Small Pieces

Breaking the slabs into small pieces will reduce the amount of movement taking place at the joints. The pavement then becomes a series of small slabs, each of which induces its small amount of movement into the crack surrounding it. In this way, the local movement taking place at any one crack or joint can be kept well below that amount which the resurfacing can absorb without cracking. One state reports success with breaking slabs into pieces having a maximum dimension of about 2 feet. It is likely that others have also used this method.

The process appears expensive and time-consuming, especially where the slabs are reinforced. The structural integrity of the concrete is, of course, destroyed, and unless the subbase is firm there is danger of vertical movement between fragments.

Increasing Thickness of Resurfacing

Increasing the thickness of the resurfacing adds to its crack resistance, or at least delays the appearance of reflection cracking at the surface. It has been noted that where resurfacings were thickened to introduce superelevation at curves reflection cracks begin at the thin edge and sometimes die out as the resurfacing becomes thicker. After 2 years of service the section of the Revere Test Road resurfaced with three inches of mix shows substantially less cracking than the 2½-inch-thick section (7). More time will be needed to establish whether this difference will be permanent.

It is not known what thickness of resurfacing would be required to prevent cracking. Undoubtedly it is greater than the 2½ to 4 inches currently being used, since 3-inch resurfacings have been found to crack over more than 90 percent of the length of transverse joints in only four years (4). The cost will increase roughly in proportion to the added thickness. A further limitation to increasing the thickness in certain locations is the amount by which the original grade can be raised.

Increasing the Stretchability of the Mix

Another method of reducing the incidence of reflection cracking is to introduce into the mix some additive which will give it the ductility necessary to absorb the joint movement without cracking. Tests have shown that the ductility of a typical bituminous concrete mix would have to be increased about five times to accommodate the stretch imposed by slabs 57 feet long such as are found in Massachusetts (5). The authors are not aware of any additive which will impart this property to a bituminous mix and question whether this much ductility can be attained without reducing the stability below acceptable limits. The addition of various types of rubber to bituminous concrete can significantly increase the ductility of the mix (19), but so far there is no indication that the increase is sufficient to prevent reflection cracking. Catalytically-blown asphalt has been used in combination with regular asphalt in an attempt to increase the stretchability of the mix (6, 7). It was thought that this mix would be more ductile at low temperatures and more resistant to cracking than the regular mix. However, the reverse proved to be true. After 14 months of service it was found that 40 percent of the transverse joints in the catalytically-blown asphalt blend section were cracked through, whereas only 14 percent of these joints were cracked in the regular Type I section. An emulsified rubber-asphalt section after the same period had only three percent of transverse joints cracked.

One disadvantage of using an additive is that, as a practical matter, it must be added to the production for the entire job, whereas it is usually only needed over small areas on each side of joints. These small areas usually comprise only a small percent of the total surface, but the cost of the additive will apply to the whole mix. Any difficulties encountered in incorporating the additive will also add to the cost.

Use of Welded Wire Fabric Reinforcing

Another possible way of eliminating cracking is to distribute the stretch imposed at the joints in some manner so that the stretch occurring at any one point in the resurfacing does not exceed the amount that the material can absorb. A number of installations of various types of wire mesh reinforcing have been made to test the effectiveness of this material. On some test roads the reinforcing has been placed over the entire pavement; in others strips have been placed only over joints. In some cases the reinforcement has been placed on the cement concrete; in others it has been placed between layers of bituminous concrete. The first installation of welded wire in a bituminous resurfacing over concrete was laid in 1946 in Texas. On this project the resurfacing was continuously reinforced with a 6 by 12-9/9 fabric.[1] Since 1946 at least 12 similar reinforcing projects have been built. Most of them have utilized a 3 by 6-10/10 fabric, which is the size currently recommended by the Wire Reinforcement Institute. Other sizes which have been used are 4 by 4-10/10, 6 by 6-10/10, 3 by 6-8/8 (12, 13, 14).

Reports available on the earlier projects indicate that the reinforcing was effective in reducing cracking in some of them. No systematic follow-up of performance appears to have been made on these projects and quantitative comparisons with unreinforced control sections are not available. Many of the projects are of recent construction and cannot be evaluated as yet (12).

Reinforcing with Strips of Mesh over Joints

Strips of wire mesh have been used to reinforce resurfacings in the area over expansion joints. The various installations cover a wide range of sizes, shapes, and weights of mesh. Expanded metal has been used on several test roads in England (9), and on the Millbury Test Road in Massachusetts (8). It is reported that the British tests reduced the amount of cracking in the first few years of pavement life, but the effects in later years must await the passage of more time. The two-foot, eight-inch strips of mesh used in the Millbury experiment were too small. Cracks developed at the edge of the strip, indicating that a definite transfer of stretch did take place. It is not known how much was actually distributed in the reinforced portion of the mix.

[1] The size of welded wire fabric is expressed by four dimensions. In order, these are the spacing of the longitudinal wires (in inches), the spacing of the transverse wires, the gage (United States Steel Wire Gage) of the longitudinal wires, and the gage of the transverse wires.

The Revere Test Road in Massachusetts included four different types of mesh over the joints. These were chicken wire (in strips 4 feet wide), a 2-by-2-inch light mesh (in strips 4 feet wide), a 6-by-6-inch heavy mesh (in strips 7 feet wide), and chainlink fencing (in strips 5 feet wide). After 14 months, the chicken wire and 6-by-6-inch mesh showed less cracking than at unreinforced control joints. The 2-by-2-inch mesh showed more cracking, but all of it occurred at the edge of the mesh, not over the joint. The strips of this material were evidently not large enough to distribute the stretch sufficiently to prevent cracking, the same condition as was found in the Millbury tests. The chainlink fence proved to be too stiff for use in bituminous concrete, and induced map cracking in the surface.

Distribution of Stretch by Breaking Bond

Another possible way of distributing movement at joints is to break the bond between the resurfacing and concrete for some distance on each side of a joint (20). A limited test of the use of metal plates to reduce bond was included in the Revere Test Road. Where 26-gage plates (3 feet wide) were placed across joints, some distribution of the stretch occurred in the area over the plate during the first year. However, cracks have developed over the edge of the plates, indicating that all of the stretch was not distributed. Heavier (11-gage) plates proved too stiff and soon caused breakup of the pavement over them.

The feasibility of thin metal plates of sufficient size to allow distribution of all the stretch is yet to be proven. The reduction of bond that is beneficial for the control of reflection cracking has the disadvantage that it renders the resurfacing more subject to shoving under horizontal braking or accelerating forces.

The Revere tests also included a limited test of common building paper as a bond-breaking medium, which did not prove effective.

Use of Base Course Between Concrete and Resurfacing

The practice of breaking bond by placing a layer of crushed stone or gravel over the old concrete before resurfacing has been used in a number of states and abroad (22). The layer is usually about 4 inches thick. Thicker courses have been used where the subgrade was poor and the concrete badly broken. The thickness of layer required has not been fully established.

The limited data available to the authors indicate that this method does reduce reflection cracking.

The addition of 4 inches or more of granualr material under the resurfacing inherently raises the final grade of the pavement. This is usually not feasible in urban areas, where the effect on curbs, sidewalks, and abutting property must be considered. In rural areas, however, this method of treatment shows good promise of being effective.

Combination of Methods

It is possible that a combination of two or more of the methods above might be more effective than any one of them alone. For example, reinforcing might be effective in a rubber-asphalt mix but not effective in standard mixes. The combination of light plates with mesh reinforcing might also be effective.

SEALING OF CRACKS

Sealing of reflection cracks has not proved uniformly satisfactory. Most of the materials and techniques currently used are those which have been developed for joints in cement concrete or for cracks in bituminous pavements on flexible bases.

While reflection cracks are similar to the cracks over flexible bases, the continuous movement in the crack due to the expansion and contraction of the concrete is an additional condition that must be overcome. Laboratory tests indicate that many materials satisfactory for sealing joints and random cracks are not capable of meeting the special conditions imposed by reflection cracks (13).

During the past year, a questionnaire was sent to most highway departments requesting information regarding the materials and pouring techniques used, and the performance of their current sealing materials. Replies were received from 34 states, the District of Columbia, and one turnpike commission. This survey revealed that most of the states use some form of asphalt cement sealer, although several are also experimenting with other types. Cutbacks of the RC and MC types are commonly used for very fine cracks. Other sealers used are rubber-asphalt compounds, tar, emulsions, catalytically-blown asphalts, and sand-asphalt mixes (for wide cracks). Two states reported that they do not make a practice of sealing reflection cracks.

The usual practice is to seal cracks in the late fall when the surface is cold and the cracks are open. When pouring, an effort is made to put the sealing material into the crack without overflow or spillage. This is difficult to accomplish where cracks are narrow and crooked. Where overflow does occur the excess material is often dusted with sand, screenings, limestone dust, cement, lime, or sawdust. The last is preferred by four states because it is highly absorbant and does not result in any appreciable buildup on the surface.

Several states specify blowing out of cracks with a compressed air jet before sealing; a few are experimenting with grooving the cracks to straighten and widen them before pouring.

The asphalt kettle and hand pouring pot are the most common types of equipment for sealing cracks. Often special nozzles or attachments are used to control more closely the flow of material into fine cracks.

Although some of the states appear satisfied with their results, others, particularly those with large mileages of resurfacing, are not and are seeking better methods. Rubber-asphalt compounds and catalytically-blown asphalt are reported better than low penetration asphalt cement in some instances, but experience with them is said to be insufficient to prove whether their higher cost is justified.

Typical of the dissatisfaction with current methods is the following comment: "The problem of sealing cracks in asphaltic concrete surfaces which are a reflection of cracks in old concrete pavements appears to be universal. We have not at this time developed either techniques or equipment which in our opinion are entirely satisfactory. We have used various types of material and methods of pouring, none of which have produced outstanding results."

Research in Sealing of Cracks

Considerable research in sealing materials and methods is currently underway. Several manufacturers of sealers are developing new types and working to improve the properties of existing types. Equipment manufacturers are developing new kettles, crack cleaning and cutting equipment, and pumps. Thinner nozzles and the extrusion of a sealer under pressure are typical examples of new techniques. Various highway departments are cooperating in making performance tests of new products and new methods.

Sawing Grooves in Resurfacing over Joints

One of the principle difficulties in sealing cracks arises from their narrow width and crooked alinement. One method of overcoming this is to saw a groove in the resurfacing over joints in the underlying pavement before the cracks appear. This procedure is similar to the construction of sawed contraction joints in concrete. The groove should be wide enough to fill easily and large enough to contain a sufficient volume of sealing material to keep the crack continuously sealed whether open or closed.

Sawing a groove into the bituminous concrete is neater and generally more satisfactory than forming one in the mix before it sets. Sawed joints have been constructed on a test pavement in Walpole, Mass.,[2] but no conclusive results are as yet available. More tests are desirable to determine the optimum dimensions for the groove and the proper age of mix for easiest sawing.

Controlled reflection cracks may be created by placing a folded sheet of heavy paper

[2]Constructed by the Joint Highway Research Project, Massachusetts Institute of Technology, and the Massachusetts Department of Public Works.

on the concrete so that the fold will extend upward into the mix. This device has been used with some success in sheet asphalt mixes. It usually causes a straight crack to form, but does not provide an adequate reservoir for sealing material.

Burlap Overlays

Some highway departments have experimented on lightly traveled roads with burlap overlays over cracks. The pavement adjoining a crack is swabbed with asphaltic material, burlap is placed on it, and it is then treated with a further coating of asphalt. It is not known how successful or long lasting this method has proved to be.

SUMMARY

This report has reviewed methods proposed for controlling the reflection cracking of bituminous resurfacing placed over old concrete pavements.

The following methods are described and commented upon: (1) elimination of joint movement by filling the joints with incompressible material; (2) breaking the concrete into small pieces with a drop ball before resurfacing; (3) increasing the thickness of the resurfacing; (4) addition of materials to the bituminous mix to increase its ductility; (5) use of mesh reinforcing in the mix over the joints in underlying pavement; (6) use of light metal plates between the concrete and the resurfacing; (7) use of granular layer placed between the concrete and resurfacing; (8) sawing grooves in the resurfacing over the joints in the concrete to form a weakened plane; (9) use of burlap layers in bituminous resurfacing over joints; and (10) sealing methods and materials for maintaining reflection cracks.

RECOMMENDATIONS

As a result of the review the following recommendations are made:

1. Research should be intensified on methods of making bituminous concrete mixes more stretchable at low temperatures and on preventing the loss of this characteristic with age. This might be accomplished by the use of additives or by changes in the refining processes of asphalt.
2. Further investigation should be made of the use of mesh reinforcing and of thin metal plates as a means for distributing stretch in the resurfacing so that the unit movement at any point will not be large enough to cause cracking.
3. Combinations of methods employing reinforcing, plates, special mixes, etc. should also be investigated.
4. More performance information should be obtained on the effectiveness of base course layers between resurfacing and concrete. Of particular interest is the thickness of courses and the types of materials used.
5. More development work should be done on sealing materials and on sealing methods for cracks in bituminous surfaces.

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