New Developments in Pavement Jointing

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SINCE the word "new" is purely relative, this paper reviews briefly some more-or-less ancient history on concrete pavement construction in Michigan to show how past procedures have led to new developments which are presently in vogue. These, in turn, will later show some deficiencies which, through research, will result in the use of new materials and techniques for pavement joint construction in the road of tomorrow. For proper continuity, this discussion of pavement joints is broken down into three main categories; namely, past, present, and a brief glimpse of the possibilities of the future.

The first Standard Specifications on file at the Michigan State Highway Department were issued in February 1918. They specified a filler for expansion joints of an asphaltic or tar felt ¼ in. in thickness, of a width equal to the thickness of the pavement plus 1 in., and of a length equal to the width of the pavement. Spacing of the joints was to be as shown on the plans and at locations where unavoidable interruptions of the paving work occurred, with no section of the pavement less than 10 ft in length. Joint spacing, as shown on the plans, was generally at the end of the day's work. No mention was made of longitudinal joints. Variations of this design were made from 1919 until 1940 with a tongue-and-groove joint being specified in 1923. The tongue-and-groove feature was the first mention of any joint in Michigan with a load transfer function. One detail which would hardly receive approval now was a requirement that expansion joint filler be trimmed off ½ in. above the pavement surface.

The 1940 Standard Specifications reveal a number of forward steps to improve the riding quality and durability of concrete pavements. For the first time, load transfer devices of the dowel bar type or equal were specified. Another new requirement was the use of plane-of-weakness joints with load transfer, except when pavement reinforcement was carried through the joint.

The requirement for longitudinal joint in concrete pavements was first adopted as a Standard Specification in Michigan in 1923. The nomenclature for this innovation was "central joint." The specification provided for a triangular strip of 16-gauge metal punched for tie bars and staking pins and placed in a vertical position on the center line of the pavement. This provision was the first effort in this state to control longitudinal cracking, which had been a contributing factor to the too-rapid deterioration of concrete pavements.

Pre-moulded asphaltic board for longitudinal joints was first used in 1929. Such joints were constructed by cutting a groove in the surface of the fresh concrete, placing a strip of filler material on edge in the groove and then restoring the surface of the concrete by hand floating. Another variation of this type of longitudinal joint was one formed by a continuous ribbon of ⅛-in. thick asphaltic felt placed in the pavement surface in the same manner as previously mentioned. Lane tie bars were used in both of these joint designs. Such pre-moulded longitudinal joints, with minor changes, endured in Michigan as a Standard Specification requirement until 1954.

It is quite apparent that the changes in pavement joint construction incorporated in the 1940 Standard Specifications reflected conclusions reached from studies of the behavior under load and also the structural effectiveness of typical longitudinal and transverse joint designs which were conducted by the U. S. Bureau of Public Roads at the Arlington Experimental Farm in Virginia in the early 1930's. Prior to the time of this research, there was an almost complete lack of data concerning the structural behavior of the existing longitudinal and transverse joint designs. Recognition of this lack made such a study almost imperative. Information was also needed regarding the effect of dowel spacing and joint width on the structural action of joints. Test procedures are omitted here, but the conclusions reached as a result are touched on briefly to show their influence on the changes in the Standard Specifications for 1940 and later years. They are as follows:

1 oints are needed in concrete pavements for the purpose of minimizing the stresses r sulting from causes other than applied load in order that the natural stress resis-

tance of the pavement may be conserved to the greatest extent for carrying traffic loads.

2. A joint is potentially a point of structural weakness and may limit the load carrying capacity of the entire pavement.

3. Joints are classified by function as (a) those designed to provide space for unrestrained expansion, and (b) those designed for the relief or control of the direct tensile stresses induced by a restrained contraction.

4. Expansion joints should be provided at no greater intervals than about 100 ft to prevent excessive joint openings.

5. The permissible unit stress of the concrete should determine the spacing of contraction joints.

6. Doweled transverse joints were quite effective in relieving stresses caused by expansion and contraction.

7. Aggregate interlock cannot be depended on to control load stresses, thus the need for independent means for load transfer in plane-of-weakness joints.

Later study on the Michigan test road verified some of these conclusions and disproved others. One notable change is the finding of the Michigan State Highway Department's Research Section that satisfactory performance of long sections of pavements under full restraint is possible without expansion joints, except at structures where excessive compressive stresses induced by expansion forces are undesirable.

Such studies resulted in the development of the design standards at the end of World War II which made provision for doweled load transfer devices using 1-in. by 15-in. round dowels supported by a wire frame. Also provided was a metal base plate at the bottom of both expansion and contraction joints to prevent the infiltration of subgrade material into the joint opening.

Bonding of concrete to the dowel bars was to be prevented by a coating of red lead or cutback asphalt, with provision for an air space at one end of the bars for expansion joints by means of a metal cap. The steel shortage in the postwar years prevented use of the metal base plate and brought into use for this purpose a substitute fabricated from a hard asphaltic board. The steel shortage also necessitated the use of No. 5 wire for the wire frame work on baskets instead of No. 3 wire, specified on the standard plans.

Several types of dowel baskets, based on the standard, appeared on the Michigan scene between 1945 and 1952. Generally, the types approved for use were field assembled and depended on tension developed between two vertical wires or loops placed at each side of the basket to hold the dowel bars in alignment, both vertically and horizontally.

After this type of joint assembly had been in use for a few years, there was trouble. Surface spalling developed immediately adjacent to joint openings and progressed rapidly to the point where, in many instances, concrete was completely crushed. Study of the failed joints disclosed that the main responsibility for the failure rested on two or three of the following factors:

1. Misalignment of the dowel bars vertically or horizontally due to basket weakness.
2. Locking of joints because of improper coating of bars prior to placement.
3. Locking of joints caused by infiltration of water. This problem resulted from the failure of joint seals in adhesion, cohesion, or both. The subsequent corrosion increased friction to the point where movement was no longer possible.
4. Careless placement of the dowel assembly during construction.
5. Infiltration of soil into the joint opening at the sides and bottom of the slab due to the rupturing of the substitute base plate material.

Drastic changes in transverse joint design were necessary at once to remedy the problem. During the winter of 1952 a dowel basket assembly, fabricated in accordan with a modification of an assembly supplied by the Bethlehem Steel Company, was approved. The new design was superior in many respects to the one previously used. The base of the new basket was 6 in. wider than the 1945 model, providing greatly increased stability. Dowel length was increased to 18 in., with bars of $1\frac{1}{4}$-in. diameter, in accor ance with recommendations of the Research Section. The basket was also constructe 0-gage wire instead of the No. 5 wire previously used. To quickly implement use o he new basket, the Department made direct purchase of the assemblies for a number of projects constructed during 1953.

Easing of the steel shortage released material for a durable base plate to prevent infiltration of earth into the bottom of transverse joint openings. Here again, during the first season the improved device was used, the Department supplied the item by direct purchase. The Bethlehem basket design made provision for the center wires of the basket to straddle the base plate parting strip and hold it in proper position during concrete placement.

This combination has proven far superior to the joint assembly previously used. Dowel alignment has been greatly improved and delays in paving operations to permit correction of improperly placed basket assemblies are negligible.

Since 1953 the Research Section of the Testing and Research Division has developed test procedures to determine whether or not baskets of various designs meet minimum requirements. Recently, baskets fabricated by five different manufacturers have been approved for use.

Since 1953, longitudinal joint design and construction procedures have been subjected to scrutiny and drastic changes have been initiated. One change involved elimination of the use of bent tie bars at formed joints. Instead, hook bolts consisting of two pieces of 9/16-in. steel, each threaded at one end and fastened together by a coupling, are now specified for this purpose. This change has resulted in positive placement of lane ties and has completely eliminated breakage of tie bars while straightening them out prior to pouring the second lane.

Another design change substituted sawed longitudinal joint construction in place of the pre-moulded type long used. It had long been realized that the placement of pre-moulded joint material involved working concrete back into the groove, which had attained initial set. This practice induced spalling and also resulted in rough surface areas adjacent to the joint. Sawing of center joints was tried experimentally on a few projects during the 1954 construction season, with results so gratifying it was made standard in 1955.

It has been apparent for some time that sealing of transverse joints with rubber asphalt compounds has resulted eventually in almost complete failure of the seal, either in adhesion to the concrete, cohesion within the seal itself, or a combination of the two.

A meeting attended by representatives of the Research Section, the Construction Division, and by individuals employed by all concerns supplying rubber asphalt sealing compounds for use in Michigan, explored ways and means of overcoming joint seal failures. One fact developed during the discussion was that the character of materials used in manufacturing the rubber asphalt had changed due to the development of synthetic rubber and the nearly complete disappearance of natural rubber from the reclaimed rubber supply. It was felt that this factor might be significant, because rubber asphalt compounded with natural rubber and used for pavement joint sealing on the Michigan test road in 1940 was still in excellent condition in 1950.

Thus, it seemed that a research project for joint sealing might possibly provide the answers for the problem at hand. Deputy Commissioner-Chief Engineer C. A. Weber promptly approved a recommendation for a test section of new concrete pavement to permit the study and evaluation of the performance of rubber asphalt joint sealing compounds. The project chosen for the test was a 10-mile section of four-lane divided highway on US 27 and M 78 between Lansing and Charlotte, conveniently located both to the Lansing office and the research laboratory. Supplemental specifications covering the joint sealing test sections were included in the bidding proposal. One roadway of the project was completed during 1956 and the second roadway is to be completed prior to July 1, 1957. Studies are now underway on the sealing completed during 1956, but to-date results have not been tabulated.

Five series of materials were used for the test sections. Included in this group is a newly developed hot-poured rubber asphalt which pours at temperatures 25 to 30 F lower than that now specified. Second, material conforming to Federal Specification SS-S-164 was introduced for control purposes. The third series included so-called hot-poured type compounds costing considerably more than materials currently used. If successful, however, the increased costs can easily be justified. The fourth series included cold applied joint sealing compounds meeting current Michigan specifications. Previous attempts to use this type of sealing compound for transverse joints have met with only mediocre success. The fifth type included two-component, jet fuel resistant, cold applied seals, and also a hot-poured material with which a primer was required. Test results should prove most useful in providing answers to problems in regard to sealing transverse joints.

Another innovation during the 1955 season was the use of jute to caulk the formed joint groove. This was placed the day after the pavement was poured. The purpose of the jute was twofold: (a) preventing the infiltration of small stones and dirt into the contraction crack below the joint groove, and (b) permitting delay in sealing joints until all earth moving and shouldering operations adjacent to the pavement had been completed. This procedure tends to prevent the formation of small areas in the joint crack where intense pressures might develop with damage to the concrete, and also reduces contamination of the sealing compounds while the material is curing. Later developments in forming joints have practically eliminated the use of jute for this purpose.

Experimental sawing of a ½-in. by 2-in. groove for contraction joints was also tried during the 1955 season. Excellent results were obtained, with no random cracking developing in the slabs in the test section. The sawing was accomplished with a standard self-propelled concrete saw using two diamond blades of ⅛-in. and ¼-in. thickness with a spacer between the blades.

Two obstacles appear to prevent adoption of this method for grooving joints. One is the cost of approximately $0.50 per lineal foot of joint; the other, the danger of uncontrolled cracking, especially critical in the 99-ft slab length used in Michigan.

Another experiment tried on the same project was the use of strips of ½-in. by 2-in. Styrofoam and ½-in. by 2-in. corrugated paper board to form contraction joint grooves. The results attained indicated that the method had possibilities for improving joint construction. The objective of the experiment was to find a substitute for sawed transverse joints at a reasonable cost and without the risk of random cracking. The Styrofoam method appeared to achieve both aims.

The materials were placed in the pavement surface in a groove formed by a T-shaped bar having a 2½-in. vertical leg. The joint material was placed immediately in back of the longitudinal float and ahead of hand-finishing operations. After placement, the surface of the concrete adjacent to the joint was restored to a smooth condition by the use of 5-ft floats and 10-ft straight edges.

Concrete saws were used on the experimental joints to remove both Styrofoam and corrugated paper, but it was discovered that the Styrofoam could easily be removed with hand tools in much less time than required for sawing. Corrugated paper was more difficult to cope with, both with saws and hand tools.

The consensus of departmental observers was that the Styrofoam method appeared to warrant additional installations. Data on riding quality, obtained by the Research Section, furthered this belief. Comparisons made of profilometer readings taken on joints formed in the normal manner, sawed ½-in. transverse joints, joints formed with Styrofoam, and those formed with corrugated paper, were as follows:

Type of Joint	Average Profilometer Reading
Normal	5.17
Sawed	1.56
Corrugated paper	3.95
Styrofoam	1.67

The readings given are weighted, with $\frac{1}{16}$ in. counted as 1; ⅛ in. as 4, and ¼ in. as 16.

Some 150 miles of concrete pavement have been constructed during the 1956 season using Styrofoam for forming joints. Results have varied somewhat from job to job, but in general have shown a two to one improvement in joint riding quality over those formed with a steel mandrel.

Some objectionable features have also developed and must be overcome. One is spalling, which occurs on some projects on the side of the joint away from the direction of paving. This trouble appears to arise from the deposit of mortar by the burlap drag as it is moved across the joint surface. Placement of Styrofoam with the upper edge not less than $\frac{1}{8}$ in. below the pavement surface seems to be the answer to this problem and also minimizes the possibility of tipped joints. Concrete consistency must be maintained at between $1\frac{1}{2}$- and $2\frac{1}{2}$ in. slump to overcome the tendency of the material to float. Refinements in installing devices currently underway should also assist in overcoming these problems.

Another problem in joint construction currently being given increased attention is the "freezing" of joints due to bond between the concrete and load transfer bars. Michigan is experimenting with bars coated with various materials to decrease friction between bars and concrete. These materials range from lubricants to stainless steel sheaths, but no conclusive test results are yet available.

Erosion of concrete around the load transfer bar is another problem undergoing scrutiny, with no cure presently in sight.

The perfect transverse joint is a goal still unattained, but the challenge to develop such a device is great. The "Model T" age still prevails in pavement joint construction.