REPORT OF COMMITTEE ON DESIGN

A T GOLDBECK, *Chairman*

Chairman Highway Research Board

CRACK CONTROL IN CONCRETE BASES FOR SHEET ASPHALT PAVEMENT

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SYNOPSIS

This is a progress report on an experimental road built in 1931 A 46 foot pavement, constructed in two lanes, has a plain concrete base on one side and experimental sections on the other These latter sections contain many methods for using wire mesh reinforcement, expansion joints and dummy joints to control cracking in a six inch concrete base Indications of success or failure of the various designs after two years of traffic and exposure are reported and recommendations made for future work based on results obtained to date

Numerous sheet asphalt pavements of conventional design, on six inch concrete bases in suburban sections of Rhode Island have developed unsightly cracks after relatively short periods of use These cracks which occur first in the base carry up through the binder and surface courses and their initial irregularities are magnified by the interlock of the ¾ inch stone in the binder course Finally they appear on the surface and wander aimlessly across the pavements in diagonals, forks or zig-zags until they reach the curb or a longitudinal joint In an effort to improve this feature of the pavement the Rhode Island Board of Public Roads, in cooperation with the Committee or Design of the Highway Research Board, set apart a project on Newport Avenue in Pawtucket for experimental purposes in September, 1931 The road was approximately 46 feet wide and was built in two sections, one lane, 16 to 20 feet wide at places including a car-track, was poured first, using ordinary methods of construction and the balance of the road 26 to 30 feet wide was selected for the construction of the experimental sections The road was built on practically an ideal subgrade of sand and light gravel and on rather flat grades No particular attempt was made to insure a slip joint between the experimental sections and the curb or the adjacent parallel lane of pavement It was thought that, if anchorage should occur on these two sides of the slab, it would increase the efficiency of the dummy joints and the included reinforcing.

A 1:2 5:5 mixture of Dragon cement, washed sand and washed crushed gravel with a 5 to 6 inch slump was used In the sections where reinforcement was used, the base was roughly screeded to 2 5 inches below the finished grade and the mesh placed as called for, with the remaining concrete deposited to final elevation and finished with the backs of shovels Three cylinders and three beams were made every second day during concrete runs and were broken at the ages of 7 days, 28 days, and 6 months The average compressive strengths were 1475, 2260 and 2883 lbs per sq in respectively while the beams gave moduli of rupture of 428, 595 and 645 lbs. per sq in at corresponding ages

A record was kept of all cracks appearing in the base before the surface courses were laid. A period of approximately seven days was available for these observations and, in most instances to date, cracks in the asphalt pavement have developed over cracks which appeared in the base before the top was placed It was rather difficult to see whether cracking of the base had really taken place at dummy joints It was observed, however, that there were no other cracks in these sections If contraction had taken place, it is quite possible that cracks may have been present at the bottom of the 1 5 inch slot without being apparent to the observers A movement at these joints at a later date is expected to show in the finished pavement

In addition to the sheet asphalt construction, a 1400 foot section was constructed with a modified sheet asphalt wearing course in which several of the experimental base sections were repeated The change in wearing course was made by adding 30 per cent of $\frac{1}{2}$ inch crushed stone (ranging in size from $\frac{1}{4}$ to $\frac{3}{4}$ inch) to the standard sheet asphalt mixture In all asphalt construction a ten-ton three-wheel roller was used for initial compaction followed by a six-ton tandem roller operating diagonally

TYPICAL BASE SECTIONS

Type A · This is a typical plain concrete base, six inches thick and easy to place, with transverse joints made only at the end of a day's run

Type B A six inch concrete base with $\frac{1}{2}$ inch expansion joints placed 30 feet apart and $\frac{2}{3}$ filled with 85–100 penetration asphalt A thin galvanized sheet was placed over each expansion joint to prevent the binder from entering and destroying freedom of movement at these joints

Type C · This section has a plain six inch concrete base with dummy joints (1 5 in deep) at short intervals designed to control contraction cracks

Type D The same six inch concrete base with welded wire reinforcement placed 2 5 inches below the surface and between dummy joints spaced approximately 12 feet apart A two inch gap between sheets of mesh at dummy joints was planned The mesh was used to hold sections together between dummy joints

Type E The same six inch concrete base containing different weights of wire mesh reinforcement placed 2 5 inches below the concrete surface but with free ends of mesh lapping four inches across dummy joints which were placed at intervals of 24 feet This type was similar to Type D except that the shearing value of the dummy joints was increased by the addition of the steel wires crossing them

Type F A six inch concrete base with continuous wire mesh reinforcement Originally it was planned to place dummy joints 21 feet apart in a portion of this section to assist the continuous mesh to break down at these intervals but the dummy joints were detailed over the locked ends of the reinforcement so that this feature was practically eliminated In effect this section has continuous reinforcement thoughout its length This was evidenced in the field by the fact that, when the cracks appeared, they did not occur over the dummy joints as made

OBSERVATIONS AT THE END OF TWO YEARS

The general observations that can be made at this time serve mainly as a basis for further experimental work

It should be kept in mind that these observations are limited to a pavement with a fairly strong concrete base which is expected to crack and that these experimental sections were designed to control these cracks rather than eliminate them

GENERAL INDICATIONS, WHICH APPLY TO BOTH PLAIN AND REINFORCED SECTIONS

1 Numerous cracks in the base appeared within seven days after the concrete was poured and before the asphalt surface was placed

2 Most of the cracks now visible in the asphalt surface occur over cracks previously observed in the base

3 Several cracks, in the wearing course, noted recently, do not reoch the curb by some four to seven feet All were over old cracks or joints in the base This seems to indicate that incipient cracking of the surface course may be accentuated by traffic whereas the area near the curb, under little or no traffic, may resist cracking even over relatively wide contraction joints

4 The above observation includes cracks over two or three dummy joints where cracks may have existed originally at the bottom of the 1 5 inch slots in the base, but were not apparent to observers before the asphalt surface was laid

5 Cracks, occurring within short distances in adjacent lanes of this pavement, generally connected up, at the expense of rather unsightly irregular longitudinal cracks in the surface

6. Irregularity of cracks starting in the base has been accentuated

before reaching the surface probably by the interlocking action of the $\frac{3}{4}$ inch binder course Even cracks above straight dummy joints are more or less uneven upon reaching the surface

7 Expansion joints designed with cover plates, have generally produced wide and unsightly cracks without adding to the structural strength of the pavement Michigan experiments* indicate that without some mechanical means of transferring loads across these joints, the pavement has been actually weakened and that the use of a cover plate, to prevent the binder from entering these expansion joints, has resulted in wide cracks on both sides of this plate The behavior of plain sections in this pavement and many years of experience with similar construction in Rhode Island indicates that there is no need for expansion joints in this type of pavement when a base with not stronger than a 1:2 5.5 mix is used We have no record of blow-ups to date

INDICATIONS WHICH APPLY TO DEFINITE TYPICAL EXPERIMENTAL SECTIONS AT THE END OF TWO YEARS

Type A Plain concrete base without joints and exclusive of area affected by car-tracks

(a) Plain concrete base sections have averaged cracks about 60 feet apart in two years although individual lengths have varied from 13 to 90 feet

(b) Practically all of the base cracks were reproduced in this asphalt wearing course at the end of two years, although one or two exceptions have been noted

(c) Individual cracks were invariably transverse, but irregular in direction and not always at right angles to curb

Type B Plain concrete base with $\frac{1}{2}$ inch expansion joints, 30 feet apart

(a) Joints in this section most consistently produced cracks where designed because all but one joint functioned This seems to indicate that definite planes of cleavage should be constructed in the base The last joint did not act because it was locked in place by a return of the base into a street intersection

(b) The objections to this design are slowness of installation, the development of double cracks in the asphalt surface caused by cover plates over these joints, and the lack of load transfer across straight joints

(c) Although the original expansion joints in the base were constructed to the curb, the only cracks visible on the surface now are narrow cracks $\frac{1}{8}$ inch wide appearing in the heavier traveled part of the street These cracks have not appeared within six feet of the granite curb

* Investigation of the Shear Resistance of Cracks, A C Benkelman *Engineering News-Record*, August 24, 1933

Type C· Plain concrete base with dummy joints, 1 5 inch deep

(a) Dummy joints made 1 5 inch deep and spaced from 12 to 21 feet apart, do not *always* appear to function as contraction joints The tension area of concrete below the joint is sufficiently strong to hold several sections together even at early ages Assuming a 500 lb tensile strength in the concrete, computations show that it is possible to develop 135 tons of resistance to breakage in a ten foot width of this base

(b) Cores have proven that all cracks in asphalt surface in this section have occurred over dummy joints in the base, but only every third or fourth dummy joint at a distance of 45 feet or more has produced a crack

(c) There is better uniformity in alignment of cracks appearing over dummy joints in both plain and reinforced sections and an absence of the diagonals, forks, and zig-zags that were observed where no joints were provided Cores have shown that minor offsets up to three inches from the straight cracks at dummy joints, are produced by the interlocking effect of the $\frac{3}{4}$ inch binder course

(d) Individual slabs in the base between dummy joints all appear to be intact No cracks in the asphalt surface developed between dummy joints in the base

Type D Concrete base with mesh reinforcement in each 12 foot section separated by dummy joints in the two inch space between sheets of mesh

(a) The tension area below dummy joints in this section caused seven sections of base to hold together as did those noted under the plain concrete section with dummy joints One single crack in this area, with 84 feet of unbroken surface on either side, was $\frac{1}{4}$ inch wide

(b) A core showed that this single crack in the base occurred at a dummy joint, although the break in the surface offset about three inches from the dummy joint below due to the interlock of the binder course

Type E Reinforced concrete base with ends of mesh lapped, with and without dummy joints

(a) Dummy joints, crossed with lapped ends of reinforcement, have had little chance to show their possible superiority over plain joints, because long sections of base including this feature have held together as was noted in the plain concrete sections

(b) Unbroken sections were, however, much longer in this area running to a maximum length of 160 feet between cracks, although dummy joints were installed at the end of every third sheet of reinforcement or about 23 feet apart The minimum length of slab in this section is 60 feet

(c) There is no choice in regard to weight of mesh reinforcement

Type F· Reinforced concrete base with ends of mesh locked with and without dummy joints

(a) As previously mentioned, dummy joints in this section were detailed and placed over the locked ends of reinforcement and, therefore, failed to act This section therefore can be regarded as one of continuous reinforcement

(b) The theory that continuous reinforcement might break the base up into minute sections, evenly distributed, was not borne out in these trials Instead, the reinforcement held the base intact in relatively long sections With 32 lb mesh the slabs between cracks averaged 75 to 86 feet in length, with a minimum of 50 feet and maximum of 100 feet of unbroken asphalt top With 42 lb mesh the slabs between cracks averaged 100 to 102 feet, with 60 feet minimum and 165 feet maximum of unbroken lengths of surface

(c) A few base cracks from 20 to 30 feet apart, which developed before the top was placed, have not appeared in the surface. This may be due to the reinforcement holding the adjacent sections close together

(d) No particular uniformity in spacing or alignment of cracks is apparent in these sections

(e) Cores have indicated that the steel has broken at least at the end of the longer sections

(f) Cores have indicated that some definite method of locking sheets of mesh should be devised that would prevent sheets from separating when walked upon by workmen, thus destroying the continuity in reinforcement desired

SUGGESTIONS FOR FUTURE EXPERIMENTAL WORK

Based on our experience with these experimental sections, the investigators working on this project make the following suggestions for trial in future experimental projects of similar nature.

1 That dummy joints, as designed in this project, be replaced by light, deformed-steel contraction joints spiked to the subgrade and left in place These joints should be just sufficiently strong to form an effective key between sections and extend at least one inch into the binder course to straighten out surface cracks This design would eliminate the tension areas in concrete at dummy joints and provide for positive load transfer across joints where a strong base is needed

2 That in areas where an excellent subgrade is available and load transfer across joints is not of extreme importance, dummy joints made to a greater depth or at least one third of the depth of the pavement be tried. A temporary steel strip extending through the binder course could be used to keep joints in sheet asphalt surface straight and could be removed after the binder is rolled

3 That thin premoulded expansion joint material or at least heavy roofing felt be placed between the concrete base and the face of curb to prevent anchorage and insure functioning of these contraction joints.

4 That these transverse contraction joints be placed at intervals of not more than 20 feet longitudinally to form relatively fine cracks which if reproduced in the asphalt surface will heal under summer traffic and require little or no maintenance in winter

5 That the same light, deformed metal strips be used for longitudinal joints to transfer loads between lanes These forms will not need to extend into the binder course if this surface course is held back from the edge of base during construction

6 That contraction joints in parallel lanes be placed opposite one another

7 That in the design of contraction joints for a base such features as manholes or the return of the base into side streets, be taken into consideration These structures give definite anchorage and might prevent the operation of contraction joints unless provided for in the design

8 That expansion joints be eliminated from all concrete base construction used under asphalt pavements

9 That wire mesh be included in sections between contraction joints if the subgrade is poor

Although this paper has mentioned many cracks in this pavement, the investigators really had to look for them and we would emphasize here that this pavement as a whole is in excellent condition today It was only with a hope that we could come nearer to perfection in building this type of surface and eliminate a certain amount of maintenance that this experimental work was undertaken We hope that by stressing certain imperfections we have not undermined your confidence in a type of pavement that is giving fine service in thousands of communities today.

AN EXPERIMENTAL ROAD OF CEMENT BOUND MACADAM[1]

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[Condensed[2]]

Resumption of construction of cement bound macadam after a dormant period of nearly two decades, disclosed a lack of knowledge of

[1] This report was presented through the Committee on Design as information on the development of an interesting type of road construction No conclusions or recommendations are offered by the Committee

[2] A more detailed report of this investigation was published in Engineering News-Record, February 15, 1934 Volume 7, page 230