Report Number: FEP-01-08

ECLIPSE® SHRINKAGE REDUCING ADMIXTURE PRODUCT EVALUATION

FINAL REPORT

December 2008

1. Report No.	2. Government Accession No.	3. Recipients Catalog No.
FEP-01-08		

4. Title and Subtitle	5. Report Date
Eclipse® Shrinkage Reducing Admixture Product Evaluation	December 2008
	6. Performing Organization Code WisDOT Federal Experimental Project FEP-02-01
7. Author(s) Irene Battaglia, M.S.; Gary Whited, P.E.; Ryan Swank	**8. Performing Organization Report** WisDOT Federal Experimental Project Report FEP-01-08
9. Performing Organization Name and Address Wisconsin Department of Transportation Division of Transportation System Development Bureau of Technical Services Materials Management Section, Foundation and Pavements Engineering Unit 3502 Kinsman Blvd., Madison, WI 53704	**10. Work Unit No. (TRAIS)**
12. Sponsoring Agency Name and Address Wisconsin Department of Transportation Division of Transportation System Development Bureau of Technical Services Materials Management Section, Foundation and Pavements Engineering Unit 3502 Kinsman Blvd., Madison, WI 53704	**13. Type of Report and Period Covered** Final Report, 2002-2007
	14. Sponsoring Agency Code WisDOT Federal Experimental Project FEP-02-01

15. Supplementary Notes

16. Abstract

The use of Eclipse® Shrinkage Reducing Admixture was investigated in this study in concrete mixtures for bridge deck parapets. Based upon in-service performance results, Eclipse® reduced concrete shrinkage cracking in both the short and long term. Many shrinkage cracks that extended the full height of the parapet were noted in control sections, while only three such cracks were recorded in the Eclipse® test section. Laboratory test results indicated that Eclipse® concrete had approximately 14 percent less length change due to shrinkage at 56 days. There was little difference in compressive strength between mixes with and without Eclipse®.

Problems were encountered achieving air void levels in the concrete at the batch plant. The air content for the constructed Eclipse® test section was 5.4 percent, on the lower side of the 6.0 ± 1.5 percent target. Two subsequent batches were discarded due to inability to achieve acceptable air contents in the concrete when the Eclipse® product was incorporated into the mix. Because of this difficulty, several other planned test sections were abandoned.

Due to its tendencies to destabilize air void contents in the concrete mix, Eclipse® Shrinkage Reducing Admixture is not recommended for use in reduction of shrinkage cracking in WisDOT concrete construction.

17. Key Words	18. Distribution Statement
Eclipse® Shrinkage Reducing Admixture, concrete shrinkage cracking, drying shrinkage	Distribution unlimited Approved for public release

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	18	

ECLIPSE® SHRINKAGE REDUCING ADMIXTURE PRODUCT EVALUATION

FINAL REPORT

Research Study # FEP-02-01

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This study was conducted by the Materials Management Section, Division of Transportation System Development, Bureau of Technical Services of the Wisconsin Department of Transportation. The Federal Highway Administration provided financial and technical assistance for this research activity. This publication does not endorse or approve any commercial product even though trade names may be cited, does not necessarily reflect official views or policies of the agency, and does not constitute a standard, specification or regulation.

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1. Introduction

A problem often encountered in the construction of concrete bridges is the tendency for cracks to develop during curing in the decks, sidewalks and parapets. Development of cracks in these bridge structure elements can significantly reduce the service life of the bridge due to deterioration from freezing and thawing and accelerated corrosion of steel reinforcement from water infiltration. Such cracking must be repaired to prevent deterioration, which results in increased maintenance costs over the life of the structure.

Cracks can be caused by normal flexural stresses that occur after the concrete is put in service or by thermal effects that occur within the first weeks after placement. Cracking might also be due to drying shrinkage, which occurs when moisture in the cement paste evaporates without contributing to the hydration of cementitious materials. Drying shrinkage is common in bridge superstructures and is almost inevitable even with a well-designed Portland cement concrete that has been properly cured. Use of products or materials that reduce the amount of drying shrinkage could increase serviceability and extend the life of concrete structures. Therefore, the Wisconsin Department of Transportation (WisDOT) initiated a research project to evaluate the effectiveness of Eclipse® Shrinkage Reducing Admixture (SRA) in bridge construction.

2. Product Description

Manufactured by W.R. Grace & Company, Eclipse® SRA is a liquid concrete admixture designed to reduce material shrinkage due to drying. The Eclipse® product may be used in any concrete application, but the manufacturer states that it provides the greatest value in cases where drying shrinkage is most severe, such as in bridge decks, parking garages, marine structures and high performance floors. Eclipse® acts chemically on the surface tension of water, which is the primary mechanism of shrinkage. By reducing the surface tension of water inside concrete pores during curing, the forces exerted by water on the pore walls are reduced. This reduction in strain leads to decreased drying shrinkage. [1]

As reported by the manufacturer, concrete containing two percent Eclipse® by weight of cement has been shown to reduce laboratory test shrinkage by up to 80 percent after 28 days and up to 50 percent at the end of one year or more as measured by ASTM C 157. [2] An ultimate shrinkage reduction in the range of 25 to 50 percent with an Eclipse® dosage of two percent by weight of cement is reported by the manufacturer. Results might vary among mix designs; the primary driving force of this difference is the water-to-cementitious materials ratio (w/cm). The manufacturer states that in general, mix designs with a lower w/cm will perform better with respect to shrinkage reduction. Manufacturer tests of concrete with a w/cm less than 0.60 and Eclipse® added at 1.5 percent by weight of cement resulted in 28-day shrinkage reduction of 80 percent or more and 70 percent reduction of 56-day shrinkage. [3] Although the manufacturer recommends a dosage of two percent Eclipse® by weight of cement to maximize

effectiveness, it states that shrinkage reduction is linear between dosages of 1.0 to 2.5 percent and can be tailored to local performance needs. The manufacturer recommends additional testing if a dosage outside the 1.0 to 2.5 percent range is used. [1]

Eclipse® is reported by the manufacturer to be compatible with other admixtures such as air entraining agents, water reducers, mid-range water reducers, superplasticizers, set retarders, accelerators, silica fume admixtures and DCI® corrosion inhibitors. Slight retarding of set is observed when using Eclipse®, with set times generally increased by less than one hour. Inclusion of Eclipse in concrete mixes may also result in a reduction of compressive strength. The reduction is typically 10 percent or less and is minimized if a low w/cm is maintained. [3]

The manufacturer's recommended concrete mixture criteria for Wisconsin's test sections are outlined in Table 1. [4]

Table 1. Manufacturer-Recommended Mixture Specifications

Mixture Component	Manufacturer Recommendation
Water/Cement Ratio	0.45 maximum
Slump	3 to 4 inches
Air Entraining Agent	Darex II, Micro Air, AE 260
Mid-Range Water Reducer	5 ounces per 100 pounds of cement
Minimum Cement Content	535 pounds per cubic yard*
Fresh Air Content	6.5% ± 1.0%**
Eclipse® SRA	1.0 gallon per cubic yard (1.5% by weight of cement)

* WisDOT standard specifications require a minimum total cementitious materials content (cement plus fly ash and slag, if used) of 565 pounds per cubic yard. [5]

** WisDOT standard specifications require that fresh air content be in the range of 6.0% ± 1.5%. [5]

3. Background

In 1996, the Virginia DOT tested Eclipse® in a 1.25-inch bonded concrete overlay on a bridge deck. Laboratory test specimens were evaluated for length change according to ASTM C 157. [2] Concrete made with Eclipse® demonstrated less change in length than concrete without Eclipse®, indicating that the admixture did reduce shrinkage in test specimens. [6] However, in-service performance of both materials was approximately equal three years after construction. [7] The authors also indicated that a considerable amount of air entraining admixture was required to achieve proper air content in the Eclipse® mixtures. [8]

The Rhode Island DOT tested Eclipse® in a concrete bridge deck mixture. One lane of the two-lane bridge deck was constructed with Eclipse® and one without. Within a short period of time, the deck

without Eclipse® developed many shrinkage cracks. After two to three years in service, the Eclipse® deck was still performing well and had no cracks. [9]

Eclipse® was used to minimize shrinkage cracking in a concrete bridge deck overlay on the grounds of H.B. Fuller Company's headquarters. After three and a half years in service, no cracks had developed in the bridge deck. [10]

In 2006, the Wisconsin Highway Research Program (WHRP) concluded a study titled "Reducing Shrinkage Cracking of Structural Concrete Through the Use of Admixtures." [11] The objective of this laboratory study was to evaluate and compare the effectiveness of three different brands of SRAs in standard WisDOT concrete mixtures using fly ash. In addition, the effects of the SRAs on concrete air content and changes in air content during the first hour after concrete production were investigated. One of the admixtures tested was Eclipse® *Plus* from Grace Construction Products. A comparison of Eclipse® and Eclipse® *Plus* Material Safety Data Sheets indicates the same chemical components for both products, though in somewhat different proportions. The manufacturer indicates that the two products have virtually the same uses, although it is specifically stated that Eclipse® *Plus* is formulated for use in air-entrained concrete. [12] The WHRP report authors concluded that Eclipse® *Plus* was effective in reducing drying shrinkage during early periods of curing. It was also concluded that the admixture did not have an adverse effect on air content stability of fresh concrete, although there was a sharp increase in demand for air-entraining admixture compared to control mixes. A 10 to 20 percent reduction in compressive and split-tensile strength was also noted. [11]

4. Project Description

4.1 Test Site Selection

A WisDOT Federal Experimental Project was initiated in October 2000 to evaluate the effectiveness of Eclipse® SRA in reducing concrete shrinkage in a field application. The chosen site was a bridge deck that carries county trunk highway "G" over I-94 in Waukesha County. During testing of the concrete mix design, inconsistent results were found with regard to air content at different temperatures. A representative from W.R. Grace & Company did not feel confident using the mix on the bridge deck. Consequently, the proposal to provide Eclipse® to WisDOT for this research was withdrawn.

In the spring of 2003, a new research study was developed to test Eclipse® at two test sites. Because the effects of the Eclipse® admixture on concrete durability and endurance were unproven, it was decided that the bridge decks themselves should not be tested in this study. Instead, the admixture was specified for use in concrete for the bridge parapets. The sites selected for the research study were twin structures B-70-190 and B-70-191 on United States Highway (USH) 10 in Winnebago County (WisDOT Northeast Region, formerly District 3), and structure B-64-0082 on Clover Valley

Road over USH 12 in Walworth County (WisDOT Southeast Region, formerly District 2). Ultimately, only the Winnebago County test site was utilized for the research study. Problems using Eclipse® on the USH 10 structures led to the decision not to test the admixture in the Walworth County project.

4.2 Test Site Location

Structures B-70-191 (EB direction) and B-70-190 (WB direction) are located in Winnebago County on USH 10 near the town of Winchester in the Northeast Region (Figure 1). Both structures cross the Rat River, have two-lane one way traffic, and run east and west. The bridges are twin structures with identical features: a deck width of 43.0 ft, roadway width of 40.0 ft, bridge length of 91.7 ft and span length of 44.9 ft.

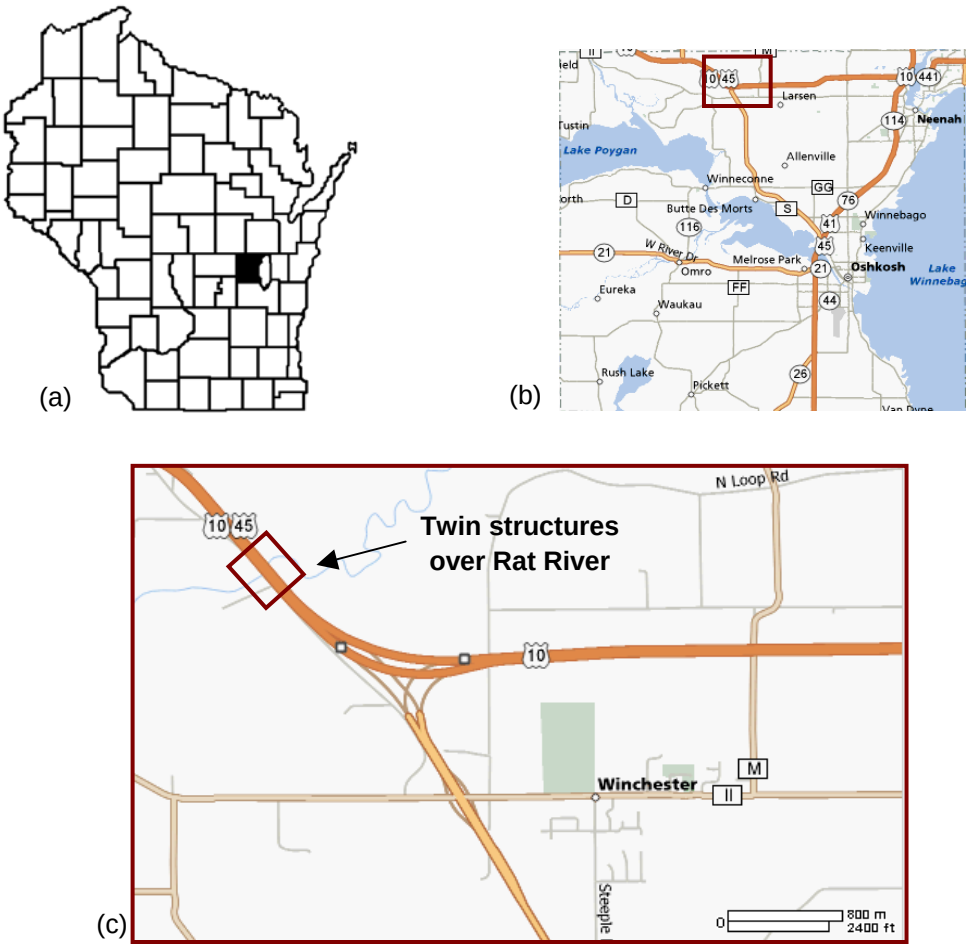

Figure 1. Study test location: (a) Winnebago County; (b) enlargement of Winnebago County with project location denoted by box; (c) detail of project location.

4.3 Test Site Description

Two structures were used for the Eclipse® product evaluation. Each of the two structures has two parapets on the north and south sides of the bridges. The eastern half of the southern parapet for structure B-70-190 was built as the test section using concrete containing the Eclipse® SRA. The remaining parapet sections on structure B-70-190 and both parapets of structure B-70-191 were built with concrete without Eclipse® and were used as control sections. (See Figures 4 and 5 in Section 7.)

5. Construction

The eastern halves of the four parapets for structures B-70-191 and B-70-190 were constructed on April 30, 2003 during cloudy and on/off light rain conditions. Mr. Chuck Stauber of W. R. Grace was on site to oversee the application of the Eclipse® product. Construction and mix procedures for Eclipse® were followed as suggested by the manufacturer, with the exception of recommended air content. WisDOT standard specifications permit an air content in the range of 6.0 percent ± 1.5 percent, rather than the manufacturer-recommended 6.5 percent ± 1.0 percent. [5] WisDOT Grade A-FA concrete, which contains 30 percent fly ash by weight of cementitious materials, was used for all mixes. [5]

Initially, both parapets on Structure B-70-190 were to be constructed with WisDOT Grade A-FA concrete containing the Eclipse® product. The eastern half of the south parapet on Structure B-70-190 was built using concrete with the Eclipse® admixture. Air content of the mix was measured at 5.4 percent, which was acceptable for construction. However, for the eastern half of the north parapet, two batches of concrete produced with Eclipse® had such low air content that they were rejected and discarded at the plant. The contractor and WisDOT then decided to terminate the trial, and the remainder of the parapet sections on structure B-70-190 were constructed with conventional concrete without Eclipse® and used as control sections in addition to the control sections on structure B-70-191. Fresh concrete test results are provided in Appendix A.

The western halves of all the parapets were constructed on May 1, 2003 using the standard WisDOT A-FA concrete mix. These parapets were also used as control structures for this study.

Based upon the air content variability problems experienced at the Winnebago County site, use of the Eclipse® product was cancelled for the Walworth County site and structure B-64-0082 was not included in the research study.

6. Laboratory Evaluation

Material was collected from the control and Eclipse® concrete batches for test specimens to measure compressive strength and shrinkage. Compressive strength was measured at 3, 7, 28 and 90 days

according to ASTM C 39 test procedures. [13] Concrete shrinkage was measured at 3, 7, 28, 56 and 90 days according to ASTM C 157 test procedures. [2] One Eclipse® and two control specimens were tested at each age.

6.1 Compressive Strength

Measured compressive strength values are provided in Table 2. Opening strength for WisDOT bridge superstructures is 3500 pounds per square inch (psi). [14] Concrete made with and without Eclipse® achieved this opening strength by approximately seven days.

Concrete compressive strength is influenced by air content. With all other properties equal, concrete with lower air content will have higher compressive strength. Because the air content of the Eclipse® concrete was more than one percent lower than the control mixes, it is important to correct for this difference for comparative purposes. The following equation is accepted for normalizing concrete compressive strength, f_c, to target air content, A_t, based on the measured air content, A_m: [15]

$$Corrected\ f_c = f_c \frac{1-0.05(A_t)}{1-0.05(A_m)}$$

The target air content for mixes in this study was 6.0 percent; all measured compressive strengths were normalized to this target value. Adjusted compressive strength values are shown in Table 3. Normalized compressive strength levels for concrete made with and without Eclipse® were within five percent at all test ages. These data indicate that with air content held constant, addition of Eclipse® did not adversely affect strength of the concrete.

Table 2. Measured Compressive Strength

Age (days)	Strength (psi)		
	Eclipse	Control 1	Control 2
3	3150	2790	2720
7	4000	3480	3510
28	5580	5210	5480
90	6880	6230	6290

Table 3. Compressive Strength Normalized to 6.0 Percent Air Content

Age (days)	Strength (psi)		
	Eclipse	Control 1	Control 2
3	3020	2980	2820
7	3840	3720	3640
28	5350	5570	5680
90	6600	6660	6520

6.2 Drying Shrinkage

Drying shrinkage occurs over time as pore water that is not consumed in the hydration reaction evaporates. Resulting internal strain causes the concrete to shrink. In constrained structures, this results in shrinkage cracking. In unconstrained test specimens, a decrease in specimen length results. Specimen length change is measured in laboratory shrinkage tests and is reported as a percentage of the specimen's original length.

Test results from this study are presented in Figure 2 and in Appendix B. Shrinkage values for the control mixes were within a typical range for normal weight concrete. [16] Shrinkage for concrete made with Eclipse® was less than that for the control mixes at all ages. Three-day and seven-day shrinkage values for Eclipse® concrete were 30 and 55 percent less than the average for the two control mixes, respectively. Later-age shrinkage reductions decreased from 23 percent at 28 days to 14 percent at 56 days. This reduction is significantly lower than the 25 to 70 percent reduction identified by the manufacturer to be possible at an age of 56 days. However, it is still a notable reduction compared to the control mixes tested in this study.

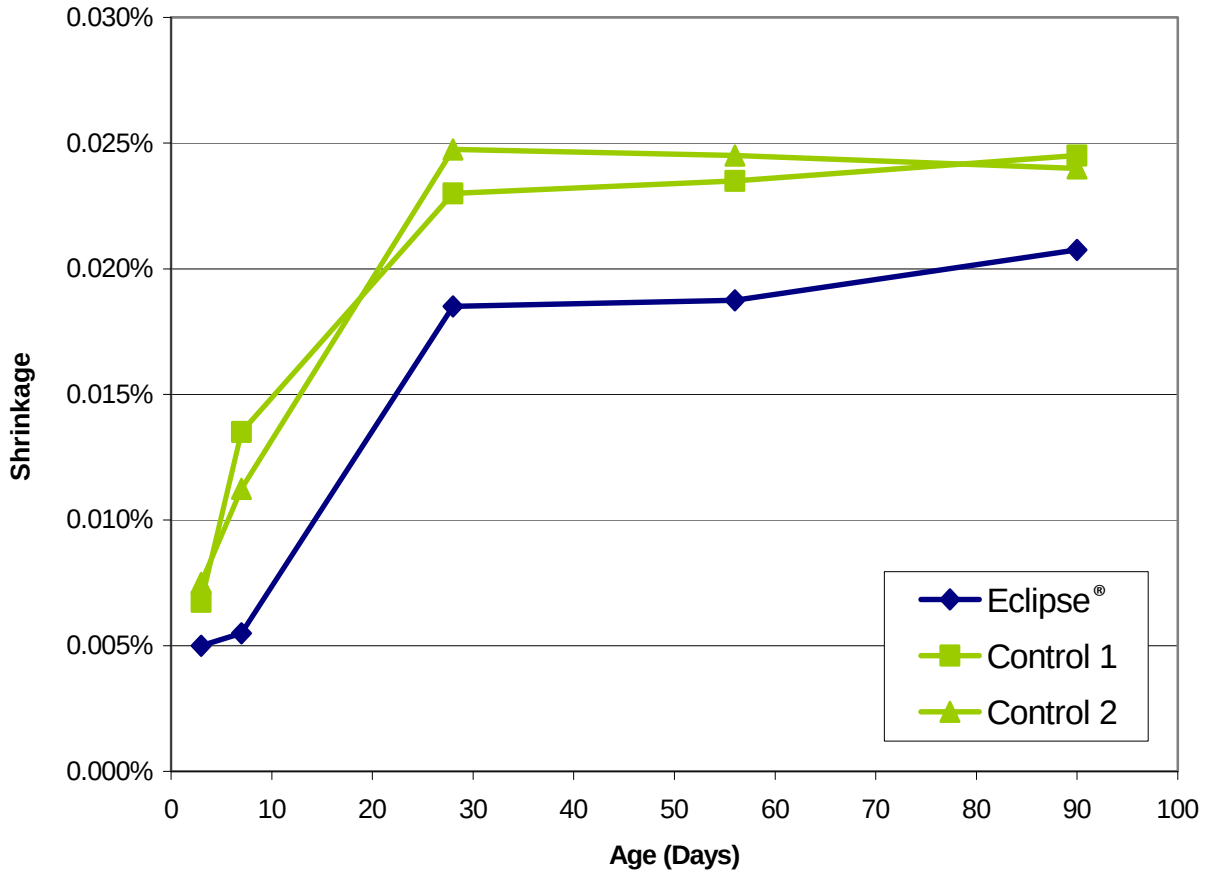

Figure 2. Shrinkage levels for Eclipse® and control mixes.

7. Performance Evaluation

To evaluate the effectiveness of Eclipse® in reducing the amount of shrinkage in the test sections, two field surveys were conducted to determine the amount of cracking that had occurred in the bridge parapets. The first survey was completed on June 24, 2003, approximately two months after construction, and the second on October 4, 2007, approximately four years after construction. The surveys included a visual examination and mapping of shrinkage cracks that had opened slightly. Surface crazing was also noted in all test and control sections. Figure 3 depicts these two types of cracking. The survey results are shown in Figures 4 and 5.

Cracking noted during the two-month evaluation is shown in Figure 4. Between three and nine cracks were identified in each parapet control section, and three cracks were documented in the Eclipse® test section. These observations indicate that addition of Eclipse® minimized shrinkage cracking in the short term.

Figure 5 shows results of the four-year evaluation. Cracks that developed after the 2003 survey are shown in red. The Eclipse® product continued to perform better than the WisDOT standard mix in the long term. All control sections had experienced further cracking while no additional cracks were noted in the Eclipse® test section. It can therefore be concluded that the Eclipse® admixture reduced shrinkage cracking in the long term.

It should also be noted that in both structures, a greater number of open shrinkage cracks occurred in parapets on the bridges' north sides. Shrinkage cracking in these south-facing parapets was likely exacerbated due to greater drying effects from the southerly sun. It was not noted whether the back sides of the north-facing parapets also had a greater number of open shrinkage cracks. Eclipse® was not tested in any of the south-facing parapets, so it is not known whether the admixture would have alleviated the sun's effects.

8. Conclusions and Recommendation

The use of Eclipse® Shrinkage Reducing Admixture in concrete mixtures for bridge deck parapets was investigated in this study. Based upon in-service performance results, Eclipse® reduced shrinkage cracking in both the short and long term. Many open shrinkage cracks that extended the full height of the parapet were noted in control sections, while only three such cracks were recorded in the Eclipse® test section. Laboratory test results indicated that Eclipse® concrete had approximately 14 percent less length change due to shrinkage at 56 days. Compressive strength test results showed little difference between mixes with and without Eclipse®.

Developing adequate air content levels in the concrete, however, was difficult. The air content for the constructed Eclipse® test section was 5.4 percent, which was on the low side of the target air content. Two subsequent batches were discarded due to unacceptably low air contents that resulted when the Eclipse® product was incorporated into the mix. Because of this difficulty, several other planned test sections were abandoned. In the time since this study's test sections were constructed, the manufacturer has developed a second product, Eclipse® *Plus*, which is specifically intended for air-entrained concrete. This product might have less of a negative impact on air content.

Due to its tendency to destabilize air void contents in the concrete mix, Eclipse® Shrinkage Reducing Admixture is not recommended for use by WisDOT to reduce shrinkage cracking in concrete bridge decks and superstructures.

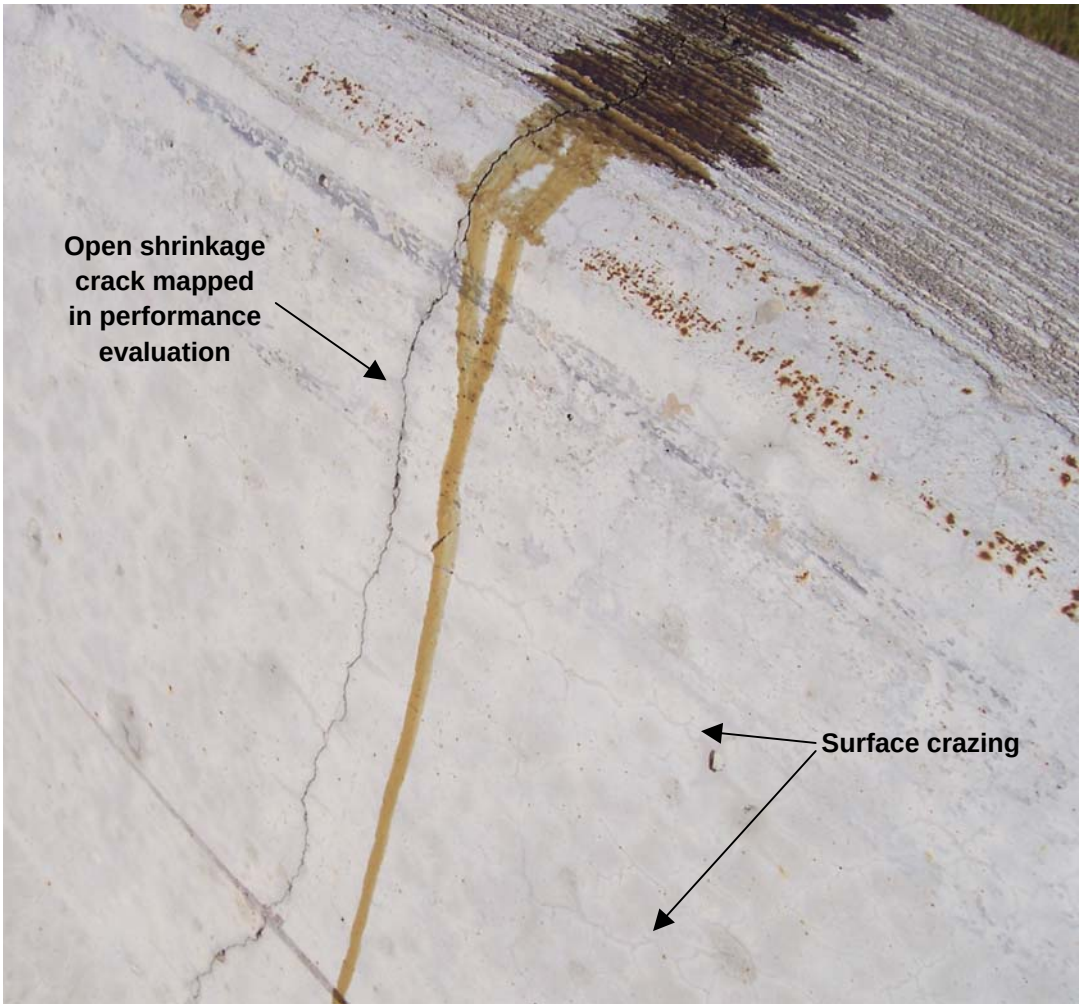

Figure 3. Cracking noted in performance evaluation.

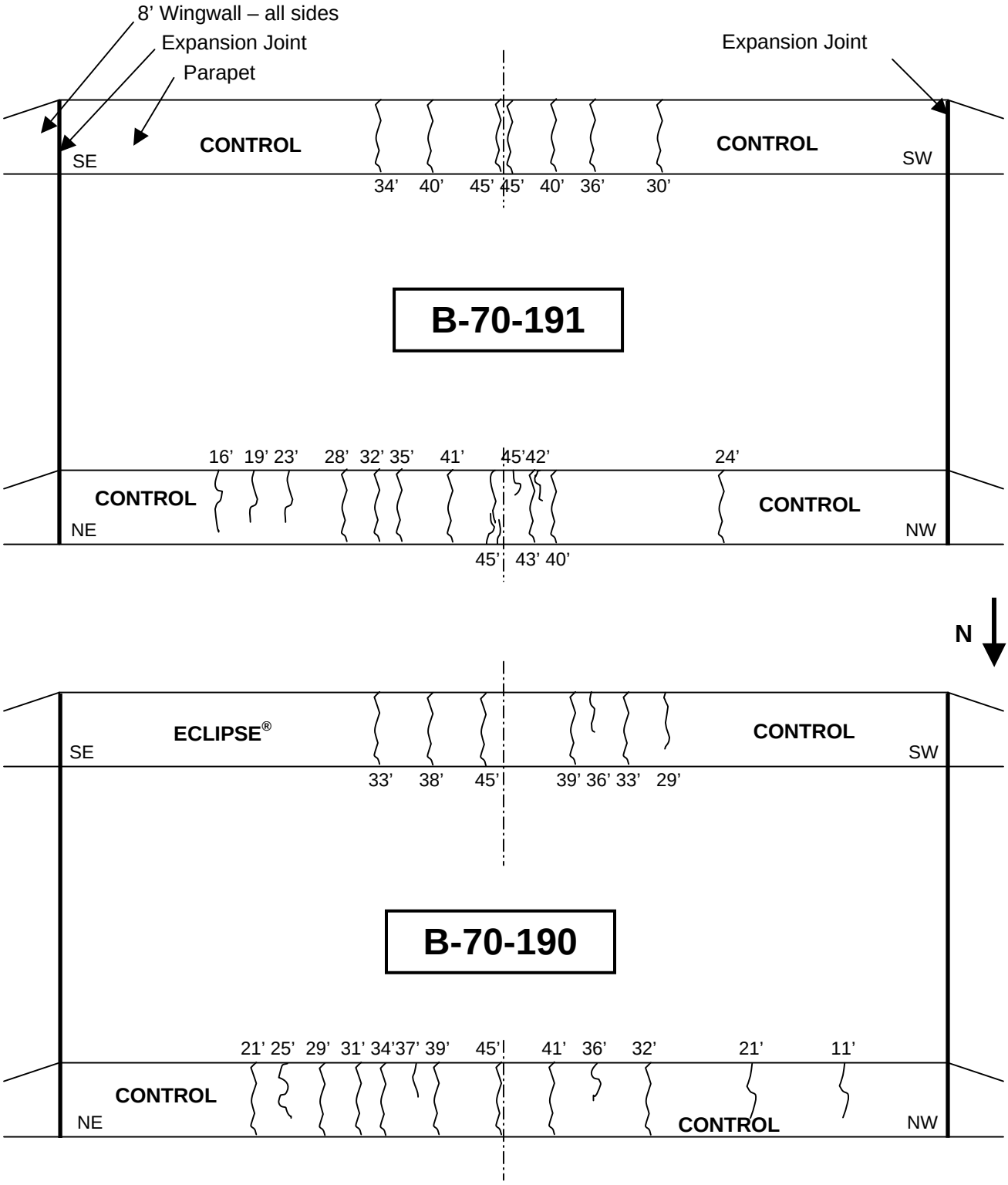

Figure 4. June 24, 2003 performance evaluation.

Note: Distances are measured from the expansion joints towards the center of the parapet.

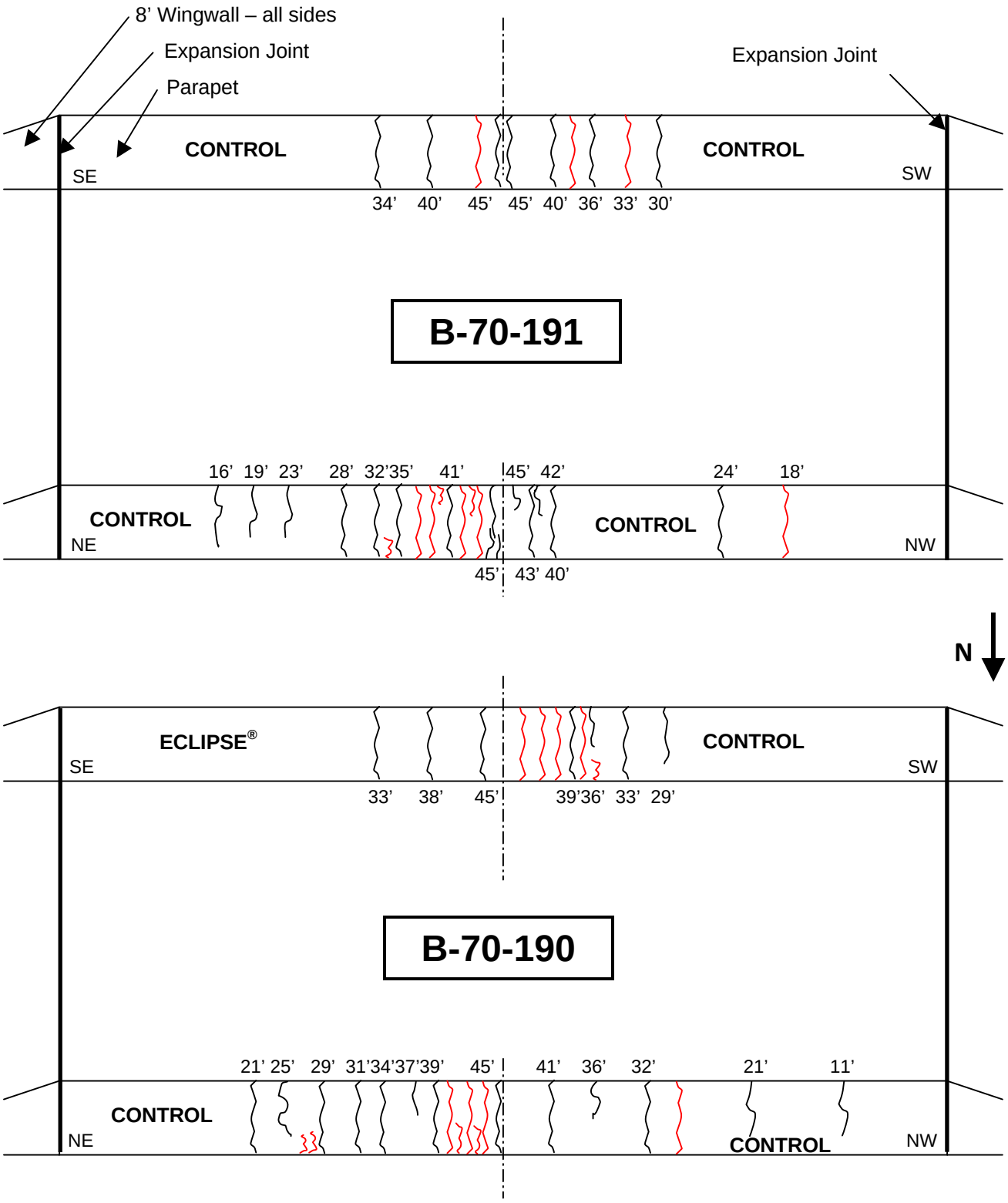

Figure 5. October 4, 2007 performance evaluation. New cracks noted in red.

Note: Distances are measured from the expansion joints towards the center of the parapet.

9. References

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APPENDIX A

Fresh Concrete Properties

Table A-1. Properties of Fresh Concrete Mixtures

Location		Air Content	Slump (inches)	Concrete Temperature (°F)
East Parapets April 30, 2003 construction	Structure B-70-191 Batch #1 Control 1	6.9%	3.5	64
	Structure B-70-191 Batch #2 Control 2	6.5%	3.25	65
	Structure B-70-190 Batch #1 Eclipse®	5.4%	3.0	64
	Structure B-70-190 Batch #2	Out of range	Tests not performed	
West Parapets May 1, 2003 construction	Structures B-70-190 and B-70-191 Control	Data not available		

Note: Ambient temperature during pour: 48°F.

APPENDIX B

Length Change Results

Note: Specimen gage length = 10 inches for all mixtures

Table B-1. Shrinkage Results for Eclipse® Mixture
Initial comparator reading = 0.0269

Age (days)	Comparator Readings			Length Change
	A	B	Average	(%)
1	0.02745	0.0264	0.026925	NA
3	0.02785	0.027	0.027425	0.005
7	0.02785	0.0271	0.027475	0.0055
28	0.0294	0.02815	0.028775	0.0185
56	0.0294	0.0282	0.0288	0.01875
90	0.0295	0.0285	0.029	0.02075

Table B-2. Shrinkage Results for Control 1 Mixture
Initial comparator reading = 0.0265

Age (days)	Comparator Readings			Length Change
	A	B	Average	(%)
1	0.0269	0.0261	0.0265	NA
3	0.02775	0.0266	0.027175	0.00675
7	0.0285	0.0272	0.02785	0.0135
28	0.0295	0.0281	0.0288	0.023
56	0.0297	0.028	0.02885	0.0235
90	0.0297	0.0282	0.02895	0.0245

Table B-3. Shrinkage Results for Control 2 Mixture
Initial comparator reading = 0.0239

Age (days)	Comparator Readings			Length Change
	A	B	Average	(%)
1	0.0223	0.02555	0.023925	NA
3	0.023	0.02635	0.024675	0.0075
7	0.0234	0.0267	0.02505	0.01125
28	0.02535	0.02745	0.0264	0.02475
56	0.025	0.02775	0.026375	0.0245
90	0.0249	0.02775	0.026325	0.024