Sawed Joints In Concrete Pavements: Progress and Problems

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● SINCE the earliest days of concrete paving, joints have been formed in the plastic concrete by various means. Recently there has developed a new practice of cutting joints in the hardened concrete by means of special sawing equipment of various makes utilizing diamond or silicon carbide blades or discs. The cut is made only part way through the slab, creating a weakened plane which subsequently cracks through the full depth of the slab.

Purpose of Sawing Joints

The purpose of experimenting with sawed joints was to find a type of joint that would be smoother riding and less subject to spalling than the customary formed joints. Considerable difficulty had been experienced in many states in obtaining consistently good results with formed joints. The various processes employed to create a weakened plane, such as inserting and removing a steel bar and the hand tooling of the joints, apparently disturbed the plastic concrete in a way that weakened it and caused subsequent spalling. Also the finishing process often resulted in elevating the concrete slightly, creating bumps at the joints. The quality of a formed joint depends largely upon the skill of the workman making the joint. In contrast the sawed joint appears to have overcome these shortcomings even when the work is done by novices.

Spread of Experimentation over the States

In the past five years the practice of sawing joints has spread rapidly over the country until at least 28 states have tried it and with minor exceptions have found the new practice to their liking. Sawed joints have been tried with apparent success upon a variety of pavement designs both reinforced and plain with slab lengths from 15 to 100 feet, both with and without load transfer devices of various designs. Kansas was the first state to make widespread use of sawed joints and was the first state to develop standard specifications. Relatively few other states have had sufficiently varied sawing experience to warrant the drafting of standard specifications.

Construction Problems

While sawed joints appeared to eliminate the spalling and roughness often associated with formed joints they created new construction problems. It became apparent in the early sawed-joint projects that random transverse cracks were likely to occur unless so-called "control" joints or relief joints were either formed at intervals of 60 to 100 feet or sawed at an early age. Kansas initially elected to use formed control joints at 80 to 100 feet thereby eliminating the problem of early sawing. With their wet earth curing, to reduce shrinkage, and their 20-foot reinforced slab design, Kansas experienced no cracking between the formed control joints up to 30 days. Other states sawed intermediate joints at various times and little or no uncontrolled cracking was encountered.

Sawing Control Joints. There was a tendency for other states to follow the lead of Kansas and to form control joints in the plastic concrete rather than saw them. However, some believed that if sawed joints were superior to formed joints it would be beneficial to have all joints sawed, provided the sawing of control joints was feasible. Minnesota's experience showed that it was feasible to saw control joints and that the best procedure to assure an adequate margin of safety between the time of sawing and the time of cracking was to saw at an early enough age of the concrete to produce a slight amount of spalling and water erosion of the joint edges. Under certain favorable conditions such as (1) uniform temperature, (2) aggregates having a low coefficient of thermal expansion, and (3) curing methods having high insulating properties, the sawing of control joints may be deferred until the concrete has hardened sufficiently to prevent spalling and water erosion.

Experience in Virginia, Minnesota, Wisconsin, California and Colorado on projects utilizing sawed-control joints indicates that concrete placed in the first part of the day or up until 12 or 1 o'clock has a tendency to crack much sooner than that placed in the afternoon. The morning concrete usually cracks the first night after placing while the afternoon concrete generally cracks the second night. Consequently it appears advisable to saw the control joints for morning concrete the same afternoon or night unless weather conditions retard the setting of the concrete to such a degree as to make sawing unfavorable. The time required for the concrete to become hard enough to saw without excessive tearing has varied from 4 hours to over 24 hours. The most common way of determining when the concrete has hardened sufficiently to saw without excessive tearing is to make a very short cut with the saw and observe the condition of the joint edges. Other means are being sought to determine the earliest time when the concrete is hard enough to saw. Experience has shown that it is impractical to define the time for sawing as a specific number of hours elapsed after placing the concrete, due primarily to the influence of weather. Hot dry weather accelerates and cool damp weather retards the hardening of the concrete.

Some uncontrolled cracking has been experienced in a number of states where control joints were sawed rather than formed; but, in practically all cases when the cracks had a tendency to occur prior to sawing the control joints the trouble was corrected by sawing at an earlier age. There was one exception to this general observation: Control joints were being sawed in the early morning within the 24-hour specification limit for concrete placed the previous day and the slab was cracking through while the saw was only part was across the pavement, producing a random crack from the blade to the opposite edge of the slab. This trouble was remedied by delaying the sawing for several hours during which time the sun raised the slab temperature and reduced the tensile stresses to the point where sawing could be accomplished without danger of premature rupture. It is probable that earlier sawing in this instance, before shrinkage and contraction stresses approached the rupture point, would also have solved the difficulty. In similar situations where cracking is occurring during the sawing operation and temperatures are not expected to rise it might be expedient to reduce the depth of saw cut.

Regarding the preceding discussion of control joints it should be pointed out that the sawing was done with diamond blades which wear out much faster in cutting the green concrete than when cutting the intermediate joints in the older concrete. Consequently this system of sawing control joints in the green concrete and sawing the intermediate joints in the older concrete was preferable to consecutive sawing of all the transverse joints in the green concrete not only because of the better quality of the joint edges but also for economic reasons. It is reported that due to the sand particles working loose from the green concrete blade life in sawing control joints is reduced to approximately one-half that in sawing intermediate joints.

Consecutive Joint Sawing. In the past two years increased use has been made of reinforced silicon carbide discs, in lieu of diamond blades, for sawing concrete made with the relatively softer aggregates such as limestone and slag. It is reported that these abrasive discs permit earlier sawing of the green concrete than diamond blades and unlike diamond blades have a longer life in sawing green concrete than for sawing older pavement. Consequently the practice with silicon carbide discs has generally been to saw all joints early and consecutively.

Cost of Sawing. From an economical standpoint there appears to be a zone of aggregate hardness where the cost of sawing is approximately equal for diamond and silicon carbide discs. For relatively softer aggregates the silicon carbide is more economical and for harder aggregates the diamond is better. In some instances silicon carbide discs were used for sawing the control joints and diamond blades were used to saw the intermediate joints.

The cost of sawing joints varies over a wide range depending upon a number of variables, such as the type of aggregate, age or hardness of concrete mortar at the time of sawing, depth of cut, type of equipment and skill of operators. Reported prices per linear foot range from a low of $0.03 to a high of $0.83 and average about $0.35 per linear foot. The largest single item of expense connected with sawed joints is the blade cost, which for a 12- by ⅛-inch diamond blade averages about $150.00. Reports on various experimental projects indicate that the blade life ranges from about 400 to 6,000 linear feet and averages approximately 1,500 linear feet.

The cost of silicon carbide discs ranges from $5 to $18 per disc which is 10 percent or less of the cost of diamond blades.

Some attempt has been made to correlate blade life with aggregate hardness as measured by the percentage loss in the Los Angeles Rattler test, however the relation is inconsistent in some instances. Two states have reported that the presence of a small percentage of flint in the coarse aggregate caused silicon carbide discs to break. Apparently when a disc strikes a piece of the hard flint rock it is deflected from a straight cut and an excessive bending movement causes the disc to shatter.

A comparison between the cost of forming and the cost of sawing joints is difficult due to the wide range in sawing costs. On several projects where aggregates were relatively hard the cost of sawing was reported as approximately double that for forming joints. On numerous other projects costs for sawing and forming were estimated to be equal. Certain benefits resulting from the sawing practice are difficult to evaluate such as elimination of mixer shutdowns to allow the joint forming operations to catch up, and reduction of time between placing the concrete and applying the curing compound.

Sawing Longitudinal Joint. Some states have experimented with the sawing of the longitudinal joint as well as transverse joints. From their experience it has been found that the time interval before sawing is not critical and the cost of sawing longitudinal joints is comparable with that for sawing intermediate transverse contraction joints.

Single-Lane Construction. Most of the pavements where sawed joints have been tried were placed full width or two lanes constructed at the same time and the preceding observations apply to that type of construction only. Where a single lane is placed and the adjacent lane is constructed later a serious construction problem is presented in placing and forming joints in the second lane. If the temperature drops after the second lane has been placed, the hardened concrete in the first lane contracts and joints in it that have cracked through, open up. This movement is transferred to the green concrete slab by way of the tie bars and edge friction thereby adding external stresses to the internal stresses caused by hardening, shrinkage and temperature contraction. California experimented with this type of construction and found that at times the initial lane transmitted enough stress to the second lane to result in an uncontrolled crack before the concrete had set hard enough in the latter to permit sawing. Subsequently other states had similar experiences and some solved the problem by using formed joints in the second lane opposite every open joint in the first lane. Others due to favorable local conditions such as relatively soft aggregates and moderate temperature fluctuations have successfully eliminated uncontrolled cracking in this type of construction by very early sawing. The use of insulation applied to the surface of both lanes has not yet been reported by any state but from theoretical considerations would seem to be worth trying.

Design Problems

Joint Depth. The sawed-joint technique has not necessarily created a new problem concerning the depth of cut since the depth of a formed joint adequate to control the location of cracking will also be adequate depth for a sawed joint. There is one important difference. The cost of forming joints does not vary appreciably with the depth. Consequently it has been customary to allow a generous safety factor in specifications for depth of formed joints. On the other hand the cost of sawing varies pronouncedly with the depth. It is reported that a 2-inch cut costs over twice as much as a 1-inch cut. Several states have varied the depth of cut from 1 to 2 inches on 8- and 9-inch slabs. Due to varying local conditions the 1-inch cut was found to be adequate in some states and inadequate in others. In all instances it was reported that 1½-inch depth of cut was satisfactory for both transverse and longitudinal joints. Colorado reports that with 1-inch cuts in 8-inch slabs all the joints cracked through, but cracks of various lengths developed about 1 to 2 inches alongside of and roughly parallel to the saw cut. These cracks were from a few inches to several feet in length and would start and end at the saw cut. It is their belief that these cracks formed around the larger aggregate particles lying close to the surface. The maximum size of aggregate was 2 inches in this case. It is believed that aggregate size is a factor in determining the minimum depth of cut.

Joint Spacing. The question as to the optimum spacing of joints has been with us since the earliest days of concrete paving and the advent of sawed joints has little effect upon the problem except as related to joint width and sealing.

Width of Cut and Sealing. While sawed joints may be cut the same width as formed joints they generally are narrower being about ⅛-inch when diamond blades are used and ¼-inch with silicon carbide discs. Wider joints may be obtained by making a second cut parallel to the first and usually shallower. The intervening concrete may be broken out with hand tools. Obviously this would materially increase the cost of jointing.

Until special equipment was made available it was difficult to introduce seal material into the narrow ⅛-inch diamond blade cuts. After elimination of this difficulty there still remained the question as to whether or not ⅛-inch provided a reservoir for sufficient seal material to withstand the stretch to which it is subjected when the joints open in cold weather. One one project having 50-foot slabs joints which were originally cut ⅛ inch were measured to be ⅜ inch at near freezing temperature. This indicates a stretch of 200 percent for the seal material which is considerably above the 50 percent stretch commonly specified for seals. Opinions vary regarding the importance of obtaining a perfect seal against moisture and foreign matter possibly due to varying local conditions. Several states are experimenting with unsealed sawed joints; however available data are insufficient to warrant the drawing of conclusions. The gathering of data regarding joint openings has been greatly simplified with the advent of sawed joints. The smooth vertical faces of the saw cut make it relatively easy to measure joint widths by means of calipers or thickness gages without the necessity for casting reference plugs in the concrete as was formerly required.

Curing. The curing method used is probably of greater importance for sawed-joint construction than for formed-joint construction. The effectiveness of the curing method with regard to water retention and insulating value affects the shrinkage stresses in the pavement and is related to the time of sawing and joint spacing. Various types of cures have been used in conjunction with sawed joints and apparently successful application of sawed-joint construction is not dependent upon the use of any one type of cure as was formerly believed by some highway engineers.

Equipment

A variety of sawing equipment is available from a number of manufacturers. There are manually pushed saws with single blades and self-propelled saws having one or several blades in tandem. The relative merits of the different types have not yet been evaluated. A separate water tank is usually required to provide ample water for cooling the blade and washing the saw kerf from the joint.

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