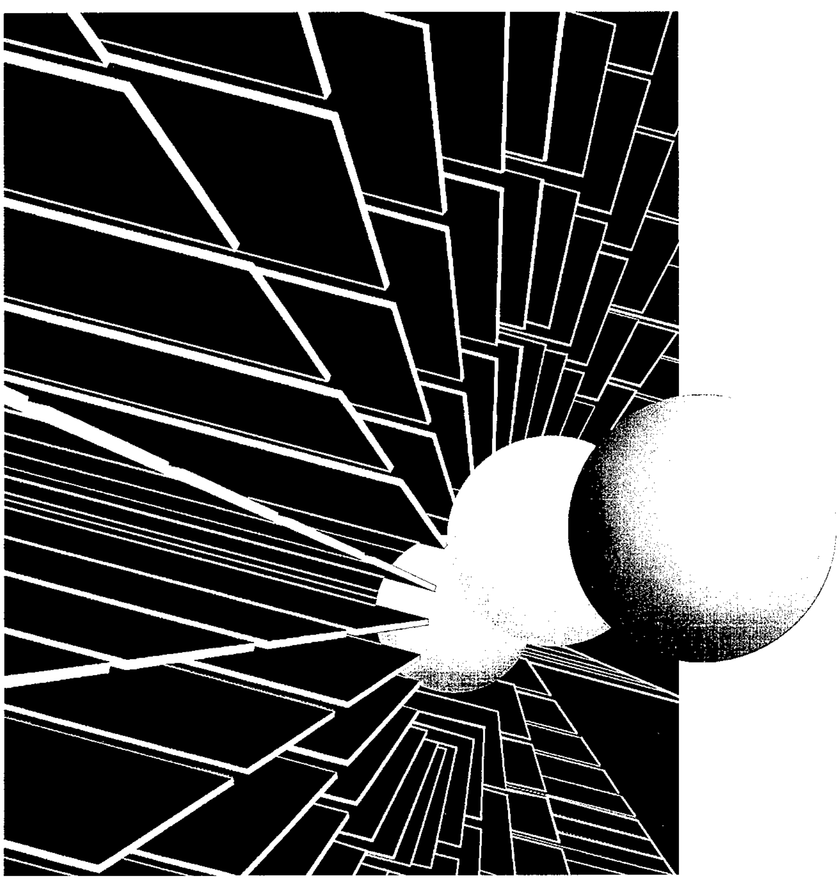
MoDOT

Research, Development and Technology

RDT 01-010

Evaluation of Early Entry Sawing of PCC Pavement

RI 99-033



August, 2001

Initial Report

RESEARCH INVESTIGATION RI99-033

EVALUATION OF EARLY ENTRY SAWING OF PCC PAVEMENT

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY

BY: TIM CHOJNACKI, P.E.

Acknowledgment to:
Jeff Joens, Senior Research and Development Technician

JEFFERSON CITY, MISSOURI
DATE SUBMITTED:
August 2001

EXECUTIVE SUMMARY

Missouri Department of Transportation standards require transverse contraction joints in concrete pavements to be sawed a minimum width of 3/8" and a minimum depth of 1/4 the pavement thickness. Longitudinal joints are required to be at least 1/8" wide and 1/4 of the pavement thickness deep. These sawed joints are cut with conventional 65hp diamond saws. According to MoDOT specifications, "sawing of the joints shall begin as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling". With conventional sawing equipment, these sawed joints are usually cut between 8 and 24 hours after concrete placement, depending on weather conditions and concrete mix characteristics.

An early entry saw is lighter than a conventional saw. Early entry sawing is a dry sawing operation, requiring no water source. The lightweight early entry saw permits sawing of the concrete at earlier ages than could be done with the heavier conventional saws. Establishing the joints earlier is believed to increase the probability that the concrete will crack at those joints rather than relieving stresses through random cracking. It is also believed that the standard joint depth of 1/4 of the pavement thickness is not necessary with early entry sawing. Joint depth of 1/10 the pavement thickness, but at least 1" is the manufacturer's recommended when using the early entry saw. Sawing can begin as soon as 1-2 hours after paving and can often be performed concurrently with paving operations.

MoDOT's first experience with early entry sawing was on US Route 60 in Wright County. Forty-two transverse joints were sawed into newly reconstructed 12" concrete pavement. The joints were 3/8" wide and 1 1/2" deep, or 1/8 the pavement thickness. These transverse joints were sawed between 3 and 6 hours after placement of the concrete. The joints cracked through sufficiently and no random cracks were observed in the pavement panels.

Because of the initial success of the early entry sawing on US Route 60, two other locations were selected to gain additional experience and to further evaluate the performance of early entry sawing. One project was located at the interchange of US 63 and US 50 in Osage County, and the other was located on US 65 in Benton County. In both instances, the sawing quality and performance of the joints has been equal to or better than the conventional sawing methods.

One early entry saw and operator was able to achieve equivalent or greater sawing production (# of joints per hour) than two conventional saws with operators.

Based on data collected from these three projects, early entry sawing of joints in concrete pavements appears to be an acceptable alternative to conventional sawing methods and should be considered as an alternate specification in concrete pavement construction. The early entry sawed joints were established under various conditions and have consistently performed as well as, or better than, the conventionally sawed joints. Joint depth of T/8, or 1/8 the pavement thickness, appears appropriate.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Stresses in concrete slabs caused by restraint, temperature gradients and dimensional changes can result in the formation of random cracks in the concrete. Random cracks in concrete pavements are a concern because they cannot be properly treated (sealed) and therefore lead to deterioration of the concrete slab.

Contraction or control joints are generally established in concrete pavements through sawing of the hardened concrete. These sawed joints create a weak plane in the slab, which promotes cracking of the slab at that plane. The joints provide the stress relief needed for the concrete while controlling the location of cracks. It is common practice in Missouri to saw transverse control joints at a 15' spacing. The sawed joints also provide a smooth wide channel in the slab that can be filled with sealant material to keep moisture and incompressible materials out of the cracks in the slab.

To establish effective joints, the concrete must be sawn at the appropriate time. Sawing too early will cause excessive raveling and may result in a marred pavement surface. Sawing too late will not provide the weak plane in time to guide the concrete to crack at that location and may result in random cracks developing in the pavement.

A number of variables play a role in determining the appropriate "sawing window". Concrete mix characteristics, base conditions and ambient conditions all affect the time the concrete should be sawed. The longer sawing is delayed, the greater chance the window of opportunity will be missed and random cracks will develop.

Early entry saws are lighter than conventional sawing equipment and some are equipped with a skid plate that reduces the amount of surface raveling resulting from the sawing operation. Because the saws are lighter, they may be used on concrete that has not yet attained the strength to withstand sawing with conventional sawing equipment. Therefore, the early entry saws are able to establish control joints in concrete significantly sooner than conventional saws. Establishing the control joints sooner is believed to increase the chance that the concrete will crack at the joint locations rather than relieving stress through random cracking.

Three projects with early entry sawing and conventional sawing were monitored to determine if the early entry sawing operation was an acceptable method for establishing control joints in concrete pavements.

OBJECTIVE

The objective of this study is to determine if early entry sawing of transverse joints in a Portland cement concrete pavement (PCCP) is an acceptable practice and if it yields any benefits over conventional sawing of transverse joints.

BACKGROUND

Missouri Department of Transportation standards require transverse contraction joints in concrete pavements to be sawed a minimum width of 3/8" and a minimum depth of 1/4 the pavement thickness. Longitudinal joints are required to be at least 1/8" wide and 1/4 of the pavement thickness in depth. These sawed joints are cut with conventional 65hp diamond saws. According to MoDOT specifications, "sawing of the joints shall begin as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling". With conventional sawing equipment, these sawed joints are usually cut between 8 and 24 hours after concrete placement, depending on weather conditions and concrete mix characteristics.

A sawing crew using the conventional equipment consists of one or more saws with operators and a water truck with a driver. Many times, such a crew has to work through the nighttime hours to perform the sawing operation, because this is when the concrete has hardened sufficiently to endure the sawing with the conventional equipment.

An early entry saw is lighter than a conventional saw. Early entry sawing is a dry sawing operation, requiring no water source. The lightweight early entry saw permits sawing of the concrete at earlier ages than could be done with the heavier conventional saws. Establishing the joints earlier is believed to increase the probability that the concrete will crack at those joints rather than relieving stresses through random cracking. It is also believed that the standard joint depth of 1/4 of the pavement thickness is not necessary with early entry sawing. The manufacturer recommends joint depth of 1/10 the pavement thickness, but at least 1" when using the early entry saw.

Early entry sawing can begin as soon as 1-2 hours after concrete placement depending on weather conditions and concrete mix characteristics. Crew size is reduced due to the fact that no water is needed, thus no water truck is required for sawing. In most cases, the sawing crew can work concurrently with the paving operation during daylight hours.

TECHNICAL APPROACH

MoDOT's first experience with early entry sawing was on US Route 60 in Wright County. Forty-two transverse joints, spaced at the standard 15', were sawed into newly reconstructed 12" concrete pavement. The joints were 3/8" wide and 1 1/2" deep, or 1/8 the pavement thickness. These transverse joints were sawed between 3 and 6 hours after placement of the concrete. The joints cracked through sufficiently and no random cracks were observed in the pavement panels. A complete letter of findings on this project is located in Appendix A.

Because of the initial success of the early entry sawing on US Route 60, two other locations were selected to gain additional experience and to further evaluate the performance of early entry sawing.

The first additional location is the ramp from US Route 63 north to US Route 50 east in Osage County. The interchange is still under construction and the ramp is currently carrying two-way traffic between Route 63 and Route 50. The pavement thickness on this project is 10" and the transverse joint spacing is 15'. The paving at this location was completed on 4/5/00 and 4/6/00. Four test sections were evaluated at this location:

- Test Section 1 pavement width ranges from approximately 10' to 22'. This section of the ramp pavement was placed next to a previously constructed section of the interchange, in which conventionally sawed transverse joints were established. This test section is tied to the adjacent pavement. The transverse joints were cut with a 20hp Soff-Cut early entry saw. The dimensions of these transverse saw cuts are 3/8" x 1 3/4", roughly 1/6 the pavement thickness. There are 31 transverse joints in this test section.

- Test Section 2 is 22' wide. This section of the ramp is not tied to an adjacent pavement. The transverse saw cuts in this section are also 3/8" x 1 3/4" or 1/6 the pavement thickness. The transverse saw cuts were made with the 20hp Soff-Cut early entry saw. There are 34 transverse joints in this test section.

- Test Section 3 is also 22' wide with no adjacent pavement. The transverse saw cuts are 3/8" x 2 1/4", or 1/4 the pavement thickness. The transverse saw cuts were made with the 20hp Soff-Cut early entry saw. There are 33 transverse joints in this test section.

- Test Section 4 is 22' wide with no adjacent pavement. The transverse joints in this test section were made with the conventional 65hp saw and are 3/8" x 3", or about 1/3 the pavement thickness. There are 34 transverse joints in this test section.

The second additional location is northbound US Route 65 in Benton County. The project consisted of upgrading a two-lane facility to a four lane divided highway. The test sections that were observed for this evaluation are located between the intersection of

US Route 65 and MO Route 52 in Benton County and the Pettis County line. This pavement is mainline pavement 12" thick and 28' wide (Two 12' driving lanes and 4' inside shoulder). Transverse joint spacing is 15'. The pavement was placed 7/10/00 and three test sections were established as follows:

- Test Section 1 contains 35 transverse joints, 3/8" wide and 1 1/2" deep, or 1/8 the pavement thickness. The saw cuts were made with the 20hp Soff-Cut saw.

- Test Section 2 contains 35 transverse joints, 3/8" wide and 2 1/4" deep or about 1/5 the pavement thickness. The saw cuts were made with the 20hp Soff-Cut saw.

- Test Section 3 contains 35 transverse joints, 3/8" wide and 3" deep which is 1/4 the pavement thickness. The saw cuts were made with a 65hp conventional saw.

The Soff-Cut saw was also used to make the centerline longitudinal joint through test sections 1 and 2. In both cases, the longitudinal joint was sawed 1/4" wide and 2" deep.

For purposes of this report, the test sections will be denoted by a combination of the route name and test section number. The test sections on the US Route 63/50 interchange are designated US63-TS1, US63-TS2, US63-TS3 and US63-TS4. The test sections on US Route 65 are designated US65-TS1, US65-TS2 and US65-TS3.

The time of paving and time of sawing were documented. Ambient temperatures were monitored from the time of paving for roughly one week after paving. The transverse saw cut joints were observed daily after paving for a week to determine when these saw cuts had developed into cracks through the pavement depth. Pavement distress surveys were conducted daily for a week to document any cracks that developed in the pavement. Table 1 includes most of the above-described data with the exception of the pavement survey data.

In March of 2001, a sample of joints that had not cracked during the initial survey period was investigated to see if, over time, cracks had developed. This investigation was only performed on the US Route 63/50 interchange because it was the "worst-case" with regard to conditions when constructed and number of joints reported as not cracked in the initial survey period.

An Internet-based review of other states' joint sawing standards, followed by an informal telephone survey, was conducted to determine if other states allow the use of early entry sawing equipment. Also determined from the telephone survey was any special conditions associated with the use of the early entry sawing equipment, such as variations from the state's standard saw cut width and depth.

RESULTS AND DISCUSSION

The early entry saw used to establish the joints for this evaluation was a Soff-Cut 20hp model. Using the Soff-Cut saw is a dry operation, eliminating the need for a water source as is needed with the conventional concrete saws. The Soff-Cut saw is equipped with a dust shield that prevents dust produced during sawing from becoming airborne. The dust is left neatly alongside and inside the saw cut. The dust is in the form of damp powder because the concrete is still green. It may be blown from the pavement with pressurized air, swept or washed with water if there is water available. The Soff-Cut saw is also equipped with a skid plate that protects against raveling. The skid plate performed well. Very little raveling was observed in the test sections that were cut with the Soff-Cut saw.

The 65hp conventional saw used in these two projects also produced good quality cuts with little or no raveling.

On both the US Route 63/50 interchange and the US Route 65 project, only one early entry saw was used to establish the joints. A single operator was able to saw 30 - 35 transverse joints with the early entry saw in 2 to 2 1/2 hours.

The conventional sawing crew on the US Route 63/50 interchange consisted of two saws, each with one operator, and a water truck driver. The water truck driver also cleaned out the joints as the crew progressed along the pavement. This three-person crew completed 34 transverse joints in approximately 3 hours. The productivity of this crew is comparable to that of one operator with the early entry saw. It should be noted that the joints in the early entry test sections (US63-TS1, US63-TS2 and US63-TS3) still needed the dust cleaned from them. With another person on the early entry crew to clean joints, it would seem one early entry saw and operator can achieve roughly the same production as two conventional saws with operators.

The conventional sawing crew on the US Route 65 project was a four-person crew consisting of two conventional saws, each with one operator, a water truck driver and a person cleaning the joints. This crew completed 35 transverse joints in 4 1/2 hours. Although the joints were cleaned, the single early entry saw operator was significantly more productive than this conventional sawing crew.

Early entry sawing can be performed as soon as the concrete can support the weight of the saw and operator without marring the final finish. In terms of compressive strength, the early entry sawing should be done between 150 psi and 800 psi. No attempt was made to measure the compressive strength on these two projects. Instead, the decision of when to start sawing was left to the saw operators, as is standard practice. The time of sawing of the test sections is located in Table 1.

The US Route 63/50 interchange was paved in April during cool ambient conditions. As can be seen in Table 1, the temperature ranged from overnight lows of around 30°F to daytime highs of around 75°F. The cool temperatures contributed to more gradual curing than is exhibited in warmer conditions. On this project, early entry sawing was started between 6 and 7 hours after paving and the conventional sawing was started between 17 and 18 hours after paving. The early entry sawing operation was stopped at approximately 7 pm, in the middle of US63-TS2, because the concrete was beginning to show slight marring due to the sawing operation. While the early entry sawing operation may have continued through the night when the concrete hardened sufficiently, the early entry operator elected to resume sawing the following morning in daylight. No sawing was done between 7 pm and 7 am. Although the early entry sawing began between 6 and 7 hours after paving, it was not completed until 18 hours after paving. For this reason, the sawing times of US63-TS2 and US63-TS3 are marked with an asterisk in Table 1. The conventional saw crew started their sawing operation 18 hours after paving.

The US Route 65 project was paved during much warmer conditions than the previous project. US Route 65 was paved in July when ambient temperatures ranged from overnight lows around 70°F to daytime highs around 95°F. Strength development of the concrete occurred much more rapidly than on the US Route 63/50 interchange. Early entry sawing was accomplished 3 to 4 hours after paving. Conventional sawing was performed between 8 and 10 hours after paving.

As stated earlier, the transverse joints were surveyed to document when cracks developed from the joint through the pavement. Because of the different ambient conditions present on each project, comparisons of crack control efficiency will only be made within each project, not between projects.

<u>US Route 63/50 Interchange</u>

Table 1 also includes the percentage of cracks that had developed at certain time periods after sawing. On the US Route 63/50 interchange project, almost all of the early entry sawed test sections (US63-TS1, US63-TS2 and US63-TS3) exhibited a higher percentage of joints that cracked at various ages than the conventionally sawed test section (US63-TS4). The exception is at seven days after sawing. The percentage of cracks that developed in US63-TS2 is slightly lower than that of US63-TS4. (38.5% and 42.9% compared to 44.1%)

The early entry sawing operation was halted for a twelve-hour period. Consequently, the sawing may not have been done at the optimum time in sections US63-TS2 and US63-TS3. This added variable somewhat confounds comparisons of crack development between sections. It appears as though the early entry sawed joints developed cracks more readily if they were tied to an existing pavement with established joints or sawed deeper. In US63-TS2, which had joints sawed around 6-7 hours and 17-18 hours, the crack development in joints was more vigorous in the part of the test section where the joints were sawed at 17-18 hours after paving.

Pavement distress surveys of these test sections at two weeks of age documented only two irregular cracks, roughly 6" to 8" in length, in one panel of US63-TS2. These were believed to be related to inadequate consolidation rather than stress relief. The absence of random cracks is considered valuable when assessing the effectiveness of the contraction joints.

The added variable of discontinuous early entry sawing somewhat confounds comparisons between sections. However, it can be stated, with regard to crack development in joints and random crack control on the US Route 63/50 interchange project, that all of the early entry sawed test sections performed as well as, or better than, the conventionally sawed test section. It can also be said the early entry sawing is sufficient for stress relief during cool ambient conditions.

Because such a low number of transverse joints were confirmed to have cracked on the US Route 63/50 project during the initial survey period of one week, a range of 41.2% to 76.5%, further investigation was conducted roughly one year after construction. Two joint locations, which were documented as having not cracked during the initial survey period, were chosen in each of the sections US63-TS2, US63-TS3 and US63-TS4. The fill material was dug away from the edge of pavement at these six locations to observe the joint at the vertical face of the pavement and determine if the crack had developed. At all six locations, a crack had developed underneath the transverse joint. No additional random cracks were observed on this project at this time. Test section US63-TS1 was not investigated at this time because the early entry sawed joints were between two conventionally sawed pavements (the previously constructed lane and the outside shoulder) and coring of the pavement was discouraged. There are no random cracks present in test section US63-TS1.

US Route 65

In general, cracks at transverse joints developed much quicker on the US Route 65 project than the US Route 63/50 interchange project. This is due to larger stress development at early ages associated with warmer conditions and faster strength gain.

One day after sawing on the US Route 65 project, about 94% of joints had cracked in the early entry sawed test sections (US65-TS1 and US65-TS2) and all of the transverse joints had cracked in the conventionally sawed test section (US65-TS3). The early entry sawed joints that were 2 1/4" deep developed cracks more rapidly than the 1 1/2" deep joints. However the 1 1/2" joints seemed to perform satisfactorily.

The longitudinal joint in US65-TS1 and US65-TS2 was established with the early entry saw. It was sawed 1/4" wide and 2" deep. There were no problems associated with using the early entry saw for the longitudinal joint. It is recommended the longitudinal joint be established in stages during the sawing operation. This requires the saw crew to establish the longitudinal joint periodically as they move along the roadway instead of waiting until all of the transverse joints are finished and then going back to saw the longitudinal joint. This process ensures that the longitudinal joint is established in the appropriate sawing window.

The two-week pavement distress survey showed no random cracks in any of the test sections on this US Route 65 project.

The performance of joints established with the early entry sawing method appears to be satisfactory. As stated earlier, establishing the joints earlier is believed to increase the probability that the concrete will crack at those joints rather than relieving stress through random cracks. Cost savings may be realized through a reduction in saw crew size, while achieving roughly the same or increased production, elimination of the water truck and sooner completion of sawing than with the conventional method. An added benefit is the reduced amount of joint sealant material required to fill a shallower joint.

On each project, a conventional saw operator was given an opportunity to operate the Soff-Cut saw. Both operators were impressed with the Soff-Cut saw and commented on its maneuverability.

The following states were contacted regarding the use of early entry sawing equipment.

Connecticut	Delaware	Oklahoma
Idaho	Iowa	South Carolina
New York	North Carolina	South Dakota
Tennessee	Washington	Wisconsin
Kansas		

These states were contacted because it was believed following an Internet search that they allowed the use of early entry sawing equipment on PCC pavements. Of these states, only Iowa has a separate standard for transverse joints sawed with the early entry saws. Iowa standards allow cuts made with approved early entry saws to be sawed a depth of 1 1/4" $\pm$ 1/4" for all their concrete pavements, including 12" thick interstate mainline PCCP. Delaware, South Dakota and Wisconsin allow the contractor to use the early entry saws with the transverse joints cut to a depth determined by the contractor. In each case the contractor is held responsible for replacement of any pavement that develop random cracks. The other states contacted would not disallow the use of early entry sawing equipment, but require the joint to be sawed at a conventional depth of 1/3 or 1/4 the pavement thickness.

Concrete mix proportions and fresh properties for both projects are located in Table 2. The Cedar Valley limestone coarse aggregate used on the US Route 63/50 interchange was Gradation D. Gradation D allows a 1" maximum particle size with 90-100% passing the 3/4" sieve. The Burlington limestone used on the US Route 65 project was Gradation A. Gradation A allows a maximum particle size of 2" with 95-100% passing the 1 1/2" sieve. The large size coarse aggregate had no apparent adverse affect on the crack development of the joints on the US Route 65 project.

CONCLUSIONS

1. The Soff-Cut saw used on these projects produced good quality joints without the presence of water to aid the sawing. In addition, very little airborne dust was visible.

2. One early entry saw and operator was able to achieve equivalent or greater sawing production (# of joints per hour) than two conventional saws with operators.

3. Crack development in the shallower, early entry sawed joints was comparable to that of the deeper, conventionally sawed joints.

4. Joint cracks developed more slowly in the pavement constructed in cool conditions. Both types of sawed joints, conventional and early entry, exhibited this slower crack development, yet no random cracks associated with the sawing technique were observed in any test sections.

5. Satisfactory crack control was observed in all test sections, including those where the early entry sawed joints were only 1/8 the pavement thickness. It was observed, however, that deeper early entry sawed joints developed cracks more rapidly than the shallower early entry sawed joints.

6. The large coarse aggregate, 2" maximum, used on the US 65 project had no apparent adverse affect on the crack development in those joints.

RECOMMENDATIONS

1. The Soff-Cut early entry saw should be allowed as an alternative to conventional sawing equipment used in concrete pavement construction. Joint depth of 1/8 the pavement thickness was successful in various conditions and should be specified with the use of the early entry saw. More conservative depths, such as 1/6 the pavement thickness may be specified initially until more data is gathered. A specification that would allow the use of the Soff-Cut early entry saw, as an alternate to conventional concrete saws, should be written

2. Actual cost information should be gathered of early entry sawing operations on projects to determine if there is a significant cost benefit due to reduced crew size and increased productivity.

3. Early entry saws produced by other manufacturers need to be evaluated in a similar fashion to determine if they meet the same quality standards as observed in this study. If these saws are acceptable, they should also be allowed as an alternate to conventional equipment.

Table 1
Test Section Details

Test Section	Dimensions of Transverse Joint	Type of Saw Used	Number of Joints	Time After Paving Joints were Established	Ambient Temp. Range from Paving to 7 days after	% of joint cracks that developed by: (from time of sawing) 1 day	3 days	5days	7 days
US63-TS1	3/8" x 1 3/4"	Soff-Cut	31	6-7 hours	30 - 75 °F	3.2%	35.5%	41.9%	51.6%
US63-TS2	3/8" x 1 3/4"	Soff-Cut	13	6-7 hours*	30 - 75 °F	0.0%	23.1%	23.1%	38.5%
US63-TS2	3/8" x 1 3/4"	Soff-Cut	21	17-18 hours*	30 - 75 °F	14.2%	38.1%	38.1%	42.9%
US63-TS3	3/8" x 2 1/4"	Soff-Cut	33	17-18 hours*	30 - 75 °F	48.5%	66.7%	72.7%	76.5%
US63-TS4	3/8" x 3"	Conventional	34	18 hours	30 - 75 °F	0.0%	20.6%	23.5%	44.1%
US65-TS1	3/8" x 1 1/2"	Soff-Cut	35	3-4 hours	70 - 95 °F	94.3%	94.3%	97.1%	97.1%
US65-TS2	3/8" x 2 1/4"	Soff-Cut	35	3-4 hours	70 - 95 °F	94.3%	100.0%	100.0%	100.0%
US65-TS3	3/8" x 3"	Conventional	35	8-10 hours	70 - 95 °F	100.0%	100.0%	100.0%	100.0%

* early entry sawing was stopped for 12 hours overnight and resumed the next morning

Table 2
Concrete Mix Proportions and Fresh Properties

	US63/50	US65
Water (lbs/cy)	220	219
Type I Cement (lbs/cy)	496	495
Class C Fly Ash (lbs/cy)	87	87
W/CM	0.38	0.38
Fine Aggregate (lbs/cy) *Class A - Missouri River Sand*	1172	1134
Coarse Aggregate (lbs/cy) *Gradation D - Cedar Valley Limestone*	1916	
Coarse Aggregate (lbs/cy) *Gradation A – Burlington Limestone*		1891
Air Entraining Agent (oz/sack) *Polychem VR*	0.79	
Air Entraining Agent (oz/sack) *PaveAir 90*		2.3
Fresh Air Content (%)	4.0	5.0
Average Slump (in.)	1.6	1.3

Appendix A

MEMORANDUM

Missouri Department of Transportation

TO: Distribution

CC:

FROM: Tim Chojnacki, P.E.
Research and Development Engineer

DATE: October 4, 1999

SUBJECT: Research, Development and Technology
RI99-033
Early Entry Sawing
Route 60, Wright County

On September 13, 1999, Jeff Joens and I traveled to Mansfield, MO to observe an early entry sawing operation that was scheduled for September 14, 1999. An agreement had been made between the contractor, the contractor's equipment supplier and MoDOT to allow early entry or "green" sawing of the transverse joints on a section of the newly reconstructed 12" PCCP. The new pavement will carry the eastbound traffic of Route 60 in Wright county.

A work plan was written outlining the scope of work, which included monitoring the sawing and performance of the transverse joints, both the conventionally sawed joints and the early entry sawed joints. We expected to monitor a 1000' section whose transverse joints were early entry sawed 2 1/4" x 3/8", a 1000' section whose transverse joints were early entry sawed 1 1/2" x 3/8" and a 1000' section whose transverse joints were conventionally sawed 3" x 3/8".

The early entry saw manufacturer representatives arrived on the morning of September 14, 1999, unaware of the above expectations. Unfortunately they did not have the equipment with them, namely saw blades, to make the number of transverse cuts we had expected. The decision was made to use the early entry sawing method (1 1/2" x 3/8") to saw as many joints as possible with the available equipment. We would then monitor those joints and an equal number of conventionally sawed joints for this study.

Following is a discussion of background, observations and conclusions made on this project. This information will be included in a report with data from future early entry sawing projects.

BACKGROUND

In recent years, lightweight saws have been developed that allow early sawing of joints in concrete. Because the saws are lightweight, joints can be cut into the concrete at an earlier age than with conventional saws. Establishing the joints earlier is believed to increase the probability that the concrete will crack at those joints rather than relieving stresses through random cracking. The early entry sawing also allows for a shallower joint depth than is required for conventional sawing. The possibility exists that the early entry sawing will be faster than conventional sawing. The concrete will be weaker at early stages, which may lead to an increase in the service life of the saw blades.

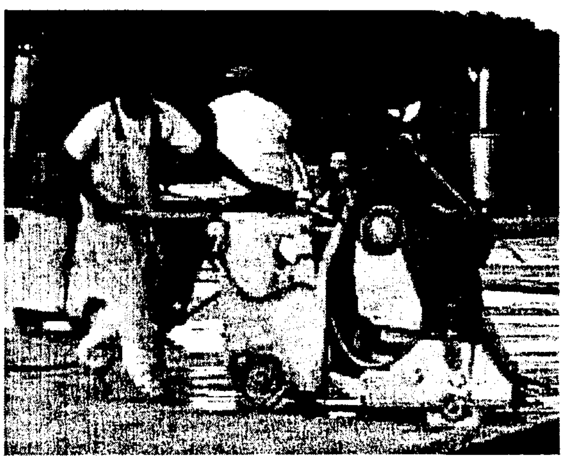
The objectives of this study were to determine the effectiveness of transverse control joints sawed with an early entry saw and to compare those transverse joints with those sawed with conventional concrete saws.

A total of 84 transverse joints were monitored for this study. Forty-two of the joints were sawed with the early entry saw, 1 1/2" deep and 3/8" wide. The sawing was performed between 3 1/2 hours and 6 hours after placement of the concrete. The other forty-two joints were sawed with the conventional saw, 3" deep and 3/8" wide. They were sawed between 8 and 9 hours after placement.

OBSERVATIONS

The early entry sawing that was demonstrated on September 14, 1999 was done with a Soff-Cut 20hp model. The early entry sawing was a dry operation that eliminated the need for a water source to cool the saw blades, as is needed with the conventional saws. The Soff-Cut saw was equipped with a blade enclosure that prevented dust from becoming airborne. The dust from the joint was left neatly alongside and in the joint. Below are pictures of both the early entry saw and the conventional saw during operation.

Conventional Saw



Early Entry Saw

The attached Table 1 includes time and temperature data that was collected on a sample of locations during paving and sawing for consideration during the evaluation of the joint performance.

The paving and sawing operations were in the direction of decreasing stations. The pavement is located in the eastbound lanes of Route 60, but was paved in the westward direction. A construction joint was located at station 210+01. The early entry sawing operation was started when the concrete achieved the desired surface strength, as determined by the saw operator. In general, the desired surface strength is achieved when the concrete can be walked on without leaving marks in the surface. In the area of the construction joint, the desired surface strength was achieved about 5 hours after the concrete was placed. Forty transverse joints were sawed consecutively from station 209+86 to 204+01, approximately 5 to 6 hours after concrete placement. Once the paving and finishing operations were well underway (away from the construction joint), the desired surface strength was achieved about 3 ½ hours after the concrete was placed. To demonstrate the joints could be sawed at this time frame, two additional early entry saw joints were cut at stations 199+66 and 199+51. Starting at station 203+86 and ending at 197+41, forty-two transverse joints were sawed consecutively with the conventional method. These conventional joints were sawed between 8 and 9 hours after concrete placement.

The quality of both types of saw cuts was good, with very little or no raveling observed after sawing. It was noted, however, the side faces of the conventionally cut joints were very smooth and had a polished appearance. The side faces of the early entry sawed joint had a rougher texture. It is possible that the rougher surface may improve the bond with the joint sealer material, although this has not been proven.

With one saw and operator, 20 transverse joints were sawed with the early entry method in 1 hour. The early entry joints would still need to be cleaned out before being filled with sealer material. Two conventional saws and operators completed 24 joints in 1 hour. A third person was on the conventional sawing crew, moving the water truck as needed and washing out the completed joints. On this project, considering only the sawing and not the cleaning of joints, it seems that one early entry saw and operator can get nearly the same production as two conventional saws and operators.

A comparison of the maneuverability of the saws used in this study is based solely on subjective criteria. The early entry saw appeared more easily maneuverable based on its size and lack of attached water lines. There are many factors, such as operator experience, that could affect the apparent maneuverability, and this study did not investigate those factors.

The attached Table 2 includes the stations for all eighty-four transverse joints, the type of joint (conventional or early entry) and the age of the joint when it was observed to have developed a crack at that joint. For every age observed, a larger percentage of the conventional joints had cracked than the early entry joints. The age of cracking and percentage of joints cracked at a certain age are indicators of the behavior of the control joints. However, the development or absence of random panel cracking is the most significant factor in evaluating the performance, or effectiveness of the control joints.

A general pavement distress survey was conducted on September 30, 1999, approximately two weeks after construction. The pavement exhibited no random cracking in the entire test section, station 197+41 to 210+01. The absence of random cracking would appear to suggest that both the conventionally sawed joints and the early entry sawed joints were effective in providing relief points in the pavement. The pavement will continue to be monitored periodically for any random cracking.

During the survey, the number of joints that had developed cracks was also updated. The two-week count of cracked joints is included in Table 2. One hundred percent of the conventionally sawed joints had cracked by two weeks of age, while about ninety percent of the early entry sawed joints had developed cracks.

Table 3 includes the mix design information for the project.

CONCLUSIONS

The Soff-Cut early entry saw used on this project produced consistent 1 1/2" x 3/8" transverse joints with nearly no dust, and without the use of water.

Early entry sawing, with one operator and saw, achieved nearly the same production on this project as two conventional saws and operators.

Cracks developed faster in the deeper (3" x 3/8") conventionally sawed transverse joints than in the early entry sawed transverse joints.

Both the conventional and the early entry saw joints appear effective in preventing random cracks from forming in 15' panels.

The performance of the early entry joints in this project warrant further study to determine long-term performance and possible cost benefits.

Additional projects are currently being reviewed to find other locations where the early entry sawing may be used and evaluated further. If you have any questions or comments, please contact me by telephone at (573)751-1040 or through LotusNotes at **chojnt**.

Attachments

Distribution: Garry Chegwidden - MA
Ken Fryer - CO
Harold Menzies - District 8

Table 1

Station	PAVING Time	PAVING Air Temp. °F	PAVING Conc. Temp. °F	SAWING Time	SAWING Air Temp. °F	SAWING Conc. Temp. °F	Type of Transverse Joint	Time of Saw after Placement
197+41	12:19 PM	78	79	8:15 PM	63	91	Conventional	7:56
198+01	12:07 PM	78	79	8:07 PM	65	90	Conventional	8:00
199+51	11:31 AM	79	76	3:11 PM	82	90	Early Entry	3:40
201+01	11:01 AM	78	76	7:33 PM	66	90	Conventional	8:32
202+51	10:30 AM	72	76	7:14 PM	67	90	Conventional	8:44
203+86	9:57 AM	66	76	6:30 PM	69	89	Conventional	8:33
204+01	9:53 AM	66	76	3:01 PM	82	92	Early Entry	5:08
205+51	9:25 AM	60	76	2:27 PM	82	92	Early Entry	5:02
207+01	8:19 AM	50	72	1:58 PM	82	88	Early Entry	5:39
208+51	7:46 AM	48	72	1:30 PM	80	87	Early Entry	5:44
209+86	7:18 AM	47	75	12:37 PM	80	86	Early Entry	5:19

Conventional joints sawed 3" x 3/8"
Early Entry joint sawed 1 1/2" x 3/8"

Table 2

Joint #	Station	Joint Type	24 hr	2 days	3 days	4 days	6 days	2 weeks
			Joint cracks developed by:					
1	197+41	C					X	X
2	197+56	C						X
3	197+71	C		X	X	X	X	X
4	197+86	C				X	X	X
5	198+01	C						X
6	198+16	C		X	X	X	X	X
7	198+31	C			X	X	X	X
8	198+46	C				X	X	X
9	198+61	C		X	X	X	X	X
10	198+76	C			X	X	X	X
11	198+91	C		X	X	X	X	X
12	199+06	C		X	X	X	X	X
13	199+21	C				X	X	X
14	199+36	C	X	X	X	X	X	X
15	199+51	E						
16	199+66	E				X	X	X
17	199+81	C		X	X	X	X	X
18	199+96	C		X	X	X	X	X
19	200+11	C				X	X	X
20	200+26	C		X	X	X	X	X
21	200+41	C				X	X	X
22	200+56	C	X	X	X	X	X	X
23	200+71	C		X	X	X	X	X
24	200+86	C	X	X	X	X	X	X
25	201+01	C		X	X	X	X	X
26	201+16	C	X	X	X	X	X	X
27	201+31	C		X	X	X	X	X
28	201+46	C		X	X	X	X	X
29	201+61	C	X	X	X	X	X	X
30	201+76	C	X	X	X	X	X	X
31	201+91	C		X	X	X	X	X
32	202+06	C		X	X	X	X	X
33	202+21	C		X	X	X	X	X
34	202+36	C	X	X	X	X	X	X
35	202+51	C		X	X	X	X	X
36	202+66	C	X	X	X	X	X	X
37	202+81	C		X	X	X	X	X
38	202+96	C	X	X	X	X	X	X
39	203+11	C		X	X	X	X	X
40	203+26	C	X	X	X	X	X	X
41	203+41	C	X	X	X	X	X	X
42	203+56	C		X	X	X	X	X
43	203+71	C	X	X	X	X	X	X
44	203+86	C	X	X	X	X	X	X

Table 2 (cont'd)

45	204+01	E		X	X	X	X	X
46	204+16	E		X	X	X	X	X
47	204+31	E		X	X	X	X	X
48	204+46	E		X	X	X	X	X
49	204+61	E						X
50	204+76	E		X	X	X	X	X
51	204+91	E						X
52	205+06	E						X
53	205+21	E		X	X	X	X	X
54	205+36	E					X	X
55	205+51	E		X	X	X	X	X
56	205+66	E	X	X	X	X	X	X
57	205+81	E					X	X
58	205+96	E		X	X	X	X	X
59	206+11	E		X	X	X	X	X
60	206+26	E		X	X	X	X	X
61	206+41	E					X	X
62	206+56	E	X	X	X	X	X	X
63	206+71	E		X	X	X	X	X
64	206+86	E		X	X	X	X	X
65	207+01	E		X	X	X	X	X
66	207+16	E		X	X	X	X	X
67	207+31	E						X
68	207+46	E	X	X	X	X	X	X
69	207+61	E						X
70	207+76	E						X
71	207+91	E		X	X	X	X	X
72	208+06	E						X
73	208+21	E						
74	208+36	E	X	X	X	X	X	X
75	208+51	E		X	X	X	X	X
76	208+66	E		X	X	X	X	X
77	208+81	E			X	X	X	X
78	208+96	E						
79	209+11	E						
80	209+26	E	X	X	X	X	X	X
81	209+41	E			X	X	X	X
82	209+56	E		X	X	X	X	X
83	209+71	E				X	X	X
84	209+86	E						

	Percentage of Joint cracks developed by:					
	24 hr	2 days	3 days	4 days	6 days	2 weeks
Conventional	31.0%	76.2%	81.0%	92.9%	95.2%	100.0%
Early	11.9%	54.8%	59.5%	64.3%	71.4%	88.1%

Table 3
Mix Proportions

Water (lbs/cy)	226
Type I Cement (lbs/cy)	488
Class C Fly Ash (lbs/cy)	86
W/CM	0.39
Fine Aggregate (lbs/cy) *Class A - Missouri River Sand*	1153
Coarse Aggregate (lbs/cy) *Gradation D - Burlington Limestone*	1916
Air Entraining Agent (oz/sack) *Polychem VR*	3.1
Fresh Air Content (%)	5.4
Slump (in.)	1.25

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
RDT01-010		

4. Title and Subtitle Evaluation of Early Entry Sawing of PCC Pavement	5. Report Date May, 2001 6. Performing Organization Code MoDOT
7. Author(s) Tim Chojnacki, P.E.	8. Performing Organization Report No. RDT01-010 /RI99-033
9. Performing Organization Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102	13. Type of Report and Period Covered Initial Report 14. Sponsoring Agency Code MoDOT

15. Supplementary Notes

The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

Contraction or control joints are generally established in concrete pavements through sawing of the hardened concrete. These sawed joints create a weak plane in the slab, which promote cracking of the slab at that plane. The joints provide the stress relief needed for the concrete while controlling the location of cracks. It is common practice in Missouri to saw transverse control joints at a 15' spacing. The sawed joints also provide a smooth wide channel in the slab that can be filled with sealant material to keep moisture and incompressible materials out of the cracks in the slab.

Early entry saws are lighter than conventional sawing equipment and some are equipped with a skid plate that reduces the amount of surface raveling resulting from the sawing operation. Because the saws are lighter they may be used to establish control joints in concrete significantly sooner than conventional saws. Establishing the control joints sooner is believed to increase the chance that the concrete will crack at the joint locations rather than relieving stress through random cracking.

Three projects with early entry sawing and conventional sawing were monitored to determine if the early entry sawing operation was an acceptable method for establishing control joints in concrete pavements. All transverse joints were sawed 3/8" wide. Conventional joints were sawed 3" deep and the early entry joints were 1.5', 1.75" or 2.25" deep. The pavements were 10" and 12" thick.

The Soff-Cut saw used on these projects produced good quality joints without the presence of water to aid the sawing. In addition, very little airborne dust was visible.

Satisfactory crack control was observed in all test sections, including those where the early entry sawed joints were only 1/8 the pavement thickness. It was observed, however, that deeper early entry sawed joints developed cracks more rapidly than the shallower early entry sawed joints.

17. Key Words	18. Distribution Statement
Early entry sawing, control joints, contraction joints, PCCP, Transverse joints, random cracks, raveling, Soff-Cut	No restrictions. This document is available to the public through National Technical Information Center, Springfield, Virginia 22161

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	25	

Form DOT F 1700.7 (06/98)