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Michael Boudreaux, P.E.

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DOTD Chief Engineer

TECHNICAL REPORT STANDARD PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
LADOTD/FHWA/06-411		

4. Title and Subtitle Evaluation of Narrow Transverse Contraction Joints in Jointed Plain Concrete Pavements	5. Report Date March 2006
	6. Performing Organization Code 98-6P
7. Author(s) Masood Rasoulian, Hani Titi, Mark Martinez	8. Performing Organization Report No.
9. Performing Organization Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	10. Work Unit No. 11. Contract or Grant No. 736-99-1022
12. Sponsoring Agency Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	13. Type of Report and Period Covered Final July 2000-December 2005 14. Sponsoring Agency Code

15. Supplementary Notes

Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This report presents the results of a research project conducted at the Louisiana Transportation Research Center (LTRC) to evaluate the performance of narrow transverse contraction joints to control cracking in jointed plain concrete pavements. In addition, the report also evaluated the early entry dry saw cutting method in crack control of jointed plain concrete pavements. Five test sections were established during the construction of a jointed plain concrete pavement on Northline Road in Port Allen, Louisiana. The first test section is 1200-ft long in which standard transverse contraction joints were created using the conventional wet double saw cut method. This section's joints were sealed. The second section is also 1200-ft long in which narrow transverse contraction joints were created using the early entry dry cut method. This section's joints were not sealed. The other test sections were 1000-ft long each in which the narrow joints were established using the conventional wet cutting method. The joints of the third test section were left unsealed, while the joints of the fourth test section were sealed without the installation of a backer rod and the joints of the fifth test section were sealed with the installation of a backer rod. Silicone was used to seal the joints in the test sections where sealing was performed. The test sections were monitored after construction for evaluation of the performance of narrow contraction joints and the development of random and controlled cracking along the investigated joint types. The monitoring program consisted of visual surveys to observe the cracking development, measurements of joint dimensions, pavement and joint distress surveys, evaluation of ride quality across the test sections, measurements of joint load transfer, and the tire–pavement noise measurements. Evaluation of the effectiveness of both joint types (standard and narrow) in controlling the random cracking in concrete pavements is presented.

17. Key Words	18. Distribution Statement
PCC paving, transverse joints, narrow joints, dry early cut	Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		65	

EVALUATION OF NARROW TRANSVERSE CONTRACTION JOINTS IN JOINTED PLAIN CONCRETE PAVEMENTS

Final Report
by

Masood Rasoulian, P.E.
Senior Pavement Research Engineer

Hani Titi, Ph.D., P.E.
Assistant Professor
Department of Civil Engineering and Mechanics
University of Wisconsin-Milwaukee

Mark Martinez
Pavement Research E.I.

LTRC Project No. 98-6P
State Project No. 736-99-1022

Conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center

March 2006

ABSTRACT

This project, conducted at the Louisiana Transportation Research Center (LTRC), evaluated the performance of narrow transverse contraction joints in plain jointed concrete pavement (JCP) as compared to the performance of joints created by the traditional wet double cut methods-typically used by the Department. The evaluation of early dry saw cutting method for creation of narrow joints is also included in this report.

Five test sections were established during the construction of a new JCP on Northline Road in Port Allen, Louisiana. The first test section's joints were created using the conventional wet double saw cut method and were sealed. The second section's joints were created using the early entry dry cut method and were not sealed. The remaining three sections' joints were created using the conventional wet cutting method. Of these three remaining sections, section 3 was left unsealed, section 4 was sealed without backer rods and section 5 was sealed with backer rods. Silicone was injected into the joints of those test sections that required sealing. Sections 1 and 2 were each 1,200 ft. long, and the remaining three sections were each 1,000 ft. long. Only section 1 had standard transverse contraction joints, all other sections had narrow transverse contraction joints.

Installation was followed by a monitoring program that consisted of visual surveys to observe cracking development, joint dimensions, pavement and joint distress, ride quality across test sections, joint load transfer, and tire-pavement noise. An evaluation of the effectiveness of both joint types (standard and narrow) in controlling the cracking in concrete pavements is presented and cost issues are discussed.

Findings indicated that the performance of the sealed narrow joints was comparable in all respects to the performance of the standard joints, with the added benefit that construction of narrow joints is less costly, less labor intensive, and less time consuming. Thus, the authors recommend that a narrow joint protocol be implemented on a statewide level to determine the full merit of the approach and to investigate the performance of narrow joints under more varied conditions. It is anticipated that a narrow joint protocol can be developed as a result of this and inclusion in the LA DOTD's Standard Specification is expected. Furthermore, implementing district level investigations will provide district engineers the opportunity to evaluate the relative merit of using narrow joints over conventional ones in their respective parishes.

ACKNOWLEDGMENTS

This research was conducted by the Louisiana Department of Transportation and Development (LA DOTD), project 736-99-1022**,** and the Louisiana Transportation Research Center (LTRC), project 98-6P. The authors would like to thank the pavement research group, Mitchell Terrell, Shawn Elisar, Gary Keel, and Glen Gore, and the concrete research group, Randy Young, and Al Mix, for their effort in different phases of the project. The cooperation of Tom Landry and Walid Shahla, Project Engineers during pavement construction, is also appreciated. The authors would also like to thank the members of the project review committee for their input, with particular thanks being given to Philip Arena, Michael Boudreaux, Samuel Cooper, and John Eggers.

IMPLEMENTATION STATEMENT

Based on the findings of this study, the authors recommend a large scale feasibility effort carried out on a number of statewide projects to determine the full merit of the approaches explored herein and to exploit those advantages where applicable. This will involve using the narrow joint concept over a wider range of conditions than was possible in this preliminary investigation. A district- or state-level effort will provide district personnel with the opportunity to evaluate the comparative advantages of narrow joints over conventional joints in their respective parishes. Once the feasibility effort is concluded, it is anticipated that a narrow joint protocol can be developed for introduction into the Standard Specification.

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INTRODUCTION

Establishing of transverse contraction joints is a necessary part of concrete pavement construction (with the exception of continuously reinforced concrete pavement). Such joints are established to control cracking that naturally occurs as concrete hardens. This cracking is inevitable and is caused by multiple factors that include the concrete's mix characteristics, environmental conditions at time of construction, and pavement age at time of joint introduction, all of which contribute to internal stresses developing as the concrete shrinks during hydration. According to the Portland Cement Association (1,2), placing concrete at high temperatures, if followed by a temperature drop in the range of from 10 to 15^{o}F or more, "may cause thermal cracks in the concrete pavement."

Making a transverse cut in a concrete pavement is required to limit the randomness of cracking. Making such a cut effectively establishes a weakened plane in the concrete, providing a path of least resistance for the stresses generated within the pavement during the shrinkage process. This allows for the controlled formation of a crack beneath the sawed joint. Load transfer devices are placed across the joints in order to provide for proper load transfer over the induced crack as the pavement is subjected to traffic. The opening initially created by sawing is later widened to allow for the placement of joint sealer materials that prevent the intrusion of water and other incompressible material into the joint. Traditionally, the appropriate cut depth and time of joint cutting are determined by practice. Figure 1 shows the elements of transverse contraction joints as used on plain jointed concrete pavements.

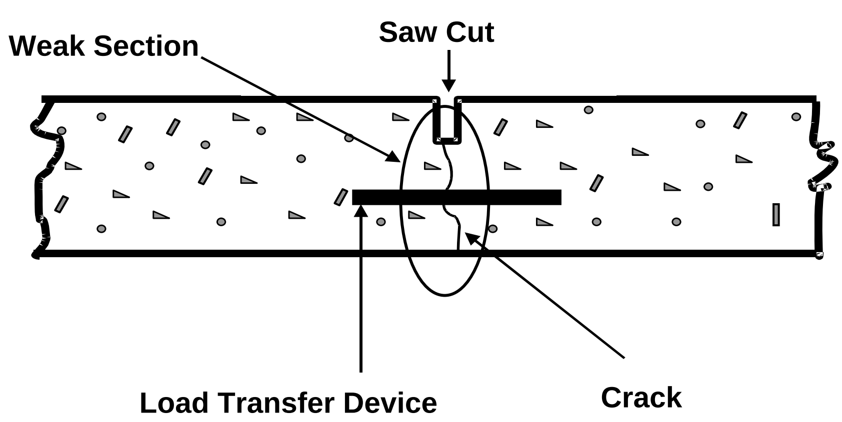
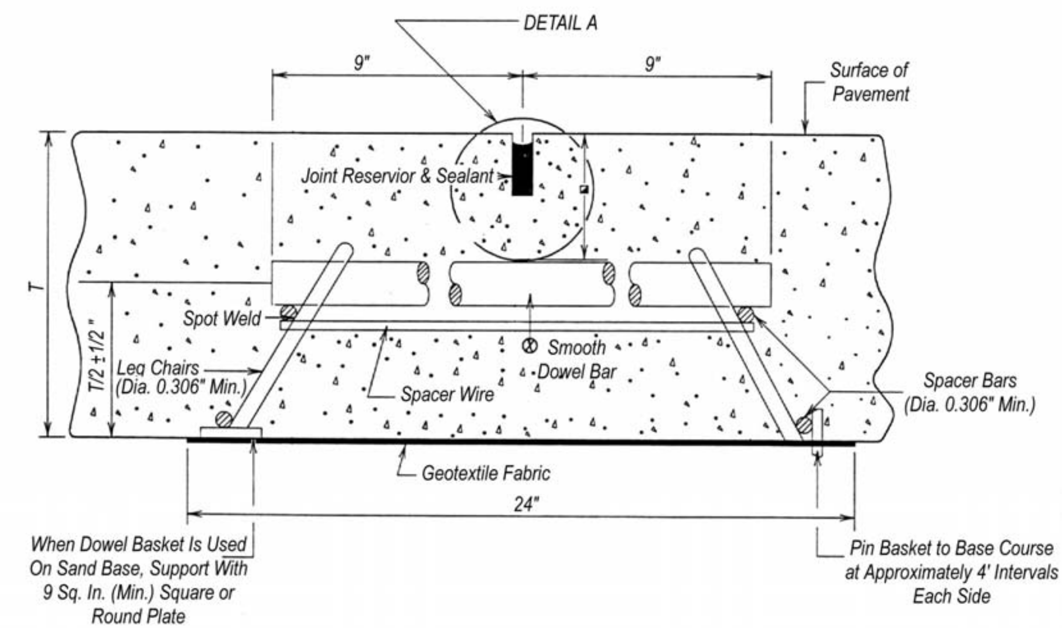


Figure 1
The elements of transverse contraction joints in plain jointed concrete pavements

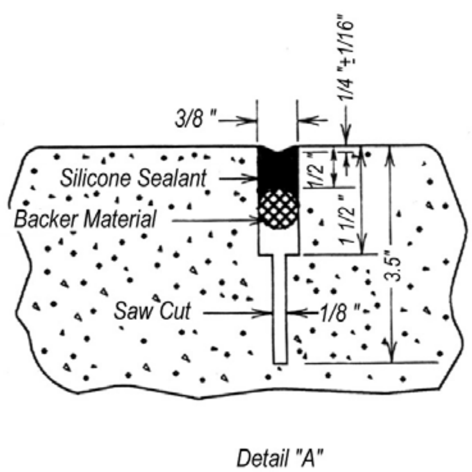
Unfortunately, the most pronounced form of deterioration observed on aging concrete pavements is typically related to problems stemming from these transverse joints. If there is a lack of joint maintenance, which involves periodic cleaning and resealing, or if there is premature sealant failure, then the possibility for the introduction of incompressible material or water into the joint increases significantly. Wide joints are particularly vulnerable to this because they can accommodate larger granular particles that have a greater capacity to impart destructive stresses to the joint walls as PCC slabs expand and contract with changing temperatures. Another problem usually associated with the older and faulted wide joints is the noise and a ride discomfort they can produce.

Such considerations have led researchers to investigate the viability of using narrower joints than State and Federal specifications normally allow. The idea of creating a thin saw cut necessary for establishing the required weakened plane has been tried or is being evaluated with great success in several states, including Wisconsin, Arizona, Colorado and Utah (3). In the typical approach, $\frac{1}{8}$ to $\frac{3}{16}$ in. wide transverse joints are created by making a single saw cut through the pavement. No secondary cut is necessary. If the joints need sealing, then the task can be accomplished with silicone at a much-reduced cost since less material is needed and backer rods may not be necessary. The investigations have shown that it is possible to develop the required weakened plane at a lower cost and in a less intrusive or labor intensive manner. The evidence indicates that there is less chance for future deterioration with narrow joints. Also, the narrow joints have been shown to produce a quieter ride. Overall, researchers have reported significant cost savings and improved pavement performance by using the narrow joints.

Other States' success with narrow joints prompted Louisiana Department of Transportation and Development (LA DOTD) researchers to consider using narrow joints in Louisiana as well. Currently, LA DOTD protocol requires the creation of non-narrow transverse contraction joints in Jointed Plain Concrete Pavement (JPCP) according to the specifications shown in figure 2. The conventional wet cut method recommends creating an initial deep thin saw cut from within a few hours to 24 hours of concrete placement.



(a) The general configuration of transverse contraction joints



(b) The most common type of transverse contraction joints

Figure 2
Transverse contraction joint used in LA DOTD jointed plain concrete pavement projects

This time period depends on a number of factors such as weather conditions and concrete materials characteristics. The LA DOTD specifications require wet initial saw cutting to achieve a joint width of $\frac{1}{8}$ in. and a joint depth of 3.5 in. on concrete pavements that are 10 in. thick. The first cut is then widened to a shallower depth a few days later to accommodate the placement of the backer rod and sealant material (usually silicone). The second cut is usually $\frac{3}{8}$ in. wide and 1.5 in. deep. Typical transverse contraction joint dimensions are shown in figure 2b.

Traditionally, policy has dictated that a saw cut from one-fourth to one-third of the slab thickness should be used to control random cracks (2). A new saw cutting methodology was introduced in 1988, called the "early entry dry cut method" (4), which stipulated that the transverse contraction joints be dry cut earlier and to a shallower depth than that required by the conventional wet cut method. This new methodology contends that its approach will effectively reduce the development of random thermal cracks in concrete pavements (5, 6). This new method initially raised concerns that the approach might allow more non-thermal random cracks to form. To avoid this risk, some specifications allow the use of the early entry dry cut method, but require that the joints be chased later using the conventional diamond saw, to increase the depth to one-fourth or one-third of the slab thickness (2).

To properly determine if the narrow joint approach would be viable in Louisiana, it was considered necessary to conduct a study within the State that would compare the narrow transverse joint approach to ones currently specified by the LA DOTD. This report presents the findings of that study.

OBJECTIVE

The objective of this research was to develop and present findings based on field investigations that would evaluate the viability of using the narrow transverse joint concept in Louisiana by comparing its performance to the performance of transverse joints created using standard approaches (conventional wet cut method, early entry dry cut method). To accomplish this, a research project was initiated by the Louisiana Transportation Research Center (LTRC) that proposed five test sections as part of a new jointed concrete pavement project built on Northline Road in Port Allen, Louisiana.

The first test section (S1) was designated as the control section. It consisted of 1,200 ft. of PCC pavement and used standard transverse contraction joints constructed according to LA DOTD conventional methods (wet double saw cut). The second test section (S2) was also 1,200 ft. long and used narrow transverse contraction joints constructed using the early entry dry cut method. And, the remaining three test sections, S3, S4, and S5, were 1,000 ft. long and used narrow transverse contraction joints constructed using the conventional method (wet saw cut). All test sections were monitored for crack development post-construction and an evaluation of the performance of joint types in all five sections is presented.

Another objective was to determine from the pilot study if the narrow joint concept would offer enough of an advantage over conventional methods to recommend its implementation on a larger scale. If it did, then the ultimate goal would be to develop and implement a narrow transverse contraction joint specification for inclusion in the LA DOTD Standard Specification.

SCOPE

The scope of this research was limited to investigating narrow transverse contraction joints in jointed plain concrete pavements and was executed on a single highway subject to actual heavy truck traffic as a pilot project. The early entry dry cut and conventional wet cut methods were used to facilitate a proper comparative investigation. Results are directed primarily at the design and construction community in the hopes that their interest can ultimately bring the Department savings in terms of labor, time, and money should the methods described become specification. This effort was intended as a pilot study and would need to be expanded to a statewide program to determine overall impact.

METHODOLOGY

Methods and procedures used to develop this research project were initiated at LTRC and were designed to achieve a threefold result: evaluate the performance of narrow contraction joints, determine if sealant is a necessary requirement on such joints, and investigate the effectiveness of using early entry dry cut narrow transverse contraction joints for cracking control of concrete pavements. This research, conducted in conjunction with the construction of a new concrete pavement on Northline Road in Port Allen, Louisiana (State project 600-21-0018) begins at the Route LA-1 service road and ends at the LA DOTD Pavement Research Facility and consisted of 1.97 miles of new jointed plain concrete pavement construction. The joints installed on the project consisted of transverse contraction type joints which utilized dowel bars for the purpose of load transfer. The new jointed PCC was built to replace an existing gravel road composed of approximately 10 inches of crushed rock that had been surfaced with a thin layer of asphalt to eliminate dust. Typical traffic is known to consist of heavy load trucks carrying steel pipes, port facility cargo, etc.

Concrete Mix Properties

The concrete mix design was conducted according to LA DOTD specifications meeting the requirements of Type D concrete paving mix. The concrete mix design called for Type IS cement with 50 percent by weight blast-furnace slag, fine aggregate, coarse aggregate with 2.5 in. maximum size, water reducer, and air entrainment agents. A computer-controlled mix plant was assembled near the site. During construction, cylinders and beams were obtained to evaluate the strength properties of the concrete. In addition, the plastic concrete properties were determined as well.

A laboratory-testing program evaluated the concrete mix properties of test specimens made at the construction site. Tests conducted were in accordance with ASTM standard procedures and included compressive strength (ASTM C39), splitting tensile strength (ASTM C496), and flexural strength (ASTM C78). The setting time of the concrete mix was established and determined under conditions similar to those in the field, and according the ASTM procedure laid out in “Time of Setting of Concrete Mixtures by Penetration Resistance” (ASTM C403).

Pavement and Transverse Contraction Joints Construction

The subgrade soil of Northline Road is mainly soft saturated clay is classified as CH (fat clay) according to Unified Soil Classification System (USCS) and A-7-6 (clayey soil) according to the American Association of State Highway and Transportation Officials (AASHTO). The water table level is close to the ground surface resulting from the site's proximity to the Intracoastal Canal and Mississippi River. Roadway construction was started by excavating the muck on the side areas. The existing roadbed, which consisted of asphaltic concrete pavement and crushed limestone, was scarified and compacted. A 10-inch-thick crushed limestone base course layer was placed on the scarified and compacted roadbed. Then, a 10-inch-thick Portland cement concrete surface layer was placed using the slip form paving method. Figures 3 through 10 show details from the construction along Northline Road, and figure 11 illustrates the constructed pavement's typical section.

Figure 3
Placement of load transfer (dowel bars) at the transverse contraction joint location

Figure 4
Slip form paver utilized during construction

Figure 5
Detail of slip form operations

Figure 6
Placement of tie bars in the finished concrete pavement

Figure 7
Finished surface of Portland cement concrete pavement

Figure 8
Creating microtexture of concrete pavement surface by use of burlap drag

Figure 9
Creating macrotexture of concrete pavement surface by tining

Figure 10
The new jointed plain concrete pavement at Northline Road

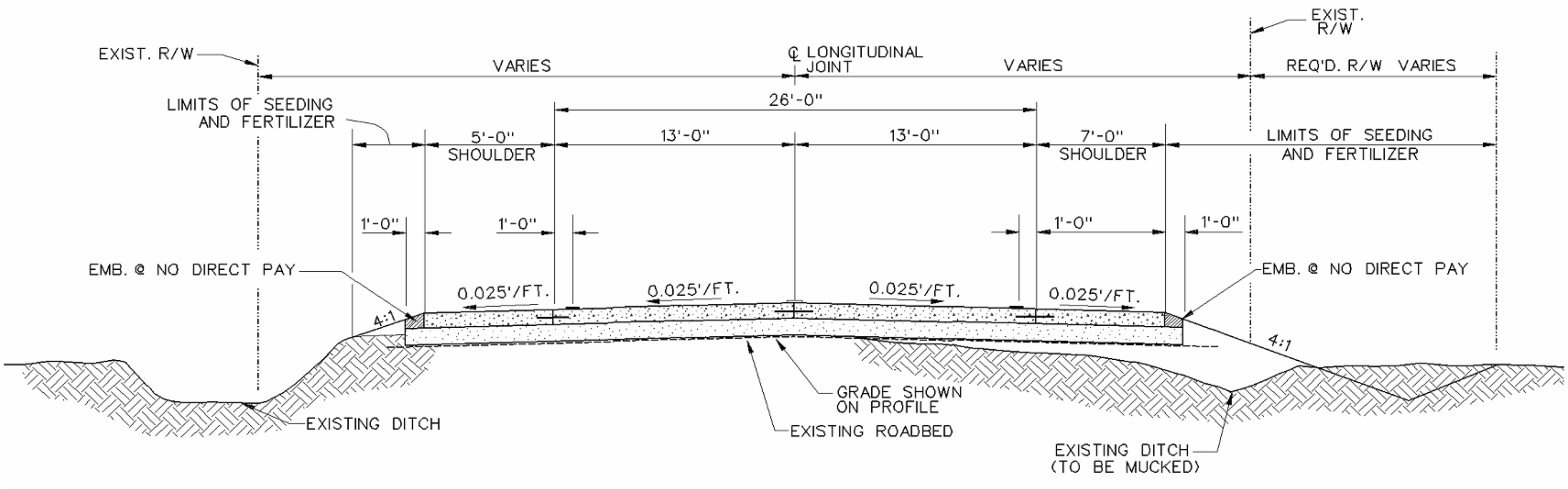
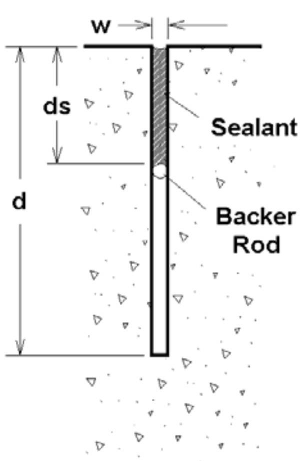


Figure 11
Typical section of the JPCP constructed at Northline Road

Five test sections, having a total length of 5,400 ft. were used to investigate joint performance. Over most of the project, the joints were created using the conventional wet cut method. Only one of the five sections had narrow transverse contraction joints installed that were cut using the early entry dry cut method. Details relating the specifics of construction are as follows:

(a) Section S1 (Control Section): the total length of this section is 1,200 ft. The transverse joint saw cut was installed using the conventional wet double cut method. The joints of this section are standard type joints. Backer rods were installed, and the transverse joint was sealed with silicone. Figure 2b shows the details of the joints created for this section.

(b) Section S2: the total length of this section is 1,200 ft. The transverse joint saw cut was placed using the early entry dry cut method. The transverse joint was left unsealed. The cut width and depth are $\frac{1}{8}$ in. and 1.5 in., respectively. (It should be noted that the S2 joints had to be deepened to 2.5 in. for reasons related to the presence of slag in the concrete mix. This was done ten days after concrete placement.) The joints of section S2 are narrow type joints. Figure 12 (row b) shows the details of the joints created for this section. Figures 13 and 14 depict the early entry dry saw being used during the cutting of the narrow joints in test section S2.



	w (in)	d (in)	ds (in)	Sealant	Backer Rod
(b)	1/8	2.5	---	no	no
(c)	1/8	3.5	---	no	no
(d)	1/8	3.5	1/2	yes	no
(e)	1/8	3.5	1/2	yes	yes

w = joint width
d = joint depth
ds = sealant depth

Figure 12
Narrow joints used in the research (sections S2, S3, S4, and S5)

Figure 13
The early entry dry cut saw used in creating the narrow joints at test section S2

Figure 14
The early entry dry cutting of the narrow joints at test section S2

(c) Section S3: the total length of this section is 1000 ft. The transverse joint saw cut was placed using the conventional wet cut method. The cut width and depth are $\frac{1}{8}$ in. and 3.5 in., respectively. Transverse joints were left unsealed. The joints of this section are narrow type joints. Figure 12 (row c) shows the details of the joints created for this section.

(d) Section S4: the total length of this section is 1000 ft. The transverse joint saw cut was placed using the conventional wet cut method. The cut width and depth are $\frac{1}{8}$ in. and 3.5 in., respectively. The transverse joint was sealed without installation of backer rod. The joints of this section are narrow type joints. Figure 12 (row d) shows the details of the joints created for this section.

(e) Section S5: the total length of this section is 1000 ft. The transverse joint saw cut was placed using the conventional wet cut method. The cut width and depth are $\frac{1}{8}$ in. and 3.5 in., respectively. The backer rod was installed, and the transverse joint was sealed. The joints of this section are narrow type joints. Figure 12 (row e) shows the details of the joints created at this section.

A plan view and cross-section for all five test sections is shown in figure 15.

Field Testing Program

A field-testing program was conducted on the pavement test sections during construction and, afterwards, during post-construction to evaluate the short term and long-term performance of the joints. The short-term performance evaluation consisted of:

(a) Conducting a visual monitoring program to observe the development of controlled cracking and the time required for the cracks to form.

(b) Conducting measurements of the dimensions of the joints after construction and during extreme hot and cold temperatures.

The long-term performance evaluation consisted of:

(b) Measurements of road profile using high-speed profiler to evaluate the ride quality of each test section. Road profile measurements to yield the

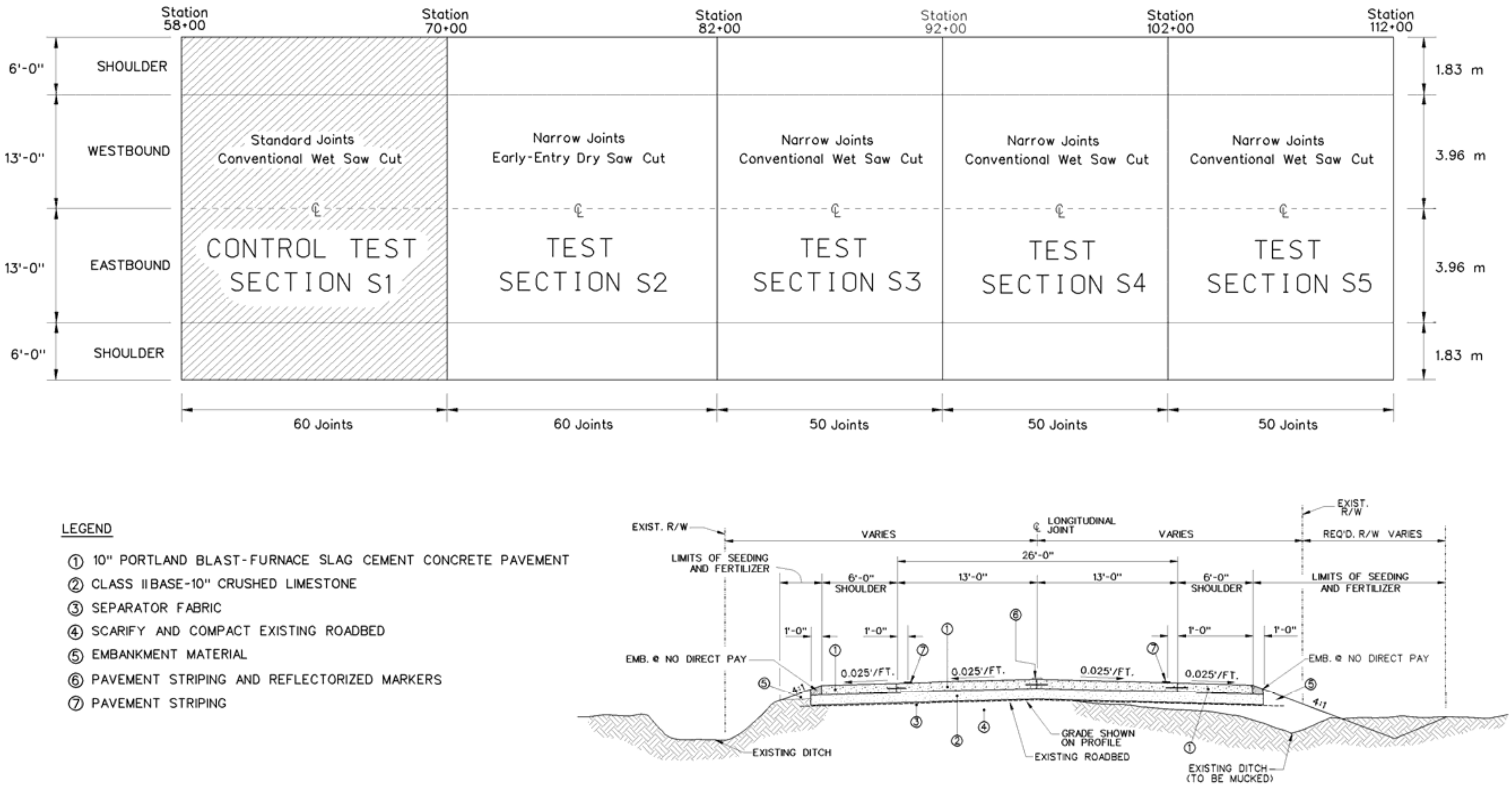


Figure 15
The standard and narrow joint test sections at Northline Road

International Roughness Index (IRI), ride number (RN), and profile index (PI) for each test section.

(b) Conducting joint evaluations twice a year during the winter and summer to measure joint width, joint faulting, and load transfer across each joint type.

(c) Conducting regular pavement distress surveys to record cracking, joint spalling, faulting, pumping, corner breaks, etc.

(d) Measurement of pavement-tire noise to evaluate the noise level across each jointed test section.

After transverse contraction joints were cut and the initial crack survey was executed to record initial conditions, a series of daily crack surveys were performed during the first week after concrete placement and every three days thereafter for one month to monitor crack development by visual inspection. Crack size was rated on an index of from 1 to 3: 1 for no cracks, 2 for hairline cracks, and 3 for large cracks.

Measurements of joint dimensions (depth and width) were recorded after pavement construction and during cold weather (38^{o}F). Monitoring the movement of these joints during the coldest temperatures provided information about the maximum width that the investigated narrow joints would exhibit.

The LTRC high-speed profiler was used to collect test section profiles. The following ride quality parameters were determined from these profiles: IRI, RN, PI with 0.2 in. banking band, and PI with 0.0 in. blanking band.

The Falling Weight Defectometer was used to conduct the load transfer measurements across the joints in the test sections.

DISCUSSION OF RESULTS

Concrete Mix Properties

The concrete mix, according to design, consisted of type IS cement with 50 percent by weight ground granulated blast furnace slag (GGBFS), fine aggregate, coarse aggregate with 2.5 in. maximum size, water reducer, and air entraining agents. Results of the laboratory-testing program that evaluated the concrete mix properties are shown in table 1 and figure 16**.** Figure 16 indicates that the concrete had achieved an average compressive strength of 4,728 psi after 28 days. The compressive, tensile, and flexural strength test figures shown in table 1 indicate that the concrete had achieved strength requirements. All testing was conducted in accordance with ASTM C39, ASTM C496, and ASTM C78. The plastic concrete properties, which consisted of slump measurements and air content measurements, met the specification requirements.

The initial setting time of the concrete was 4.4 hours with a concrete temperature of 91^{o}F. The final setting time was 6.62 hours with a concrete temperature of 99^{o}F. These temperatures were higher than the range specified in the ASTM C403 laboratory procedure (from 68 to 77^{o}F). But, they were in accordance with ASTM C989-82, which covers GGBFS cement and recognizes that the setting times of concretes containing slag will increase as the slag content increases.

Development of Controlled Cracks

The visual survey conducted 24 hours after concrete placement showed that the controlled cracks did propagate along the transverse contraction joints in both sections S1 and S2 as expected. Photographs of the cracks are shown in figure 17, where the controlled cracks can be seen underneath the conventional wet cut standard joint (test section S1) in figure 17a and where they can be seen underneath the early entry dry cut narrow joint (test section S2) in figure 17b.

Figure 18 shows the results of the cracking development surveys conducted 11 and 16 days after concrete construction for test sections S1 and S2. For the conventional wet cut standard joints 11 days after construction, 53 percent of the joints had not cracked. By comparison, 87 percent of the early entry dry cut narrow joints had not cracked. It is evident from both test sections that the rate of propagation of controlled cracking along the joints was slow. The use of cement-slag concrete mix, containing 50 percent slag, was the cause of these delays. Such delays can be beneficial for

Table 1
Results of the laboratory tests on the concrete mix used in the construction of the JPCP, Northline Road

Concrete Property	Specimen Age (day)	Strength (psi)	
		Average	Range
Compressive Strength (Compressive Strength of Cylindrical Concrete Specimens – ASTM C39)	3	3,017	2,119-3,968
	7	3,758	2,889-5,120
	28	4,728	3,948-6,158
Tensile Strength (Splitting Tensile Strength of Cylindrical Concrete Specimens – ASTM C496)	3	245	229-260
	7	368	357-379
	28	362	348-375
Flexural Strength (Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) – ASTM C78)	3	383	382-384
	7	500	485-515
	28	616	568-664

(The apparent drop in average tensile strength of 6 psi over the 28 day analysis period is considered to be negligible and indicates that there was no was no real gain in tensile strength based on specimen testing)

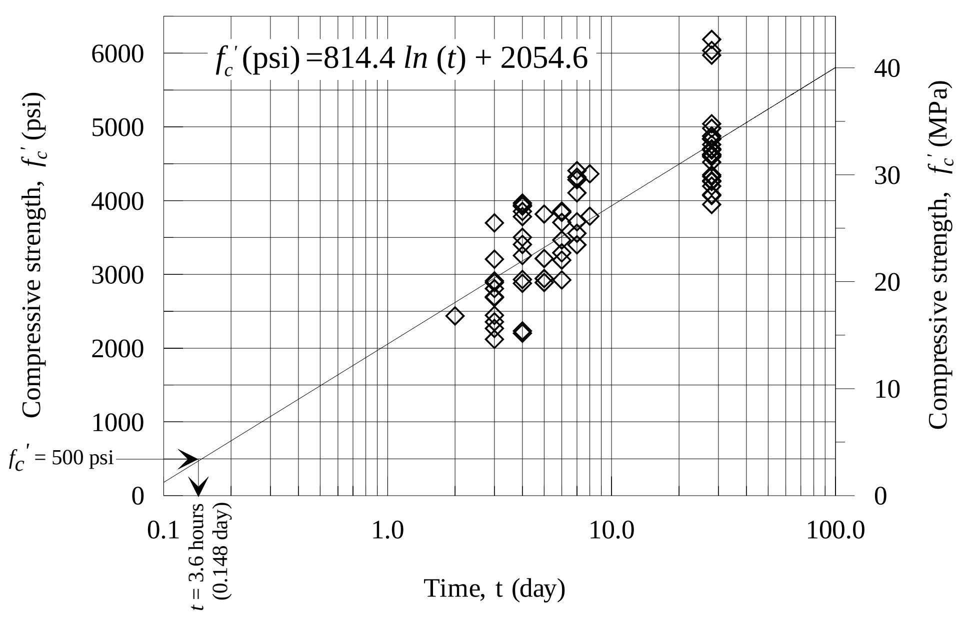


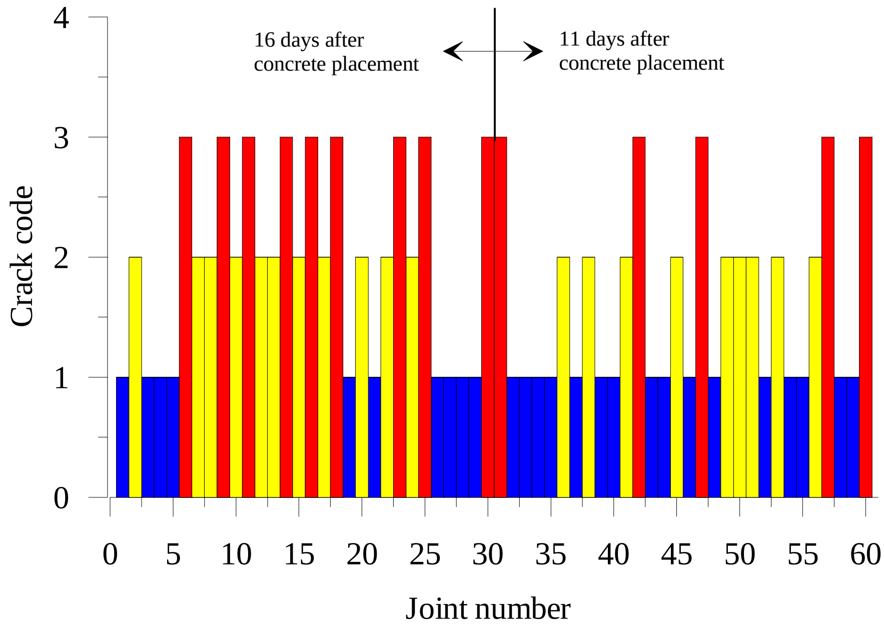
Figure 16
Compressive strength of the cement-slag concrete mix used for the pavement construction

(a) Controlled crack developed underneath the standard contraction joint at test section S1 established using the conventional wet saw cut method

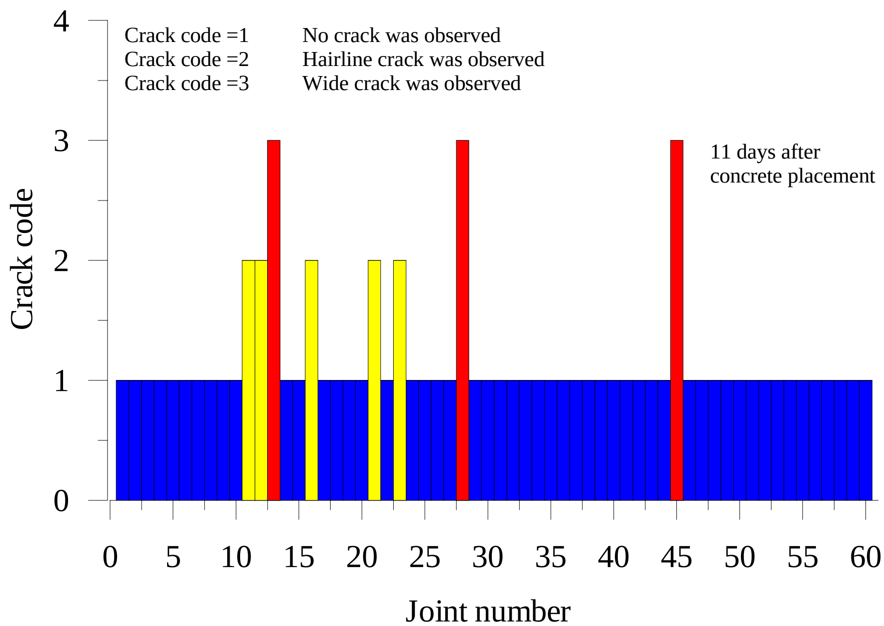
(b) Controlled crack developed underneath the narrow transverse contraction joint at test section S2 established using the early entry dry saw cut method

Figure 17

Development of controlled cracking in the investigated test section at Northline Road



(a) Control section (S1) with wet cut standard joints



(b)Test section S2 with early entry dry cut narrow joints

Figure 18
Development of controlled cracks across the transverse contraction joints

eliminating random cracking during pours in hot weather. But, the use of slow curing slag admixtures, together with the early entry dry cut method on narrow joints, had the effect of retarding the development of controlled crack formation along the S2 joints. There was a fear that the lack of controlled cracking would lead to the development of random cracking. In an effort to prevent this, the joints of section S2 were deepened 10 days after concrete pouring. This second cut (made to a depth of 2.5 in.) was not a widening cut. The S2 joints were kept narrow and the action was only taken to force the joints to crack more quickly.

The results of the cracking surveys for sections S1 and S2 are presented in Figure 19. Inspection of the figure shows that about one month after concrete construction, 100 percent of the joints monitored on sections S1 and S2 had developed cracks.

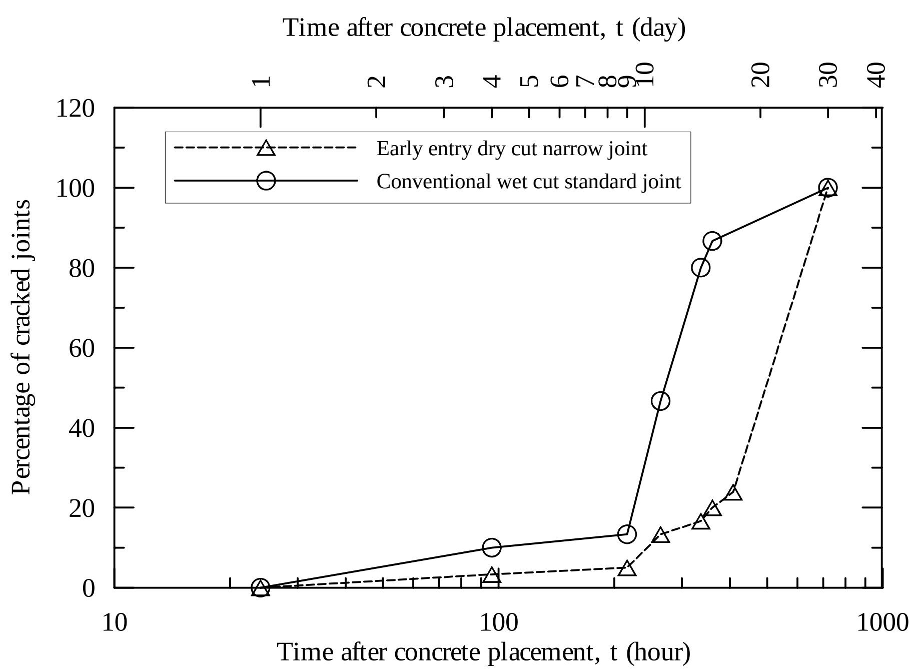


Figure 19
Comparison of the rate of propagation of controlled cracking within the investigated joint cut methods

The visual inspection conducted 6 six months after construction showed that the joints in the various sections had fully developed cracks. Figure 20 illustrates a controlled crack that developed across a narrow joint. This joint was exposed for the purpose of visually verifying crack development.

Figure 20
Verification of the development of the controlled crack across the narrow transverse contraction joints

Early Entry Dry Cut

One of the concerns with section S2 was the fear that making the early entry dry cut before the concrete had a chance to achieve final set might cause concrete raveling during the saw cutting process, which was not the case. In this study, no raveling or damage to the concrete on the early entry dry cut joints was observed. It was known that raveling of concrete due to saw cutting can be avoided by creating joints on concrete designed to have a compressive strength of

500 psi (5). Laboratory test results indicated that the concrete mix used to construct the pavement achieved a strength of 500 psi within 3.6 hours of placement, as shown in figure 16. For this reason, it was considered safe to cut at that time.

Another possible concern, related to the early entry dry cut method, was that using the diamond saw on fresh concrete might cause particle segregation in the concrete mix as the saw vibrated. In order to investigate this, core samples were taken from one of the joints on section S2. This joint developed a controlled crack 2 days after the initial 1.5 in. deep early entry dry saw cut had been made. As shown in figure 21, the controlled crack formed beneath the contraction joint and extended itself through to the bottom of the slab. It was also clear that the crack did not go around the aggregate particles but rather through them, as shown in figure 21b (aggregate particles A, B, etc.). Moreover, the aggregate particles, which were up to 2.5 in. diameter, were uniformly distributed within the concrete mass. These details provided enough evidence to show that the concrete had hardened enough at the time of diamond cutting to resist any form of particle segregation.

(a) Crack propagation underneath the early entry dry saw cut

(b) Uniformly distributed and split aggregates within the concrete mass due to crack propagation

Figure 21
Core sample taken at the early entry dry cut narrow transverse contraction joint of the test section S2

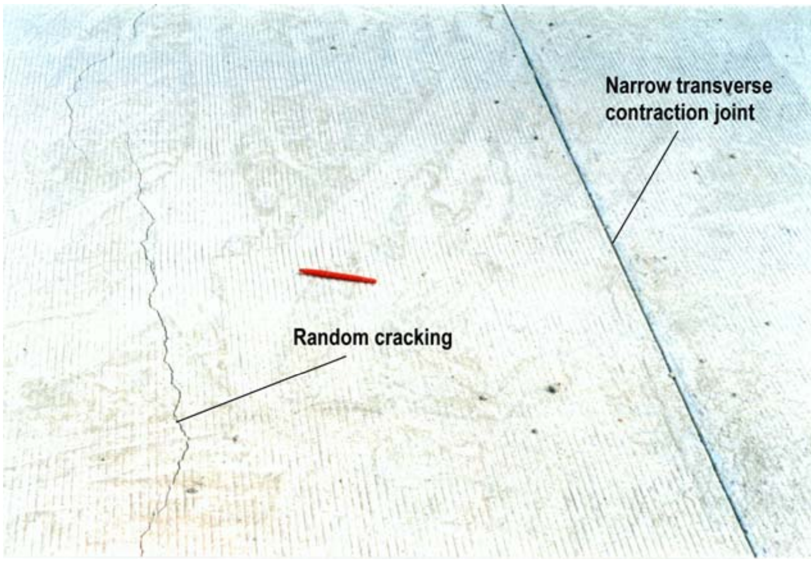
Pavement Distress Survey

Cracking surveys showed that random cracks did develop over the length of the project with time. Over the entire 1.97-mile structure, only four cases of random transverse cracks were recorded. All had formed approximately 3 to 4 ft. from nearby transverse joints. Of these four, two of the cracks were located within the early entry dry cut narrow joints test section and the other two were located within the conventional wet cut standard joints pavement section. Such an equal distribution makes it impossible to link random crack development with any particular joint type. But, it is noteworthy that those narrow joints that did develop random cracking were located in section S2 where the early entry dry cut narrow joints had to be deepened to expedite the controlled cracking process. The random cracks did not appear until after the re-cut. But, it is possible that had the S2 joints been, initially, cut more deeply then a re-cut may not have been necessary and the random cracking may not have occurred.

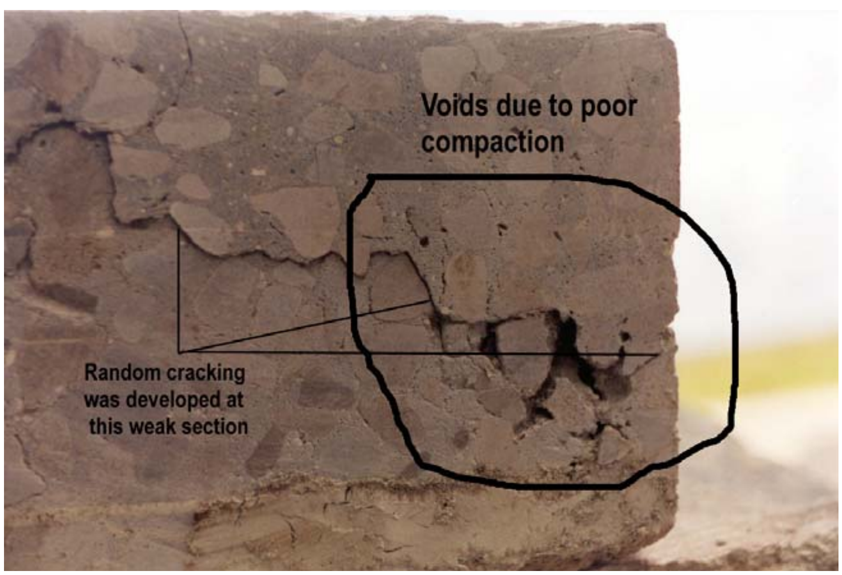
Even if this were not the case, the distribution of random cracks show that the narrow joints performed as well as the standard joints. This is to be expected because standard joints are widened only to provide a reservoir for sealant and not to help with the cracking process. Upon closer examination, researchers could suggest that the narrow joints may have performed marginally better than the conventional because one of the four random cracks, associated with a narrow joint in the early entry dry cut section, may have resulted from construction errors during concrete placement and therefore would not have been considered a random occurrence. Closer inspection of the crack, during a repair effort, showed large voids had formed within the concrete slab adjacent to the crack. Photos of this are provided in figure 22. A pavement distress survey conducted 1.5 years after construction showed that all of the pavement test sections were still in good condition.

Other observed distresses recorded as part of the survey and associated with the unsealed narrow transverse contraction joints of section S3 included some isolated cases of low severity spalling, as shown in figure 23. In addition, the section S3 joints showed signs of intrusion by a large amount of granular debris. This debris will, likely, affect future pavement performance particularly during hot temperature periods when the joints are expected to close up.

Such intrusion by debris was related to the presence of many unpaved roadways in the area that serves industrial sites adjacent to the test pavement. The mud and gravel depicted in figure 24 was tracked onto the pavement by the heavy trucks that use these facilities and is likely to cause accelerated joint failure if the joints are not cleaned and sealed.



(a) Random crack propagated in the concrete slab about 3 ft. from the early entry dry cut contraction joint



(b) Poor construction practice resulted in development of random cracking within the concrete pavement slab

Figure 22
Picture of the random cracking developed within the concrete pavement slab of the test section S2

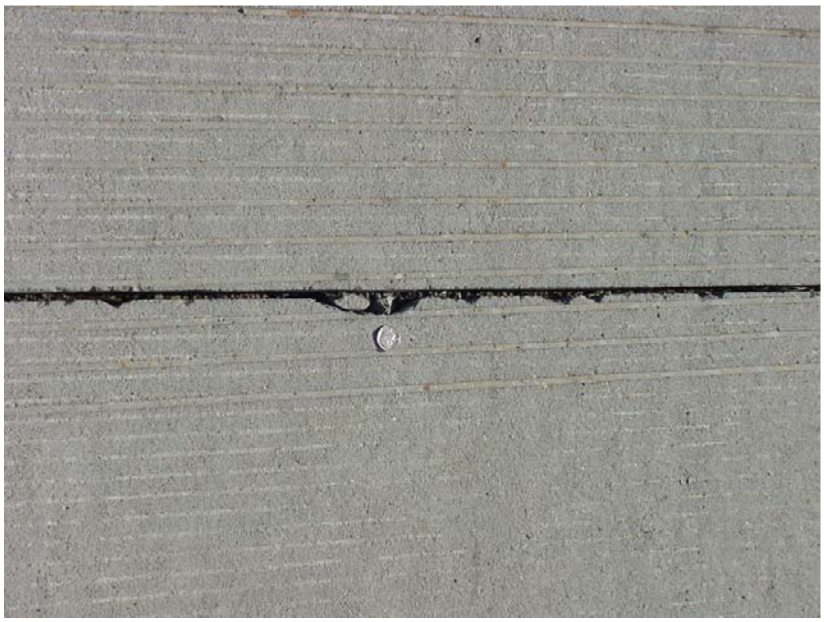


Figure 23
Low severity spalling of unsealed narrow contraction joints at test section S3

Figure 24
Debris tracked on pavement

Such conditions are not typical. But they do exist often enough in the field to raise concerns about the wisdom of leaving any joint unsealed, including narrow joints. Researchers have considered the idea of using unsealed narrow joints in certain non-critical highway conditions. There may be some monetary savings associated with this idea, but the potential losses arising from a required rehabilitation if the joints fail may make the concept an unwise one.

In August of 2002 and February of 2003, joint distress surveys were again conducted on all test sections. The numbers of joints showing spalls exceeding 5 in. were identified and recorded. A summary of the spalling survey can be found in table 2 which indicates that the narrow sealed joints showed the least amount of overall damage. Percentages were determined as number of joint exhibiting such damage divided by the total number of transverse joints in that particular section.

Table 2
Joint damage assessment

Survey Period	Control Section	Narrow Unsealed	Narrow Sealed
August 2002	7%	29%	7%
February 2003	22%	48%	16%

Evaluation Pavement Roughness

Measurement of road profile across the different test sections did not show significant differences in IRI and PI values. This is to be expected since the pavement was newly constructed, and for such a pavement is unlikely to develop joint faulting in the short term.

The average IRI for all test sections is 68 in./mile and the average ride number RN is 3.9 as shown in table 3. These numbers are typical for newly constructed pavement. Details of the pavement roughness measurements are presented in Appendix A.

Table 3
Average International Roughness Index (IRI) and Ride Number (RN) for the investigated section

Test Section #	Avg. IRI	Avg. RN
1W	70	3.9
1E	75	3.9
2W	75	3.89
2E	67	3.87
3W	72	3.87
3E	65	4.05
4W	59	4.11
4E	66	3.92
5W	63	4.05
5E	63	4.05

Efficiency of Joint Load Transfer

The load transfer efficiency of the joints at the test sections were evaluated using the Falling Weight Deflectometer (FWD) data. This was done at the lowest possible temperature so as to obtain the minimum values for load transfer efficiency. Table 4 shows the load transfer efficiency ratings taken at cold temperatures, which are considered to be the most critical. Based on studies conducted by FHWA, joint efficiency measurements of less than 50 percent would warrant consideration of restorations. By this criterion, all of the joints showed good load transfer efficiency. Details of the load transfer measurement for all test sections are presented in Appendix B.

Table 4
Average load transfer efficiency during winter season.

LOAD TRANSFER EVALUATION WITH FWD - JANUARY 2001 TEST SECTION AVERAGES									
SECT NO.	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE	AIR TEMP	SURF TEMP
1 - EAST	5.79	5.45	5.86	3.93	1.07	0.67	72%	58	62
1 - WEST	3.49	3.25	5.03	3.37	1.07	0.68	73%	54	55
2 - EAST	4.66	4.36	4.68	3.88	1.07	0.83	89%	60	62
2 - WEST	4.16	3.91	5.45	3.75	1.06	0.69	74%	53	53
3 - EAST	4.01	3.76	5.28	3.94	1.07	0.75	80%	57	59
3 - WEST	3.92	3.69	5.59	3.81	1.06	0.68	73%	51	52
4 - EAST	3.34	3.10	5.76	3.25	1.08	0.57	61%	42	38
4 - WEST	3.59	3.35	5.71	3.32	1.07	0.58	63%	47	47
5 - EAST	3.57	3.30	5.82	3.36	1.08	0.58	63%	44	40
5 - WEST	3.35	3.10	5.68	3.12	1.08	0.55	60%	43	42

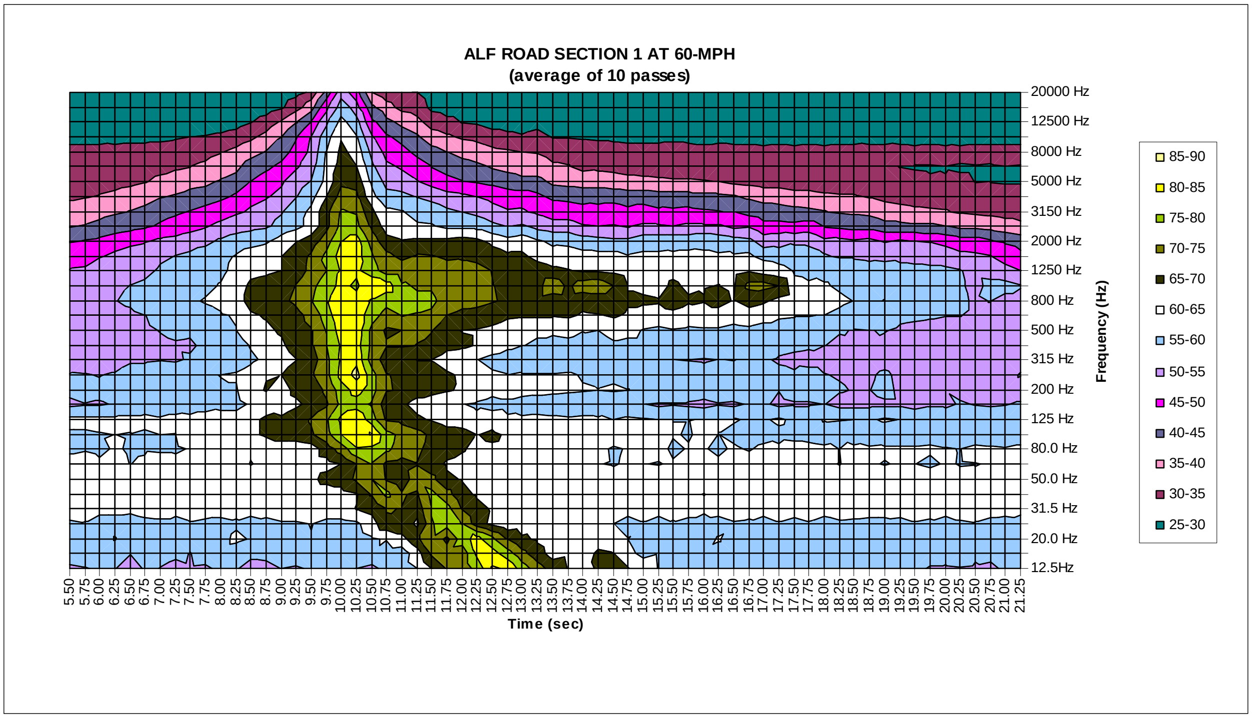
Pavement-Tire Noise

The Northline Road sound tests were conducted with a Larson Davis System 824™ Precision Sound Level Meter and Real Time Analyzer. It made use of a 1/2 inch diameter condenser microphone and recorded the Energy Equivalent Sound Level (Leq) of the sound produced by the passage of a test vehicle over the pavement sections being studied. The test setup involved placement of the microphone a distance of 3 ft. from the edge of the pavement section and recording the sound levels of the test vehicle traversing the sections at a constant speed of 60 mph. The test segments were grouped into three sections: the control section (CS) narrow joints without sealant (NWO) and narrow joints with sealant (NWS).

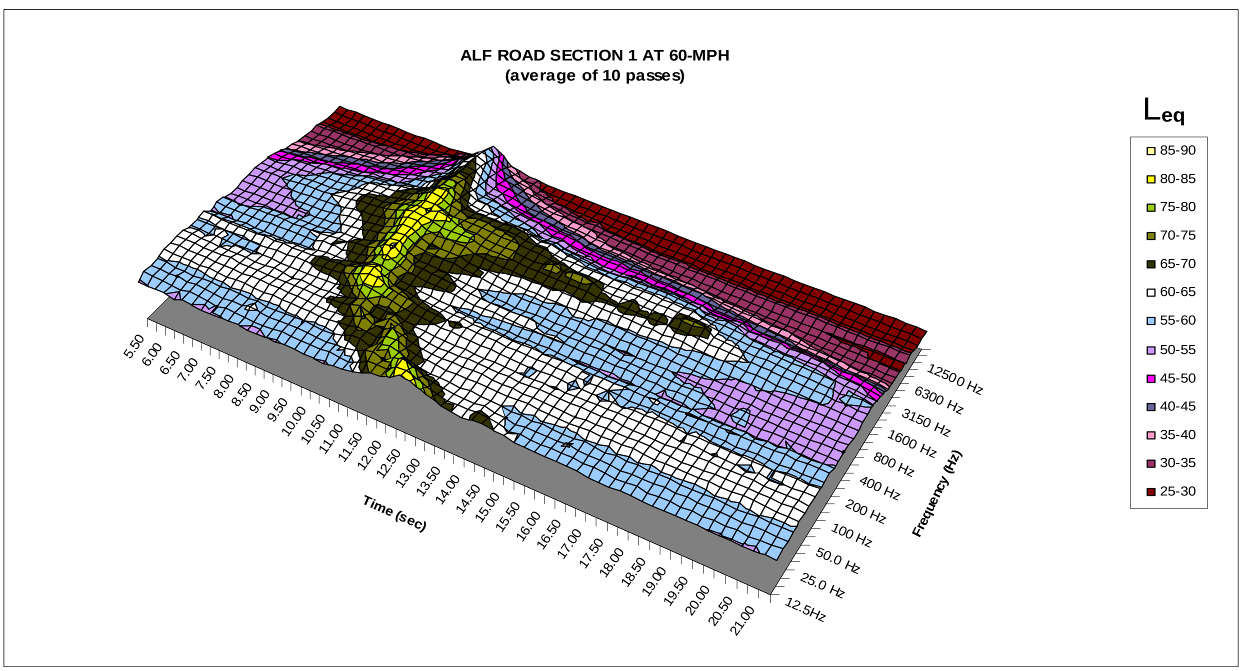
The microphone remained stationary during each sections testing and variations in pitch and sound level detected were a function of the Doppler Effect∗ and of the natural rise and fall in sound magnitude as the test vehicle passed the microphone. Approximately 10 passes of the vehicle were recorded on each section, and the levels were averaged and normalized so as to eliminate the effects of transient noise that might be present during individual passes.

∗ Austrian mathematician and physicist, Christian Doppler (1803-53) who discovered the variations in pitch of sound are due to a shift in the frequency of sound waves.

The System 824™ was used to spectrally analyze the averaged/normalized sound data and to convert it into its equivalent 1/3 octave time-dependant spectral distributions. These distributions are shown in figures 25 and 26. In each figure, the X-axis depicts time and

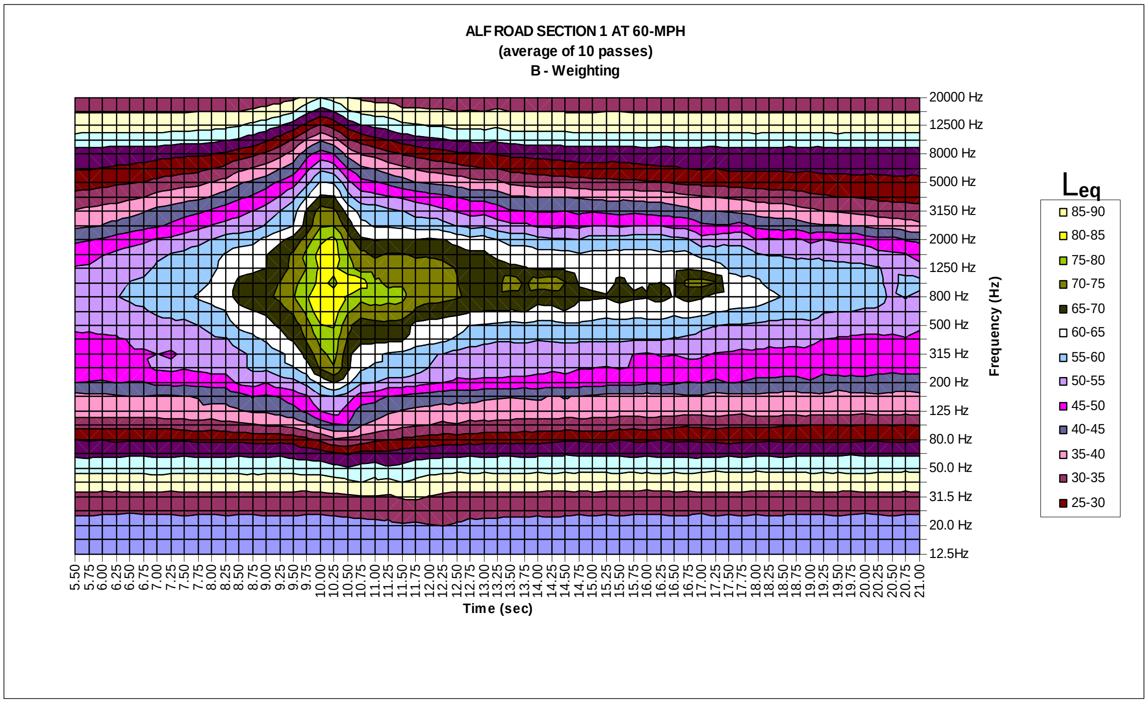


(a) Plan view

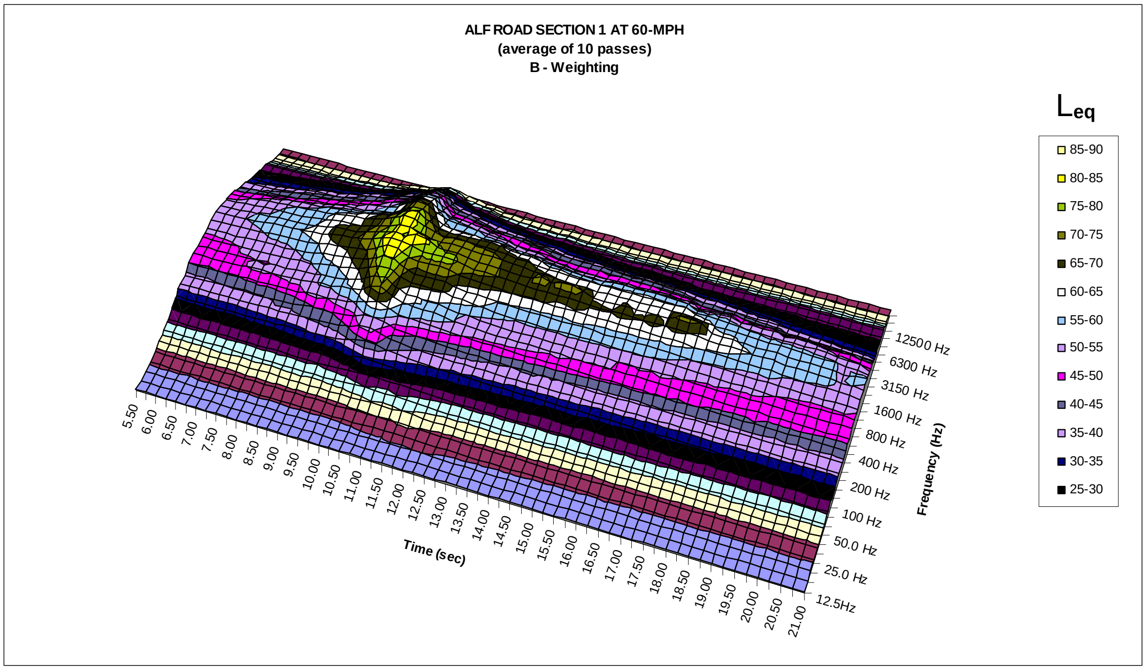


(b) Three dimensional view

Figure 25
Flat response two & three-dimensional view of sound frequency and time distribution



(a) Plan view



(b)Three dimensional view

Figure 26
B-weighing response, two and three-dimensional view of sound frequency and time distribution

indicates its progression in quarter-second intervals. The YZ-plane in figures 25b and 26b illustrate the spectral distributions of the recorded sound at each time interval along the X-axis and is displayed in perspective. For purposes of clarity, figures 25a and 26a depict the same information in a topographic format. To illustrate how these graphs should be read, consider that in figure 25a the peak sound for the test occurred at t = 10.25 seconds. This peak occurred at a frequency of 250 Hz and had a relative Leq in the 85 to 90 dB range. In all four plots, the Y-axis distributions are divided into 1/3 octave frequency intervals that extend from 12.5 Hz thru to 20,000 Hz (the effective range of human hearing). Sound magnitudes, or Leq, given in decibels (dB) at each frequency are indicated as elevations in figures 25b and 26b. The dB ranges are shown in the legend to the right of each plot in each figure.

The Environmental Protection Agency (EPA) considers sounds above 65 dB to be excessive. Using this level as a criterion to evaluate the environmental impact of each test section in terms of noise, each test section was rated using their respective spectral distribution plots. By measuring and summing the effective area of each contour outline in the plots that are greater than or equal to 65 dB, it is possible to approximate a volumetric quantity that indexes the amount of sound in excess of EPA acceptable levels. The higher the sum, the more environmentally unacceptable the section becomes with respect to sound.

Two sets of plots were required for each test section in this regard. The first set, termed flat-response plots, indicate what the microphone “hears”. Flat-response plots represent the true or actual sound that is produced by the passing vehicle at all frequencies examined. The problem with using these plots to evaluate noise is that the human ear is not a flat-response system. It cannot detect sounds at very low or very high frequencies as effectively as the microphone can. For this reason, various weighting schemes have been developed to compensate for the differences. This study used a filter algorithm that models human hearing in the range of sound volumes typical of highway noise environments. The algorithm was applied to the flat-response plots so that a revised set of response plots could be developed that better approximate human hearing. This modification is termed B-weighting (A-weighting and a C-weighting schemes are intended for other types of sound environments).The results of the comparison of the pavement sections according to the Flat Response system are shown in table 5. Values shown represent the sound levels calculated to be in excess of or within the Leq range of the levels shown. Results are based on time-frequency plots where the frequency varies from 20 Hz to 20,000 Hz. Based on the Flat Response analysis, the ranking of the sections, as determined by the sum, from quietest to loudest was NWO, CS, and NWS as indicated in table 5. Table 6 shows the B-Weighted response analysis over the same frequency range. Based on B-Weighting, the ranking of the sections from quietest to loudest was NWO, NWS, and CS. Such testing showed that the narrow joints were quieter than the conventional joints for a person with normal hearing and adhering to the EPA's 65 dB threshold.

Table 5
Northline Road Sound Test (Flat Response) -- 60 mph

L_{eq} Range	CS	NWO	NWS
85 – 90	0.00105	0.00054	0.01232
80 – 85	0.09535	0.09828	0.11543
75 – 80	0.23029	0.22469	0.24020
70 – 75	0.54208	0.48864	0.60255
65 – 70	1.12843	0.93038	1.13749
Sum	***1.99720***	***1.74253***	***2.10799***

Table 6
Northline Road Sound Test (B-Weighted Response) -- 60 mph

L_{eq} Range	CS	NWO	NWS
85 – 90	0.00000	0.00000	0.00130
80 – 85	0.03759	0.02780	0.04099
75 – 80	0.09901	0.07846	0.08633
70 – 75	0.23345	0.15580	0.23636
65 – 70	0.47218	0.31494	0.38780
Sum	***0.84223***	***0.57700***	***0.75278***

Effect of Temperature on Joints

Figures 27 and 28 provide a summary of joint measurements taken at the time of construction and, later, during a period of cold weather (38^{o}F) at the test site. The average width for the narrow joints at the time of construction was about 0.13 in. while the average width for the standard joints was about 0.33 in.

The joints width measurements during cold temperatures showed that the narrow joints opened to around twice the original saw cut width (from 0.13 in. to 0.23 in. on average). Since this is considerably narrower than the width of the widening cut on conventional joints, it has been argued that narrow joints are more naturally protected from external destructive forces like debris and water than conventional joints. Such considerations, along with other ideas like using an aggregate base course to help avert potential damage from rainwater intrusion, have led a number of researchers to propose using unsealed narrow joints occasionally on certain projects. Once again the large amount of mud and debris that worked its way into the unsealed narrow joints, as observed on this study (and which can still become a problem over the long term), forces the authors to advise against it.

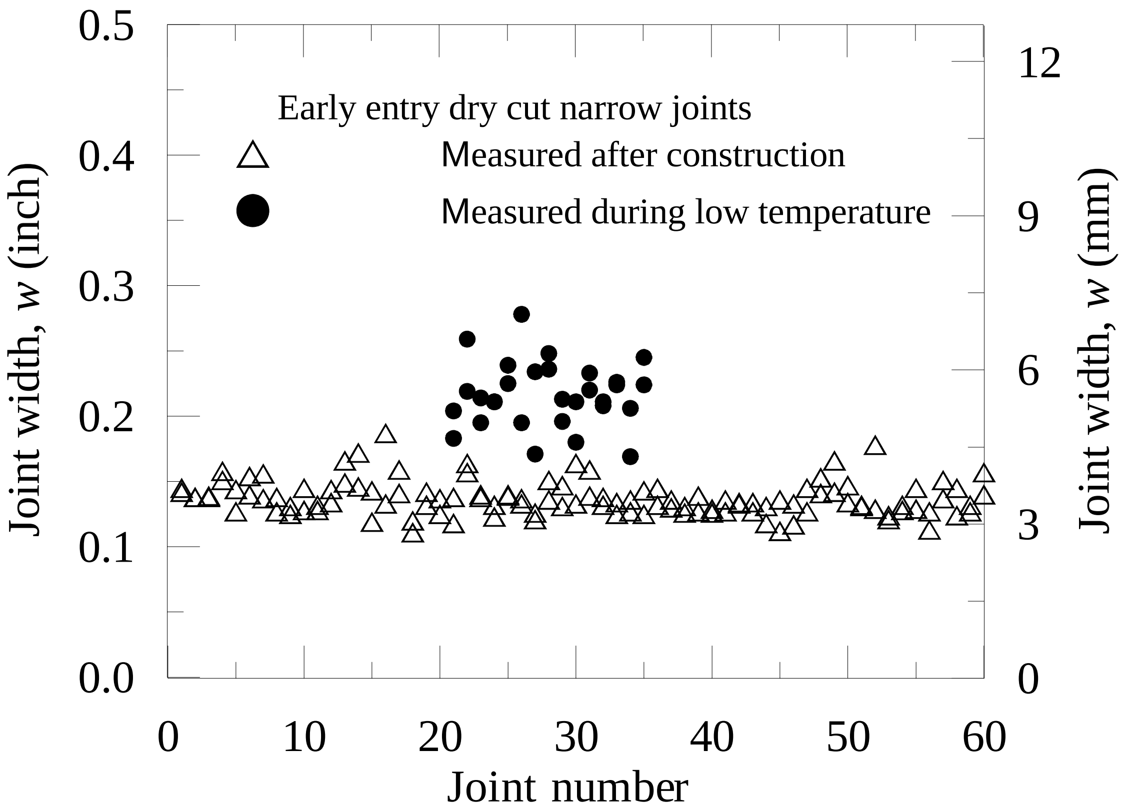


Figure 27
Results of the measurements of joints dimensions after construction and during the extreme low temperature season, early entry dry narrow joints

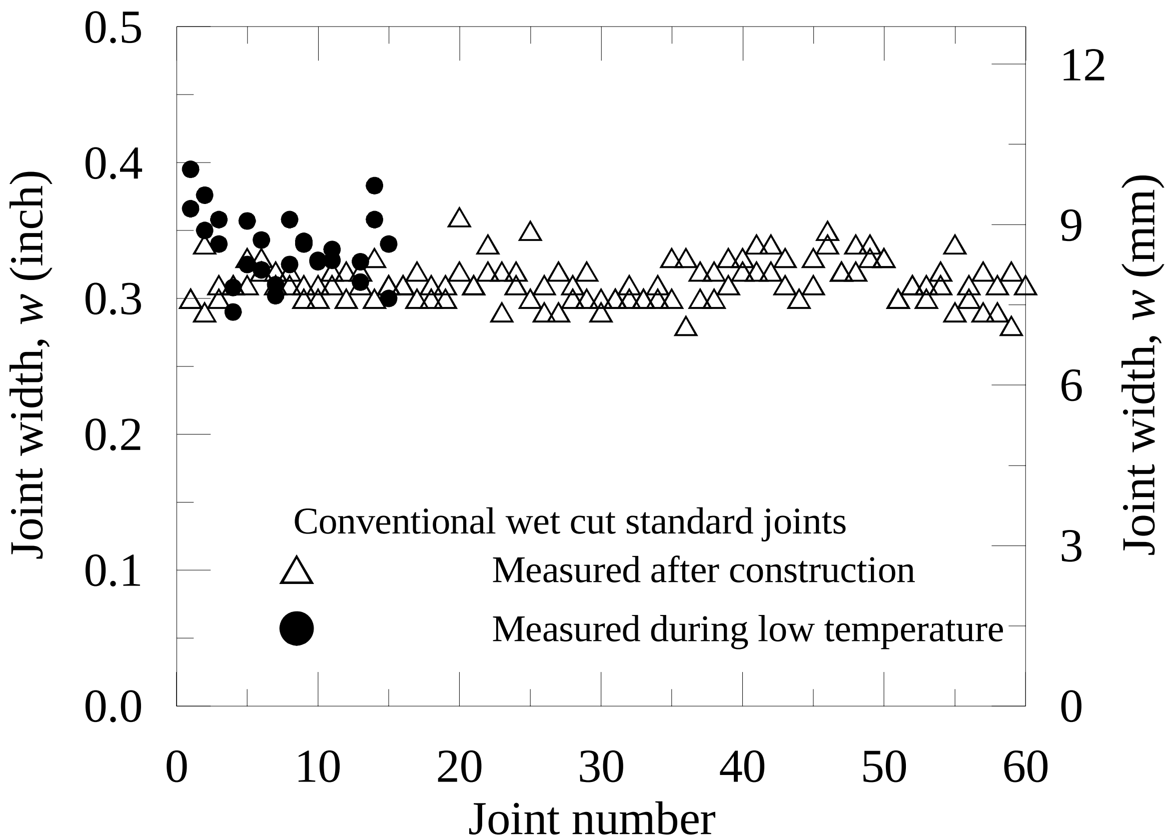


Figure 28
Results of the measurements of joints dimensions after construction and during the extreme low temperature season, conventional wet cut standard joints

Joint Depth Requirements

Figures 29 and 30 provide a summary of the joint cut depths that were achieved in the field for the early entry dry cut narrow joints as well as for the conventional wet cut standard joints. The plans specified that the early entry narrow joints and widening cut on the standard joints be 1.5 in. deep. Figures 29 and 30 indicate that, on average, the depths achieved during the cutting operation for the narrow joints were closer to meeting specification requirements than the standard joints. The average depth achieved for the standard joints was slightly deeper than the 1.5 in. requirement at 1.8 in. Although the difference did not significantly impact performance, it does seem to indicate that there may be some difficulties, logistically, in attempting to achieve design requirements when attempting to widen joints.

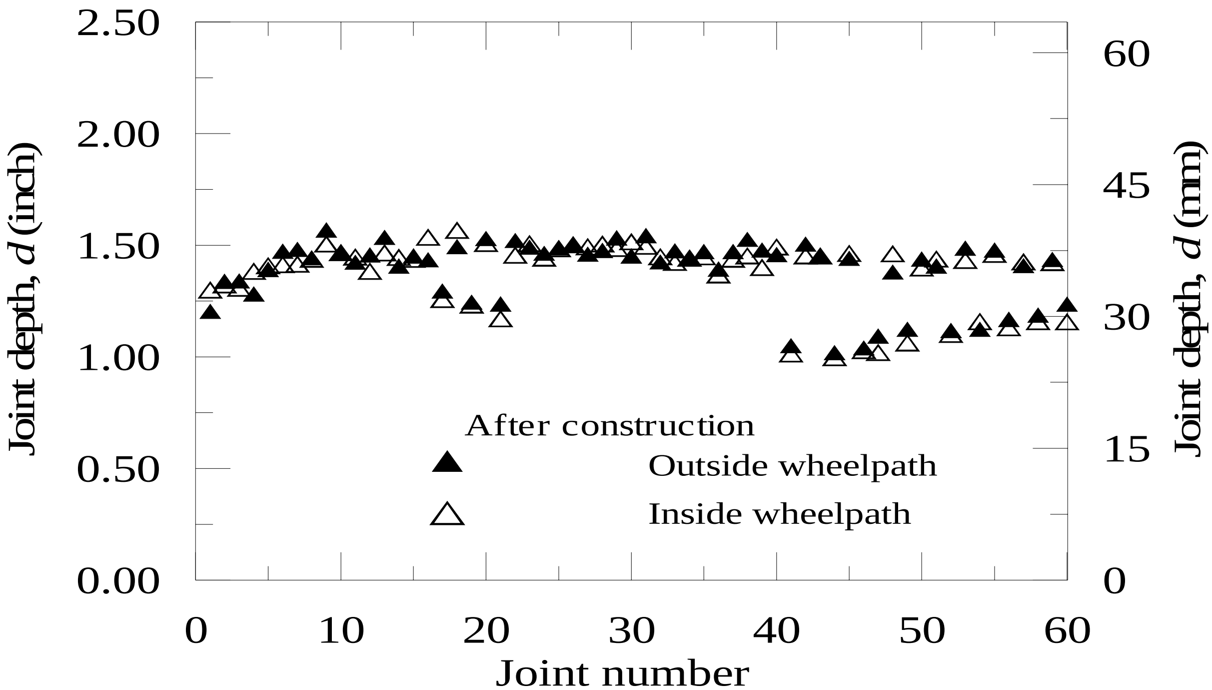


Figure 29
Results of the joint depth measurements, early entry dry cut narrow joints

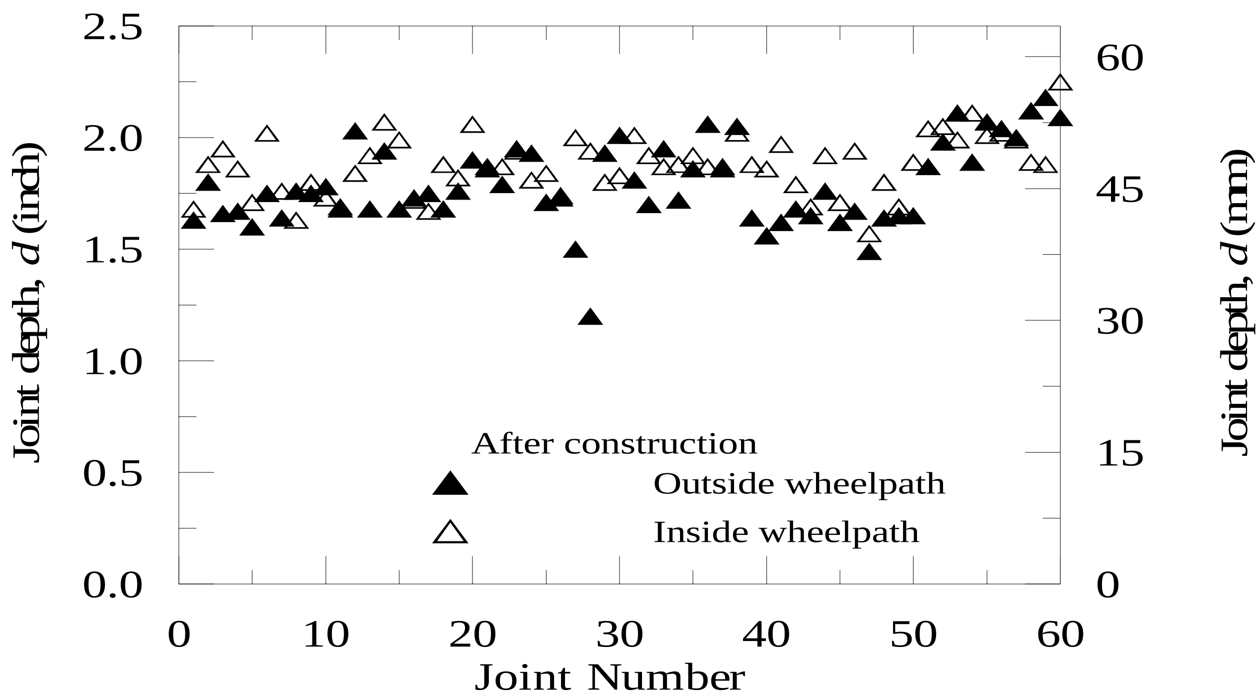


Figure 30
Results of the joint depth measurements, conventional wet cut standard joints

Sealed Narrow Joints

As shown in table 2, the sealed narrow joints of sections S4 and S5 had the least amount of damage for all sections. This included the control section S1. In comparing section S4 to S5, when considering the use of backer rods, findings indicated that narrow joints may be sufficiently narrow enough to support the effective application of silicone without their use. Nevertheless, based on the opinion of the joint material installers, a more uniform application of silicon in the joint was achieved when backer rods were used.

Although there is not enough evidence from the study to draw conclusions about the use of backer rods over the long term on narrow joints, the study clearly shows that the use of sealant is necessary. The performance of the unsealed narrow joints of section S3 was relatively poor when compared to their sealed counterparts in sections S4 and S5. It is possible that the test site's excessive mud and debris may have skewed the findings to favor the sealed joints. Still, the field conditions on Northline Road serve to show that excessive amounts of such material can exist as a threat in the field. The study findings show that the use of sealant is a sufficient means to protect against mud and debris.

CONCLUSIONS

The overall findings of this report suggest that using narrow joints that are wet-cut and sealed to control random cracking is a viable and cost effective alternative to the conventional wet double-cut method currently specified by the LA DOTD. The study indicates cutting narrow joints will cost less in terms of money, labor, and time than is required by the conventional approach because narrow joints require only a single pass of the diamond saw to cut the joints. Also, since the joints are narrower, they will require less sealant to fill them than is currently required.

It was possible to infer from the random cracking survey evidence that the narrow joints performed as well as the conventional, wet-cut joints. This survey identified four random cracks, two of which were connected to narrow joints and two of which were connected to conventional joints, making the performance seem equal. But, because there were more narrow jointed sections across the project and because there was evidence that one of the random cracks in the narrow jointed sections may have been caused by construction errors, it is possible that the narrow joints performed marginally better.

For this study, the wet-cut, sealed narrow joints performed equal to or better than the conventional joints. Findings also indicated that they will be less likely to develop problems in the future. Crack surveys, IRI, PI, RN, and FWD tests along with other distress evaluations that examined spalling, faulting, pumping, corner breaks, and noise all showed the performance of wet-cut, sealed narrow joints to be very good, equal to that of the conventional.

Evidence from the study did show that sealed narrow joints are much less problematic and perform much better than unsealed narrow joints. Excessive amounts of mud and debris located at the test site made its way into the unsealed joints of section S3 and may have skewed the results somewhat. Still, the intrusion of foreign debris into the unsealed joints did affect performance, as can be assessed from table 2, and all indications are that the problems already observed in connection to this will only worsen over time.

Controlled cracks in the S2 section did not appear in the time frame expected. This was due to the presence of GGBFS which is known to have a retardation effect on the curing of concrete and which causes delayed crack formation at the sawed joint locations. To prevent the occurrence of random cracks in section S2 and to accelerate joint formation, the joints were re-cut to a deeper depth (same width). No raveling or particle separation occurred as a result of either saw-cutting operation. Subsequently, once the second cut was made, all joints cracked as required. The performance of section S2 joints indicate that when using the dry entry method on pavements whose mix design have retarded curing properties, it is necessary for the depth of joint cut to be made deeper than current policy dictates.

RECOMMENDATIONS

The results of this study are directed primarily at LA DOTD's highway design and construction community in the hopes that it will promote an interest in the use of narrow transverse contraction joints for control of random cracking in newly constructed plain concrete pavement. Narrow transverse contraction joints cut according to the conventional, wet-cut method are recommended for use on LA DOTD projects as part of a large scale feasibility initiative to better assess the strengths and limitations of the concept and to provide support for the future development of a narrow joints protocol for introduction into the Standard Specification if warranted. The development of narrow joints by the early-entry, dry-cut method is also recommended for consideration in the feasibility initiative, but only provided that these joints are cut to a reasonable enough depth to insure proper and full controlled joint cracking or provided the concrete mix design be sufficient to achieve the same.

As part of this initiative, it is recommended that narrow joints should be 1/8 in. at a depth required by the plan when the conventional, wet-cut method is used. When the early-entry, dry-cut method is used, narrow joints should be 1/8 in. wide and at the required depth. In all instances, joints should be silicone-sealed, and the use of backer rod is recommended. Joint spacing should be determined in accordance with LA DOTD policy. Upon completion of the initiative, the development of a LA DOTD narrow joints specification should proceed, provided enough empirical evidence has been collected and analyzed to warrant the advancement of a protocol.

The initiative is proposed for introduction on a statewide level to better determine the wider merit of the narrow joint approach and assess its performance under a greater variety of environmental and design circumstances than was possible in this preliminary research. Based on this study, such an effort is considered necessary because the narrow joint concept has proven itself to have considerable merit as it has performed equally with conventional double-cut joints in all respects and because the narrow joint concept provides a means of achieving substantial reductions in time, labor, and money.

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APPENDIX A

Pavement Smoothness Data

Table A-1 Smoothness data for test section S1

TS-1W					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
94	87	90	3.71	3.82	3.76
72	52	62	3.87	4.15	3.99
64	58	61	3.84	3.93	3.88
75	54	64	3.33	3.95	3.58
94	74	84	3.55	3.74	3.64
81	81	81	3.5	3.66	3.58
73	90	82	3.87	3.77	3.82
67	47	57	3.88	4.07	3.96
91	69	80	3.67	3.84	3.75
54	51	52	4.05	4.03	4.04
46	42	44	3.96	4.15	4.05
66	53	60	3.87	4.15	4
TS-1E					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
102	62	82	3.46	4.04	3.7
70	56	63	3.82	4.11	3.95
62	92	77	3.94	3.7	3.81
63	72	67	3.91	3.88	3.89
72	72	72	3.82	3.72	3.77
99	57	78	3.39	4.03	3.65
86	97	92	3.71	3.64	3.67
90	128	109	3.48	3.31	3.39
91	88	90	3.68	3.95	3.8
67	74	70	4.02	4	4.01
87	50	69	3.82	4.17	3.97
133	64	99	3.31	4.11	3.62

Table A-2 Smoothness data for test section S2

TS-2W					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
93	77	85	3.41	3.6	3.5
63	68	65	3.87	3.67	3.76
73	93	83	3.96	3.8	3.88
58	72	65	3.94	3.87	3.9
78	82	80	3.68	3.86	3.77
89	70	80	3.76	3.91	3.83
88	65	77	3.77	3.84	3.8
64	63	63	3.91	3.82	3.86
75	55	65	3.82	3.87	3.85
76	55	66	3.78	3.9	3.84
77	81	79	3.91	3.74	3.82
96	116	106	3.7	3.42	3.55
TS-2E					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
73	66	70	3.9	4.09	3.99
84	62	73	4.01	4.17	4.09
68	50	59	3.96	4.19	4.07
74	55	64	3.85	4.09	3.96
60	34	47	3.96	4.35	4.13
58	45	52	3.98	4.13	4.05
81	50	66	3.54	3.82	3.66
96	50	73	3.48	3.99	3.7
105	66	85	3.15	3.83	3.43
113	87	100	2.66	3.33	2.94
85	66	75	3.39	3.55	3.47
69	51	60	3.87	4.11	3.98

Table A-3 Smoothness data for test section S3

TS-3W					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
84	62	73	3.64	3.99	3.79
75	75	75	3.77	3.79	3.78
53	51	52	4.06	4.11	4.09
63	42	52	3.98	4.22	4.09
85	72	78	3.56	3.67	3.61
62	53	57	3.88	3.94	3.91
98	92	95	3.6	3.63	3.61
71	62	67	3.75	3.84	3.79
71	58	64	3.75	3.72	3.73
70	92	81	3.59	3.6	3.59
TS-3E					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
51	59	55	3.99	4.06	4.03
75	49	62	3.86	4.24	4.02
97	51	74	3.48	4.18	
65	53	59	3.9	4.05	3.97
74	55	65	4.06	4.2	4.12
61	54	57	3.95	4.03	3.98
64	53	59	3.77	4.17	3.94
70	51	61	3.82	4.07	3.94
81	54	68	3.85	4.04	3.94
77	57	67	3.87	4.07	3.97

Table A-4 Smoothness data for test section S4

TS-4W					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
84	68	76	3.76	3.88	3.82
64	57	60	3.74	4.05	3.88
55	45	50	3.98	4.12	4.05
66	49	57	3.98	3.99	3.99
68	44	56	3.81	4.1	3.94
68	56	62	3.98	4.21	4.08
71	41	56	4.09	4.3	4.19
59	59	59	4.25	4.24	4.25
59	40	50	4.05	4.27	4.15
71	64	67	3.97	4.05	4.01
TS-4E					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
66	57	61	3.76	3.97	3.86
112	78	95	3.12	3.49	3.28
76	50	63	3.69	4.06	3.86
88	48	68	3.54	4.23	3.81
71	58	65	3.83	4.2	3.99
68	45	57	3.72	4.12	3.89
59	36	47	4.15	4.38	4.25
75	59	67	3.95	4.21	4.07
60	46	53	3.82	4.14	3.97
89	67	78	3.72	3.98	3.84

Table A-5 Smoothness data for test section S5

TS-5W					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
48	37	42	4.12	4.2	4.15
57	63	60	4.12	4.01	4.06
62	55	58	4.15	4.26	4.2
62	45	53	4.02	4.18	4.09
75	68	72	3.94	4	3.97
101	90	96	3.61	3.68	3.65
63	80	72	3.67	3.41	3.53
54	53	53	3.92	4.07	3.99
84	67	76	3.84	3.94	3.89
53	63	58	4.06	4.09	4.08
TS-5E					
IRI-IWP	IRI-OWP	IRI-AVG	RN-IWP	RN-OWP	RN-AVG
86	58	72	3.39	4.09	3.67
93	58	76	3.55	4.1	3.78
62	44	53	3.76	4.07	3.9
64	54	59	4.07	4.04	4.06
81	59	70	3.9	4.14	4.01
68	43	56	3.87	4.1	3.98
91	55	73	3.62	4.12	3.83
73	50	62	3.66	4.02	3.82
76	55	65	3.89	4	3.95
102	69	85	3.65	4.01	3.81

APPENDIX B

Load Transfer Efficiency

Table B-1 Load transfer efficiency for test section S1 during summer season

TEST SECTION # 1 EAST BOUND STATIONS 61+90 TO 64+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	5.46	5.08	4.54	4.26	1.07	0.94	101%
2	4.88	4.51	4.47	4.22	1.08	0.94	102%
3	4.6	4.23	4.35	4.07	1.09	0.94	102%
4	4.7	4.35	3.97	3.72	1.08	0.94	101%
5	4.12	3.9	4.27	4.05	1.06	0.95	100%
6	5.18	4.84	4.43	4.13	1.07	0.93	100%
7	5.92	5.6	4.54	4.24	1.06	0.93	99%
8	5.84	5.44	4.18	3.83	1.07	0.92	98%
9	5.18	4.81	4.41	4.09	1.08	0.93	100%
10	5.41	5.05	4.33	4.09	1.07	0.94	101%
11	5.03	4.64	4.35	4.1	1.08	0.94	102%
12	4.35	4.04	4.44	4.18	1.08	0.94	101%
13	4.48	4.17	4.44	4.14	1.07	0.93	100%
14	5.42	5.04	4.22	3.96	1.08	0.94	101%
15	5.01	4.67	4.16	3.85	1.07	0.93	99%
AVG	5.04	4.69	4.34	4.06	1.07	0.94	101%
AVG AIR TEMP = 99							
AVG SURFACE TEMP = 125							
TEST SECTION # 1 WEST BOUND STATIONS 64+90 TO 74+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.67	3.45	4.23	3.96	1.06	0.94	100%
2	3.56	3.35	4.22	3.94	1.06	0.93	99%
3	3.52	3.31	4.08	3.7	1.06	0.91	96%
4	3.45	3.23	3.74	3.6	1.07	0.96	103%
5	3.52	3.31	3.84	3.61	1.06	0.94	100%
6	3.43	3.17	3.7	3.48	1.08	0.94	102%
7	3.42	3.26	3.94	3.7	1.05	0.94	99%
8	3.56	3.32	4.11	3.86	1.07	0.94	101%
9	3.69	3.47	4.1	3.92	1.06	0.96	102%
10	3.67	3.48	4.62	4.27	1.05	0.92	97%
11	3.37	3.1	4.13	4.01	1.09	0.97	106%
12	3.25	3.07	3.4	3.21	1.06	0.94	100%
13	3.41	3.2	3.81	3.62	1.07	0.95	101%
14	3.41	3.18	3.85	3.7	1.07	0.96	103%
15	3.44	3.26	3.76	3.57	1.06	0.95	100%
AVG	3.49	3.28	3.97	3.74	1.07	0.94	101%
AVG AIR TEMP = 94							
AVG SURFACE TEMP = 104							

Table B-2 Load transfer efficiency for test section S2 during summer season

TEST SECTION # 2 EAST BOUND STATIONS 73+90 TO 76+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	4.76	4.44	3.81	3.49	1.07	0.92	98%
2	4.49	4.22	3.8	3.52	1.06	0.93	99%
3	4.75	4.48	3.76	3.46	1.06	0.92	98%
4	5.61	5.31	3.67	3.33	1.06	0.91	96%
5	4.94	4.67	3.77	3.48	1.06	0.92	98%
6	4.24	3.88	3.66	3.41	1.09	0.93	102%
7	4.03	3.78	3.72	3.46	1.07	0.93	99%
8	4.55	4.19	3.99	3.64	1.09	0.91	99%
9	4.02	3.7	3.69	3.44	1.09	0.93	101%
10	4.31	4.01	3.71	3.44	1.07	0.93	100%
11	4.1	3.79	3.93	3.65	1.08	0.93	100%
12	4.16	3.91	4.56	4.17	1.06	0.91	97%
13	3.71	3.41	3.52	3.26	1.09	0.93	101%
14	3.46	3.27	3.47	3.24	1.06	0.93	99%
15	4.27	4.02	7.05	6.66	1.06	0.94	100%
AVG	4.36	4.07	4.01	3.71	1.07	0.92	99%
AVG AIR TEMP = 99							
AVG SURFACE TEMP = 126							
TEST SECTION # 2 WEST BOUND STATIONS 76+90 TO 74+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.41	3.22	3.22	3.04	1.06	0.94	100%
2	3.24	3.07	3.17	2.96	1.06	0.93	99%
3	3.56	3.28	3.25	3.03	1.09	0.93	101%
4	3.41	3.21	3.35	3.17	1.06	0.95	101%
5	3.28	3.02	3.18	3.02	1.09	0.95	103%
6	3.38	3.11	3.35	3.15	1.09	0.94	102%
7	3.37	3.19	3.4	3.27	1.06	0.96	102%
8	3.49	3.33	3.41	3.18	1.05	0.93	98%
9	3.36	3.17	3.6	3.3	1.06	0.92	97%
10	3.42	3.21	3.48	3.25	1.07	0.93	100%
11	3.35	3.17	3.52	3.27	1.06	0.93	98%
12	3.55	3.3	3.86	3.63	1.08	0.94	101%
13	3.73	3.5	3.63	3.4	1.07	0.94	100%
14	3.78	3.52	3.91	3.66	1.07	0.94	101%
15	3.7	3.49	3.79	3.54	1.06	0.93	99%
AVG	3.47	3.25	3.47	3.26	1.07	0.94	100%
AVG AIR TEMP = 95							
AVG SURFACE TEMP = 103							

Table B-3 Load transfer efficiency for test section S3 during summer season

TEST SECTION # 3 EAST BOUND STATIONS 84+90 TO 86+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.64	3.35	3.74	3.43	1.09	0.92	100%
2	3.59	3.41	3.72	3.46	1.05	0.93	98%
3	3.67	3.38	3.72	3.45	1.09	0.93	101%
4	3.65	3.42	3.57	3.34	1.07	0.94	100%
5	3.63	3.4	3.83	3.57	1.07	0.93	100%
6	3.71	3.44	3.7	3.39	1.08	0.92	99%
7	3.67	3.44	3.68	3.38	1.07	0.92	98%
8	3.74	3.52	3.85	3.56	1.06	0.92	98%
9	3.92	3.63	3.97	3.71	1.08	0.93	101%
10	4.13	3.81	3.99	3.74	1.08	0.94	102%
11	4.04	3.77	4.02	3.72	1.07	0.93	99%
12	3.9	3.61	4.02	3.74	1.08	0.93	101%
13	3.82	3.57	3.76	3.47	1.07	0.92	99%
14	3.92	3.67	3.74	3.5	1.07	0.94	100%
15	4.08	3.86	3.65	3.43	1.06	0.94	99%
AVG	3.81	3.55	3.80	3.53	1.07	0.93	100%
AVG AIR TEMP = 94							
AVG SURFACE TEMP = 109							
TEST SECTION # 3 WEST BOUND STATIONS 87+90 TO 85+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.73	3.48	4.13	3.84	1.07	0.93	100%
2	4.06	3.93	3.99	3.73	1.03	0.93	97%
3	3.87	3.67	4.26	3.93	1.05	0.92	97%
4	4.2	3.94	4.18	3.93	1.07	0.94	100%
5	4.34	4.11	4.45	4.14	1.06	0.93	98%
6	4.07	3.8	4.3	4.02	1.07	0.93	100%
7	3.94	3.7	4.2	3.89	1.06	0.93	99%
8	3.92	3.66	4.2	3.93	1.07	0.94	100%
9	3.79	3.57	4.22	3.91	1.06	0.93	98%
10	3.65	3.46	4.21	3.98	1.05	0.95	100%
11	3.73	3.48	3.91	3.65	1.07	0.93	100%
12	3.65	3.43	3.83	3.58	1.06	0.93	99%
13	3.54	3.39	3.85	3.55	1.04	0.92	96%
14	3.5	3.27	3.66	3.39	1.07	0.93	99%
15	3.22	3.02	3.61	3.37	1.07	0.93	100%
AVG	3.81	3.59	4.07	3.79	1.06	0.93	99%
AVG AIR TEMP = 93							
AVG SURFACE TEMP = 99							

Table B-4: Load transfer efficiency for test section S4 during summer season.

TEST SECTION # 4 EAST BOUND STATIONS 94+90 TO 97+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	4.07	3.75	4.63	4.19	1.09	0.90	98%
2	4.13	3.83	4.67	4.17	1.08	0.89	96%
3	4.23	3.97	4.37	3.92	1.07	0.90	96%
4	3.86	3.6	4.02	3.71	1.07	0.92	99%
5	3.9	3.67	4.06	3.76	1.06	0.93	98%
6	3.91	3.66	4.28	3.81	1.07	0.89	95%
7	4	3.73	4.32	3.93	1.07	0.91	98%
8	3.82	3.57	4	3.63	1.07	0.91	97%
9	3.88	3.64	3.93	3.69	1.07	0.94	100%
10	4.31	4.04	4.26	3.88	1.07	0.91	97%
11	4.37	4.06	4.32	3.98	1.08	0.92	99%
12	4.12	3.85	4.05	3.75	1.07	0.93	99%
13	3.93	3.62	3.84	3.55	1.09	0.92	100%
14	3.81	3.57	3.94	3.65	1.07	0.93	99%
15	4.28	3.99	4.06	3.7	1.07	0.91	98%
AVG	4.04	3.77	4.18	3.82	1.07	0.91	98%
AVG AIR TEMP = 96							
AVG SURFACE TEMP = 114							
TEST SECTION # 4 WEST BOUND STATIONS 97+90 TO 95+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	4.09	3.86	4.27	3.96	1.06	0.93	98%
2	3.96	3.74	4.14	3.89	1.06	0.94	99%
3	3.8	3.56	4.09	3.77	1.07	0.92	98%
4	3.89	3.64	4.6	4.25	1.07	0.92	99%
5	4.01	3.74	4.23	3.89	1.07	0.92	99%
6	4.09	3.85	4.22	3.88	1.06	0.92	98%
7	3.92	3.62	4.73	4.3	1.08	0.91	98%
8	3.78	3.51	4.22	3.88	1.08	0.92	99%
9	3.86	3.55	4.08	3.78	1.09	0.93	101%
10	3.9	3.67	4.1	3.89	1.06	0.95	101%
11	3.83	3.59	3.93	3.7	1.07	0.94	100%
12	3.59	3.37	3.84	3.56	1.07	0.93	99%
13	3.55	3.31	3.72	3.41	1.07	0.92	98%
14	3.56	3.35	3.71	3.42	1.06	0.92	98%
15	3.77	3.44	3.91	3.6	1.10	0.92	101%
AVG	3.84	3.59	4.12	3.81	1.07	0.93	99%
AVG AIR TEMP = 102							
AVG SURFACE TEMP = 118							

Table B-5: Load transfer efficiency for test section S5 during summer season.

TEST SECTION # 5 EAST BOUND STATIONS 104+90 TO 108+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE

1	4.08	3.75	4.21	3.88	1.09	0.92	100%
2	4.26	3.97	4	3.76	1.07	0.94	101%
3	4.65	4.33	4.11	3.78	1.07	0.92	99%
4	4.57	4.24	4.36	3.99	1.08	0.92	99%
5	4.04	3.78	4.22	3.92	1.07	0.93	99%
6	4.21	3.93	4.04	3.78	1.07	0.94	100%
7	4.44	4.15	4.19	3.92	1.07	0.94	100%
8	4.19	3.91	4.2	3.92	1.07	0.93	100%
9	4.07	3.77	4.57	4.29	1.08	0.94	101%
10	4.08	3.8	4.78	4.39	1.07	0.92	99%
11	4.09	3.8	4.13	3.85	1.08	0.93	100%
12	4.25	3.92	4.16	3.84	1.08	0.92	100%
13	3.98	3.68	3.92	3.56	1.08	0.91	98%
14	3.96	3.59	4.25	3.93	1.10	0.92	102%
15	3.81	3.49	4.26	4	1.09	0.94	103%
AVG	4.18	3.87	4.23	3.92	1.08	0.93	100%
AVG AIR TEMP = 97							
AVG SURFACE TEMP = 119							
TEST SECTION # 5 WEST BOUND STATIONS 108+90 TO 105+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.73	3.49	3.76	3.56	1.07	0.95	101%
2	3.87	3.59	3.76	3.52	1.08	0.94	101%
3	3.86	3.65	4.11	3.8	1.06	0.92	98%
4	3.83	3.52	4.02	3.64	1.09	0.91	99%
5	4.24	3.89	3.99	3.62	1.09	0.91	99%
6	3.98	3.79	3.61	3.37	1.05	0.93	98%
7	3.71	3.5	3.65	3.42	1.06	0.94	99%
8	3.89	3.64	3.7	3.48	1.07	0.94	101%
9	4	3.75	3.73	3.46	1.07	0.93	99%
10	3.99	3.72	3.98	3.63	1.07	0.91	98%
11	3.76	3.46	3.89	3.57	1.09	0.92	100%
12	3.62	3.34	3.63	3.34	1.08	0.92	100%
13	3.55	3.34	3.57	3.26	1.06	0.91	97%
14	3.73	3.46	3.61	3.39	1.08	0.94	101%
15	3.67	3.32	3.48	3.16	1.11	0.91	100%
AVG	3.83	3.56	3.77	3.48	1.07	0.92	99%
AVG AIR TEMP = 102							
AVG SURFACE TEMP = 121							

Table B-6: Load transfer efficiency for test section S1 during winter season.

TEST SECTION # 1 EAST BOUND STATIONS 61+90 TO 64+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE

1	5.5	5.18	6.37	4.47	1.06	0.70	75%
2	5.14	4.78	6.32	3.83	1.08	0.61	65%
3	5.54	5.09	5.87	3.92	1.09	0.67	73%
4	5.35	5.01	5.16	3.76	1.07	0.73	78%
5	4.17	3.87	5.81	3.72	1.08	0.64	69%
6	6.54	6.17	5.65	4.03	1.06	0.71	76%
7	7.54	7.23	5.8	3.86	1.04	0.67	69%
8	7.36	7.04	5.8	3.64	1.05	0.63	66%
9	5.48	5.3	6.11	3.98	1.03	0.65	67%
10	5.81	5.43	5.91	3.73	1.07	0.63	68%
11	5.88	5.43	5.74	3.87	1.08	0.67	73%
12	4.78	4.46	5.22	4.57	1.07	0.88	94%
13	4.79	4.44	6.15	3.92	1.08	0.64	69%
14	7.46	7.01	6.2	3.93	1.06	0.63	67%
15	5.58	5.26	5.83	3.68	1.06	0.63	67%
AVG	5.79	5.45	5.86	3.93	1.07	0.67	72%
AVG AIR TEMP = 58							
AVG SURFACE TEMP = 62							
TEST SECTION # 1 WEST BOUND STATIONS 64+90 TO 74+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.54	3.3	5.15	3.45	1.07	0.67	72%
2	3.61	3.34	4.92	3.47	1.08	0.71	76%
3	3.45	3.24	5.13	3.48	1.06	0.68	72%
4	3.46	3.2	4.67	3.11	1.08	0.67	72%
5	3.63	3.33	5.04	3.4	1.09	0.67	74%
6	3.31	3.14	5.02	3.29		0.66	69%
7	3.51	3.27	5.25	3.37	1.07	0.64	69%
8	3.57	3.37	5.33	3.31	1.06	0.62	66%
9	3.63	3.4	5.67	3.31	1.07	0.58	62%
10	3.74	3.52	5.47	3.59	1.06	0.66	70%
11	3.3	3.09	4.89	3.89	1.07	0.80	85%
12	3.29	3.08	3.43	3.22	1.07	0.94	100%
13	3.38	3.19	5.16	3.11	1.06	0.60	64%
14	3.37	3.09	5.07	3.34	1.09	0.66	72%
15	3.61	3.26	5.22	3.24	1.11	0.62	69%
AVG	3.49	3.25	5.03	3.37	1.07	0.68	73%
AVG AIR TEMP = 54							
AVG SURFACE TEMP = 55							

Table B-7: Load transfer efficiency for test section S2 during winter season.

TEST SECTION # 2 EAST BOUND STATIONS 73+90 TO 76+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE

1	5.19	4.83	4.83	3.91	1.07	0.81	87%
2	4.74	4.47	4.85	3.93	1.06	0.81	86%
3	5.46	5.17	4.73	3.93	1.06	0.83	88%
4	5.03	4.75	4.87	3.7	1.06	0.76	80%
5	4.93	4.56	4.36	3.95	1.08	0.91	98%
6	4.39	4.07	4.48	3.83	1.08	0.85	92%
7	4.37	4.11	4.57	4.04	1.06	0.88	94%
8	4.84	4.56	4.89	4.08	1.06	0.83	89%
9	4.53	4.19	4.83	4.05	1.08	0.84	91%
10	5.08	4.78	4.53	3.91	1.06	0.86	92%
11	4.57	4.23	4.26	3.85	1.08	0.90	98%
12	4.57	4.28	4.59	3.72	1.07	0.81	87%
13	3.76	3.45	3.88	3.32	1.09	0.86	93%
14	3.54	3.31	4.55	3.78	1.07	0.83	89%
15	4.86	4.6	6.04	4.24	1.06	0.70	74%
AVG	4.66	4.36	4.68	3.88	1.07	0.83	89%
AVG AIR TEMP = 60							
AVG SURFACE TEMP = 62							
TEST SECTION # 2 WEST BOUND STATIONS 76+90 TO 74+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.85	3.6	5.14	3.26	1.07	0.63	68%
2	3.6	3.34	4.91	3.46	1.08	0.70	76%
3	4.16	3.89	4.8	3.49	1.07	0.73	78%
4	3.39	3.27	5.59	3.39	1.04	0.61	63%
5	3.32	3.08	4.72	3.09	1.08	0.65	71%
6	3.83	3.57	4.65	3.37	1.07	0.72	78%
7	4.93	4.61	5.57	3.89	1.07	0.70	75%
8	3.58	3.36	5.86	3.48	1.07	0.59	63%
9	4.55	4.24	5.4	3.62	1.07	0.67	72%
10	3.59	3.36	4.98	4.06	1.07	0.82	87%
11	3.43	3.31	5.36	3.4	1.04	0.63	66%
12	3.59	3.37	4.67	3.5	1.07	0.75	80%
13	5.28	5	4.97	4.18	1.06	0.84	89%
14	5.93	5.61	7.29	5.16	1.06	0.71	75%
15	5.35	5.04	7.85	4.9	1.06	0.62	66%
AVG	4.16	3.91	5.45	3.75	1.06	0.69	74%
AVG AIR TEMP = 53							
AVG SURFACE TEMP = 53							

Table B-8: Load transfer efficiency for test section S3 during winter season.

TEST SECTION # 3 EAST BOUND STATIONS 84+90 TO 86+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE

1	4.03	3.73	4.61	4.01	1.08	0.87	94%
2	4.26	3.99	5.4	3.99	1.07	0.74	79%
3	4.28	3.99	5.27	3.86	1.07	0.73	79%
4	3.9	3.62	5.31	3.79	1.08	0.71	77%
5	3.82	3.53	5.48	3.95	1.08	0.72	78%
6	3.87	3.64	5.28	3.89	1.06	0.74	78%
7	3.94	3.67	5.11	3.78	1.07	0.74	79%
8	3.87	3.65	5.35	4	1.06	0.75	79%
9	4.06	3.84	5.72	4.22	1.06	0.74	78%
10	4.44	4.18	5.48	4.16	1.06	0.76	81%
11	4.2	3.99	5.33	4.17	1.05	0.78	82%
12	3.93	3.67	5.15	4.06	1.07	0.79	84%
13	3.74	3.55	5.28	3.82	1.05	0.72	76%
14	3.82	3.6	5.24	3.67	1.06	0.70	74%
15	3.95	3.71	5.16	3.75	1.06	0.73	77%
AVG	4.01	3.76	5.28	3.94	1.07	0.75	80%
AVG AIR TEMP = 57							
AVG SURFACE TEMP = 59							
TEST SECTION # 3 WEST BOUND STATIONS 87+90 TO 85+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.89	3.65	5.53	3.72	1.07	0.67	72%
2	4.12	3.81	5.59	3.89	1.08	0.70	75%
3	4.03	3.78	5.59	4.08	1.07	0.73	78%
4	4.14	3.85	5.8	3.81	1.08	0.66	71%
5	4.35	4.09	6.58	4.07	1.06	0.62	66%
6	4.18	3.94	6.28	4.1	1.06	0.65	69%
7	3.99	3.8	6.04	3.93	1.05	0.65	68%
8	4.06	3.86	5.74	4.02	1.05	0.70	74%
9	3.98	3.76	5.67	3.87	1.06	0.68	72%
10	3.83	3.59	5.5	3.89	1.07	0.71	75%
11	3.81	3.59	5.38	3.68	1.06	0.68	73%
12	3.79	3.56	5.03	3.8	1.06	0.76	80%
13	3.75	3.59	5.24	3.59	1.04	0.69	72%
14	3.56	3.33	5.24	3.31	1.07	0.63	68%
15	3.29	3.15	4.68	3.38	1.04	0.72	75%
AVG	3.92	3.69	5.59	3.81	1.06	0.68	73%
AVG AIR TEMP = 51							
AVG SURFACE TEMP = 52							

Table B-9: Load transfer efficiency for test section S4 during winter season.

TEST SECTION # 4 EAST BOUND STATIONS 94+90 TO 97+80							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.56	3.37	6.15	3.53	1.06	0.57	61%
2	3.65	3.38	6.42	3.78	1.08	0.59	64%

3	3.65	3.39	6.31	3.69	1.08	0.58	63%
4	3.34	3.1	5.86	3.35	1.08	0.57	62%
5	3.3	3.06	5.89	3.25	1.08	0.55	60%
6	3.26	3.02	5.39	3.21	1.08	0.60	64%
7	3.22	3	5.26	3.13	1.07	0.60	64%
8	3	2.8	5.39	2.95	1.07	0.55	59%
9	3.06	2.87	5.48	2.86	1.07	0.52	56%
10	3.3	3.1	6.5	2.67	1.06	0.41	44%
11	3.47	3.2	5.6	3.24	1.08	0.58	63%
12	3.41	3.2	5.33	3.67	1.07	0.69	73%
13	3.34	3	5.53	3.08	1.11	0.56	62%
14	3.19	2.95	5.53	3.03	1.08	0.55	59%
15	3.28	3.07	5.83	3.34	1.07	0.57	61%
AVG	3.34	3.10	5.76	3.25	1.08	0.57	61%
AVG AIR TEMP = 42							
AVG SURFACE TEMP = 38							
TEST SECTION # 4 WEST BOUND STATIONS 97+90 TO 95+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.9	3.56	6.26	3.56	1.10	0.57	62%
2	3.86	3.6	5.93	3.59	1.07	0.61	65%
3	3.67	3.42	5.87	3.14	1.07	0.53	57%
4	3.78	3.54	5.76	3.4	1.07	0.59	63%
5	3.7	3.47	5.57	3.43	1.07	0.62	66%
6	3.81	3.56	6.65	3.09	1.07	0.46	50%
7	3.63	3.39	5.76	3.5	1.07	0.61	65%
8	3.52	3.23	5.75	3.48	1.09	0.61	66%
9	3.58	3.32	5.42	3.28	1.08	0.61	65%
10	3.67	3.4	5.68	3.29	1.08	0.58	63%
11	3.44	3.18	5.48	3.24	1.08	0.59	64%
12	3.34	3.14	5.13	3.5	1.06	0.68	73%
13	3.19	3.03	5.55	3.08	1.05	0.55	58%
14	3.31	3.16	5.44	3.09	1.05	0.57	59%
15	3.52	3.2	5.43	3.16	1.10	0.58	64%
AVG	3.59	3.35	5.71	3.32	1.07	0.58	63%
AVG AIR TEMP = 47							
AVG SURFACE TEMP = 47							

Table B-10: Load transfer efficiency for test section S5 during winter season.

TEST SECTION # 5 EAST BOUND STATIONS 104+90 TO 108+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.53	3.26	5.52	4.01	1.08	0.73	79%
2	3.63	3.33	5.74	3.7	1.09	0.64	70%

3	3.52	3.29	5.64	3.81	1.07	0.68	72%
4	3.62	3.32	5.84	3.48	1.09	0.60	65%
5	3.47	3.26	5.57	3.25	1.06	0.58	62%
6	3.46	3.25	6.36	3.3	1.06	0.52	55%
7	3.65	3.44	5.72	3.83	1.06	0.67	71%
8	3.61	3.37	5.9	3.24	1.07	0.55	59%
9	3.53	3.32	5.65	3.5	1.06	0.62	66%
10	3.68	3.36	6.14	3.29	1.10	0.54	59%
11	3.6	3.36	6.41	2.92	1.07	0.46	49%
12	3.68	3.34	5.8	3.22	1.10	0.56	61%
13	3.48	3.19	5.95	2.91	1.09	0.49	53%
14	3.59	3.28	5.82	2.73	1.09	0.47	51%
15	3.55	3.19	5.28	3.19	1.11	0.60	67%
AVG	3.57	3.30	5.82	3.36	1.08	0.58	63%
AVG AIR TEMP = 44							
AVG SURFACE TEMP = 40							
TEST SECTION # 5 WEST BOUND STATIONS 108+90 TO 105+00							
JOINT #	MS-D1	MS-D3	LT-D1	LT-D3	A	LT	LTE
1	3.33	3.13	4.89	3.58	1.06	0.73	78%
2	3.46	3.25	5.93	3.11	1.06	0.52	56%
3	3.47	3.24	5.62	3.51	1.07	0.62	67%
4	3.31	3.03	5.46	3.34	1.09	0.61	67%
5	3.55	3.27	6.1	2.97	1.09	0.49	53%
6	3.43	3.25	6.29	3.35	1.06	0.53	56%
7	3.29	3.07	5.68	3.37	1.07	0.59	64%
8	3.32	3.09	5.99	3.07	1.07	0.51	55%
9	3.33	3.09	5.69	2.97	1.08	0.52	56%
10	3.42	3.18	6.25	2.74	1.08	0.44	47%
11	3.35	3.11	5.62	2.83	1.08	0.50	54%
12	3.33	3	5.39	3.13	1.11	0.58	64%
13	3.24	2.96	5.57	2.84	1.09	0.51	56%
14	3.26	2.99	5.45	2.74	1.09	0.50	55%
15	3.12	2.88	5.21	3.25	1.08	0.62	68%
AVG	3.35	3.10	5.68	3.12	1.08	0.55	60%
AVG AIR TEMP = 43							
AVG SURFACE TEMP = 42							