Joint Construction in Concrete Pavement

GORDON K. RAY, Manager, Highways and Municipal Bureau,
Portland Cement Association

Research and design engineers have developed a vast storehouse of information on performance of various types of joints in portland cement concrete pavements. The performance of such joints depends to a large degree on the type and quality of their construction. Careless construction practices or incorrect methods of construction resulting from a lack of knowledge of the joint function results in pavements with below standard riding characteristics and maintenance problems. Correct construction procedures for various joint types are outlined and illustrated. Installation of dowels, tiebars and expansion joint fillers is explained.

● DURING THE last two decades, design engineers, research engineers and materials engineers in our highway departments have learned much about the performance of joints in concrete pavements. Laboratory studies, experimental pavements and condition surveys of existing pavements have enabled them to design and specify simpler, better joints for concrete. Construction engineers have not always attached sufficient importance to the precision of joint construction methods to assure that they will function as designed.

There are four general types of joints in use today, each with a different purpose. All will perform properly in pavement if they are properly constructed. To insure proper construction of joints, the construction engineer, the resident and the inspector should understand their function. If they understand how a joint should work and why the design engineer selected a particular type of joint for a particular location, they will do a better job of construction supervision. If they in turn explain to the contractor's personnel how a particular joint will function, it is more apt to be built as planned.

The four joint types, their purpose and design will be discussed. Then each joint type is taken up and satisfactory construction procedures outlined. In some cases there may be several different methods of construction which will produce a suitable joint. Wherever possible more than one acceptable method will be discussed.

JOINT TYPES

All concrete pavement joints can be grouped into one of the following general types: longitudinal, contraction, expansion, and construction. Each has a different but specific function if the pavement, highway or airfield is to give the most satisfactory performance under traffic. All joints connect individual slabs to form a pavement and all permit some type of movement. Slab edges represent structural weaknesses in the slab and joints must be designed to strengthen these edges and prevent differential vertical movement. For this reason nearly all joints are provided with some type of load transfer between slabs.

Longitudinal center joints are joints in the direction of paving and are provided in all street and highway pavement built in lanes over about 15 ft wide. They are also used in some airfield pavement but may be omitted in thicker pavements by some engineers. These center joints are intended to relieve the transverse stresses which develop from wheel loads and slab curling or warping due to moisture and temperature differentials in the pavement and variable subgrade support resulting from soil swelling or shrinking.

These center joints are not intended to open and close. To prevent such horizontal movement they are usually provided with deformed tiebars embedded in both slabs across the joint (Fig. 1). Load transfer between lanes is usually provided by the aggregate interlock which develops below the surface groove. Some states have used a deformed metal plate for this joint to provide a keyway or tongue and groove for load transfer. Some engineers refer to these center joints as hinged joints. In some states using lane-at-a-time paving, construction joints take the place of these center joints.

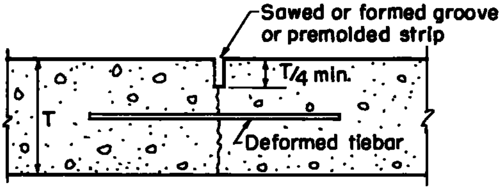

Figure 1. Longitudinal center joint.

Contraction joints are transverse joints used to relieve longitudinal stresses due to contraction as the concrete cools and loses moisture. Contraction joints also relieve longitudinal stresses due to loads and curling or warping and control the location of transverse cracking if properly spaced. Some engineers refer to these as cracker joints, plane of weakness joints, or dummy grooves. They all relieve contraction stresses in the concrete. Since contraction joints generally open somewhat as the slab cools and hardens, some space develops at each joint for later pavement expansion. If all foreign material is kept out of these openings, the contraction joints also serve as expansion joints, making regularly spaced expansion joints unnecessary.

Load transfer to strengthen transverse slab edges and prevent differential movement under traffic is provided by means of aggregate interlock or by means of dowels or other mechanical load-transfer devices (Fig. 2). The need for dowels is determined by the design engineer and is based upon joint spacing, traffic, subgrade support and other factors.

No tiebars are used, since they would prevent pavement contraction and free longitudinal movement at these joints. If dowels are provided for load transfer, they must be coated with a bond breaker to permit free horizontal movement in the pavement. Some engineers carry distributed steel or deformed tiebars through certain transverse joints and discontinue it at others. This restricts longitudinal contraction at these so-called warping joints and causes larger movement at the other joints where dowels are normally provided.

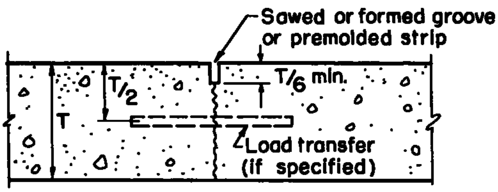

Figure 2. Contraction joint.

Expansion joints are usually transverse joints used to relieve expansion stresses in the concrete by providing room for expansion. An expansion joint is filled with a nonextruding, compressible material. The filler must have sufficient strength partially to resist horizontal slab movement but to permit such movement before crushing or buckling stresses developed in the concrete.

Engineers have found that closely spaced contraction joints provide adequate space for expansion under normal conditions and, therefore, regularly spaced expansion joints are no longer used in most pavement. They are still used, however, adjacent to most bridges and other fixed structures and at certain intersections. They may also be used in the longitudinal direction in certain wide pavement areas such as airfields to protect hangars and drainage structures from expansion stresses in the transverse direction.

In these joints, the expansion filler prevents aggregate interlock from serving as load transfer so dowels or other load transfer devices must be provided between slabs (Fig. 3). These dowels must be free to slip in the concrete to permit horizontal movement in the joint. A recess or socket must be provided at one end of the dowel equal to the thickness of the filler if the joint is to be able to function properly. In some cases where dowels are not used as load transfer devices at expansion joints, the slab edges adjacent to the filler are thickened at this location. While this design may provide the extra strength usually furnished by dowels, it does not prevent differential vertical movement at the joint.

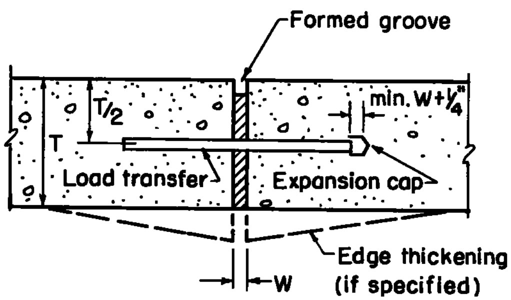

Figure 3. Expansion joint.

Construction joints are transverse header joints put in at the end of each day's run or longitudinal joints between lanes of multiple lane pavement. The purpose of such joints is to divide large pavement areas into convenient sizes for paving. Longitudinal construction joints are usually provided with deformed tiebars or tiebolts to prevent horizontal movement and keyways or tongue and grooves built into slab edges to provide load transfer between lanes.

A transverse construction joint may serve as a contraction or expansion joint if its location coincides with that of a planned transverse joint. If it is to be a contraction joint, a butt-type joint is formed by the header or transverse form and dowels are used for load transfer across the joint. If the joint is to be an expansion joint, a filler is placed against the temporary header. Transverse construction joints which do not occur at regular joint locations

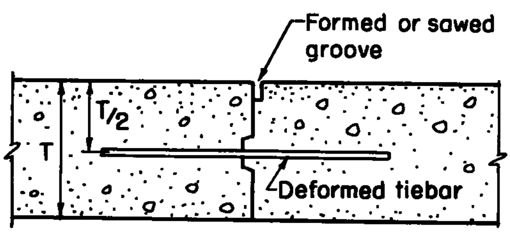

Figure 4. Construction joint.

are generally tied with tiebars to prevent movement (Fig. 4). This is imperative in multiple lane pavements. Keyways may be provided in such cases to insure load transfer since tiebars alone are not adequate for this purpose across butt joints.

CONSTRUCTION PROCEDURES

There are a number of methods of constructing each joint type which are satisfactory if proper attention is paid to each detail of construction. Some of the more common acceptable methods of joint construction are discussed. The method selected must result in a durable, smooth-riding joint which will function as intended without spalling, cracking or differential vertical movement.

Longitudinal center joints are nearly always some type of surface groove. These grooves reduce the pavement cross-section and the resulting plane of weakness in the slab will result in a crack below the groove as transverse stresses develop. The depth of groove must be equal to at least one-fourth of the slab thickness to control longitudinal cracking.

The best method of forming these grooves is by sawing the hardened concrete (Fig. 5). This may be done any time before the pavement is opened to traffic. Sawing may be done wet or dry with diamond or abrasive blades, depending on which method is more economical for the particular aggregate. Usually the center joint can be flushed out, dried and sealed immediately after sawing, eliminating a second cleaning. Self-guided saws are excellent for sawing center joints.

Figure 5.

If a premolded bituminous strip is used to form the surface groove, it must be of the proper dimension and must be vertical and flush with the surface to prevent spalling of the concrete. If it is installed ahead of the finishing machine and longitudinal float, proper alignment is difficult to maintain. If it is installed behind the mechanical finishing equipment, the surface over the joint must be straightedged to remove the bump created during the formation of the groove by a vibrating bar or cutting wheel.

Full-depth deformed metal plates have limited use today. They provide excellent load transfer through the keyway provided by the plate but they must be buried slightly to permit proper finishing. If the plate is too deep unsightly spalling and raveling of the joint may result. A depth of 1/8 in. below the finished surface should be the maximum permitted.

Tiebars across the longitudinal center joint may be supported on chairs driven into the subgrade or may be inserted in the concrete just behind the spreader. This may be done by hand using a simple improvised device or automatically by a wheel which inserts the bars at the proper spacing as the spreader moves forward. The tiebars must be ungreased, of the proper dimensions and placed at the proper intervals shown on the plans. Absolute accuracy as to level and alignment is not critical with tiebars.

Contraction joints are also of the surface groove type. Since these transverse grooves relieve longitudinal contraction stresses which develop during early slab hardening and cooling, while the concrete is relatively weak, the reduction in cross-section does not have to be so great as in longitudinal center joints. Experience has shown that a depth of groove equal to one-sixth of the slab thickness will generally control all transverse cracking.

The best method of forming these contraction joint grooves is by sawing the hardened concrete (Fig. 6). Since contraction stresses develop as soon as the concrete hardens, these joints must be sawed very early. The exact time of sawing depends upon the type of aggregate, curing, meth-

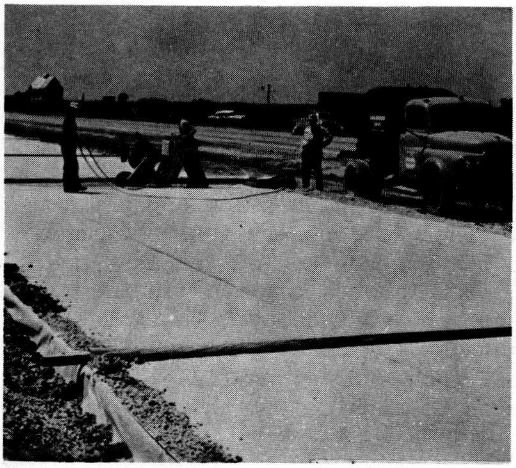

Figure 6.

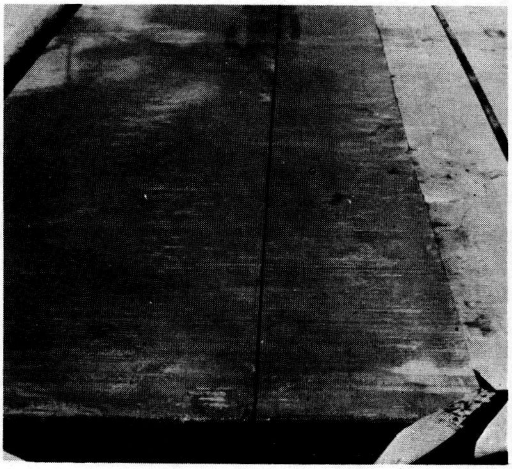

Figure 7.

Figure 8.

Figure 9.

od, cement factor and weather (Fig. 7). Generally all joints should be sawed as soon as possible without damage to the surface. A slight amount of raveling is permissible and desirable since it gives the operator a good gauge of his timing (Fig. 8). If there is no raveling at all, the concrete is too hard and cracks may develop ahead of the saw. All joints should be sawed in succession to provide the plane of weakness at the time of maximum contraction and before the slab gains too much strength. This will insure cracking and uniform opening at all joints. Sawed joints should be thoroughly flushed out immediately after sawing to remove all residue (Fig. 9).

The location for sawing transverse joints may be marked by snapping a string line on the concrete during final finishing operations. The choice of saw blade type and the decision to saw wet or dry should be based on economy and will depend on many local factors. The width of cut should be a decision for the design engineer based on joint spacing and anticipated joint opening. If a crack should develop at the approximate joint location, or if the slab cracks ahead of the saw, sawing should be omitted at that joint location. The crack will function as a contraction joint.

In some areas where very hard coarse aggregates are used, sawing costs may be prohibitive. In these areas, preformed inserts are frequently specified to reduce sawing costs. These inserts may be made of corrugated, paraffin-treated paper or premolded bituminous strips similar to expansion joint fillers. Boards of cane fiber with a low asphalt content have been most successful to date. Those strips are inserted in a groove formed by vibrating a T-bar into the surface behind the last mechanical finishing equipment (Fig. 10). The insert is placed in the groove slightly below the surface and then the surface over the joint must be finished with a scraping straightedge. A crack will develop below the insert since it functions as a surface groove. A fine crack will also develop above the insert which serves as a guide for the saw oper-

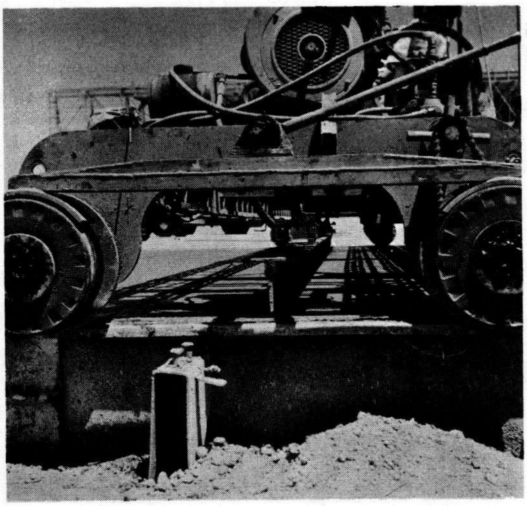

Figure 10.

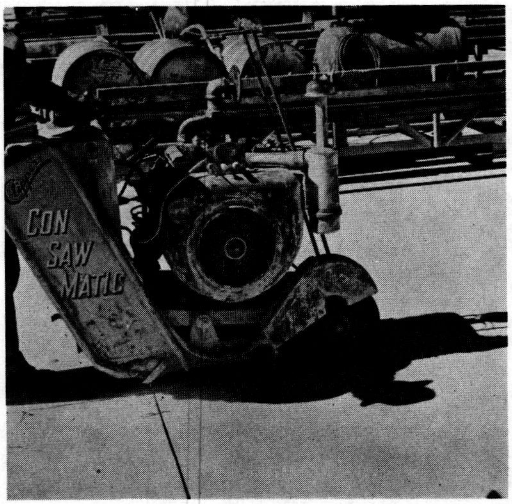

Figure 11.

ator. The sawing out of the insert can be done dry using an abrasive-type blade slightly wider than the insert thickness to remove all paper from the sides of the joint. If bituminous impregnated strips are used, only the top 1 to $1\frac{1}{2}$ in. need be removed for sealing. This type of joint acts as positive crack control and sawing can be delayed until after all paving is completed and the contractor is ready to seal joints (Fig. 11).

One or two highway departments use a premolded bituminous strip which is left in place without any sawing or sealing. This strip also must be placed in a groove made by vibrating a T-bar in the concrete behind all mechanical finishing. The surface over the joint must be carefully straightedged to remove any bump adjacent to the strips. These strips must be flush with the surface to be successful. They must also be vertical and continuous from form to form. If they are buried too deep, if they are tipped, or if gaps or offsets exist between strips, spalling results later.

Dummy grooves hand formed in the plastic concrete are no longer used extensively. They are difficult to build properly. Bumps, spalling and lack of durability are all too common on hand-formed joints. If they are specified, the template used to maintain the groove must be clean and well oiled after each use. It must be removed early enough to prevent damage to the slab. Hand formed joints should be edged with a wide-flange double edger and the surface must be checked with a long straightedge to insure a smooth riding joint (Fig. 12). Edging and hand finishing must be held to a minimum to prevent overworking.

Both the dummy groove and the unsawed, premolded strip types of contraction joints are more difficult to build properly than sawed joints and should only be used when sawing is not permitted. They require much more attention and inspection to insure a surface which is smooth riding and free from spalling or other defects. Overworking of hand formed joints frequently results in mortar concentrations which lack durability and strength.

When dowels are specified in contraction joints, they are generally placed in baskets or assemblies on the subgrade at the joint location prior to placement of the concrete. The baskets must be securely staked to the subgrade to prevent displacement during paving. The basket must be rigid enough to maintain proper dowel alignment and level during paving. Baskets or assemblies which are found to be inadequate must be rejected by the engineer.

Dowels must be of the proper dimensions and spacing and they must be uniformly greased or painted as specified to prevent bond and insure a free-moving joint. They must also be parallel to the centerline and surface of the pave-

Figure 12.

ment or restraint to slab movement will develop. Proper alignment can be checked at each end with a specially prepared template. Proper level should be checked frequently, using a special level with adjustable legs which can be used on the individual dowels. It is first set on the form at the joint location to adjust the legs so that the level bubble is centered. It can then be used on the dowels to determine whether they are parallel to the surface. This device should be used before concrete is placed and occasionally after machine finishing operations to determine whether or not the dowel assembly does hold the dowels in proper alignment.

To prevent unnecessary dowel displacement, some care must be taken in placing and spreading concrete. The operator should not be permitted to dump concrete directly on the dowels and workmen should not step on them during paving operations.

Expansion joints require that the expansion filler be installed vertically. It must be continuous from slab edge to slab edge with no gaps or offsets between adjacent pieces. To insure proper placement, the filler must be staked securely to the subgrade. It should be shaped to the subgrade or placed in a shallow trench to prevent any concrete from flowing under the filler. Any concrete which bridges the expansion gap will prevent free movement of the joint. If a metal keyway is attached to the side forms, the filler must also be shaped to fit this form.

Since most plans call for the expansion filler to be recessed 3/4 to 1 in. below the pavement surface, some type of installation guide or cap is normally used in construction. This may be a metal channel which fits over the filler or a wooden strip of the same width nailed temporarily to the filler. In any case, the cap is usually close to the surface so that it can be found after the final machine finishing operation. These installation caps must be removed as soon as possible, without damaging the concrete, after it has set sufficiently to prevent slumping into the groove above the joint filler.

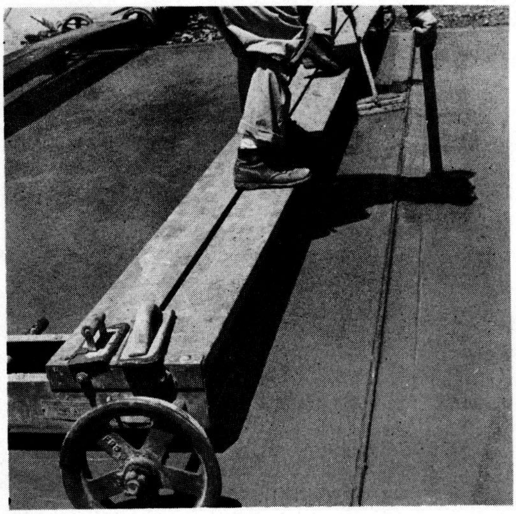

Figure 13.

The cap should be strong enough to maintain the filler in a straight line and it must be cleaned and oiled after each use to facilitate removal. It is normally raised partially to permit edging of the concrete on both sides with a wide flanged double edger and then completely removed. The groove above the filler must be carefully inspected to see that it is as wide as the filler and to insure that there is no concrete bridging above the filler. The groove should be inspected again after side forms are removed to see that there are no plugs of concrete in the expansion space. Such plugs cause spalls in the slab when the joint attempts to close.

The final operation in expansion joint construction is a careful surface check with a straightedge to see that no hump or depression has been created during the edging operation. As in contraction joint construction, any smooth surface left by the edging tool should be roughened with a broom or burlap drag to match the rest of the surface texture (Fig. 13).

Construction joints between lanes or at the end of a day's run also require some attention from the inspector if they are to function properly. Keyways are formed in the edge of the first lane by attaching a metal keyway of proper dimensions to the form at the midpoint of the slab depth. The keyway form should be oiled prior to paving to facilitate removal. If tiebars are used across construction joints, they are usually bent so that one-half projects into the first lane to be paved and the other half lies between the keyway form and edge form. After form removal the keyway is removed and the bent portion of the tiebar is straightened for embedment in the second slab. Tiebolts are made so that the first half is attached to the form by bolts. Frequently these bolts are also used to attach the keyway to the form. After forms have been removed, the second half is attached to the portion embedded in the first lane.

Specifications usually call for slab edge vibration to insure adequate consolidation along the keyway, thus creating a uniformly strong tongue and groove to provide proper load transfer. Both edges of a construction joint should be edged during finishing operations. Special care must be taken during finishing of the second lane to prevent any overhang on the adjacent lane which would spall off under traffic. To prevent this and provide a recess for sealing material along the longitudinal joint, plans should call for a definite groove at this location. Such a groove may be formed during the edging of the second lane or by sawing the groove along the joint after the second lane has hardened.

If dowels are specified across construction joints, they are normally installed by drilling holes of proper dimension in the forms at the specified spacing. The dowels then project through the form, half into the concrete and the other half outside the form. They should be supported to insure proper alignment by welding supporting brackets on the outside of the form. In doweled longitudinal construction joints, form removal may be facilitated by giving each dowel a twist before final hardening of the concrete. The half of the dowel embedded in the first lane must, of course, be properly coated with grease or paint. After hardening, the dowel can then be removed. It is replaced after completion of form removal and fine grading in the adjacent lane. Sectional dowels or plastic dummies which can be attached to the forms are now in use on some airfield projects where doweled longitudinal construction joints are specified.

SUMMARY

Construction of all joints in concrete requires attention to details. Joints are an important part of the pavement and are designed to control cracking and prevent excessive stresses from developing. They must be built properly if they are to do the job and not be a source of trouble to the motorist and the maintenance engineer. Proper joint construction should be demanded, giving the public what it pays for—smooth-riding durable joints free from bumps, spalls, and maintenance problems.