CONCRETE BARRIER DISTRESS IN LA GRANDE, OREGON

Final Report

PROJECT SR 500-211

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by

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16. Abstract

Several precast concrete barriers in eastern Oregon were noted to be deteriorating at an advanced rate. The ODOT Research Unit took several core samples from the barriers and conducted analyses. Petrographic evaluations determined that the strongest link between barrier deterioration and any one factor was the amount of entrained air. In general, older, poor-quality concrete, which was continually exposed to freeze-thaw events, exhibited advanced signs of distress.

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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
	NOTE: Volumes greater than 1000 L shall be shown in m^3.			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Concrete barriers are just one of many roadside safety devices used by transportation departments. In Oregon, several concrete median barriers were observed to be deteriorating at an accelerated rate, either due to age or other unknown factors. The purpose of this study was to investigate the cause(s) of distress and/or deterioration in barriers located in eastern Oregon, near the town of La Grande. The research approach involved the collection of core samples from several barriers. These samples were then sent to a lab for petrographic analysis. The data collection methods and the results of the analyses are discussed in this report. Overall findings and conclusions are also included.

1.2 PROJECT AREA LOCATIONS

Initial field observations of barriers in the La Grande area, combined with supplemental research, helped to identify three distinct project areas. The project areas were generally located in northeastern Oregon, in ODOT Region 5, District 13, near the town of La Grande. The project areas consisted of the following three locations along Interstate-84: Upper Meacham at approximately milepost (MP) 244; Lower Meacham at approximately MP 258; and Ladd Canyon at approximately MP 272 (Figure 1.1).

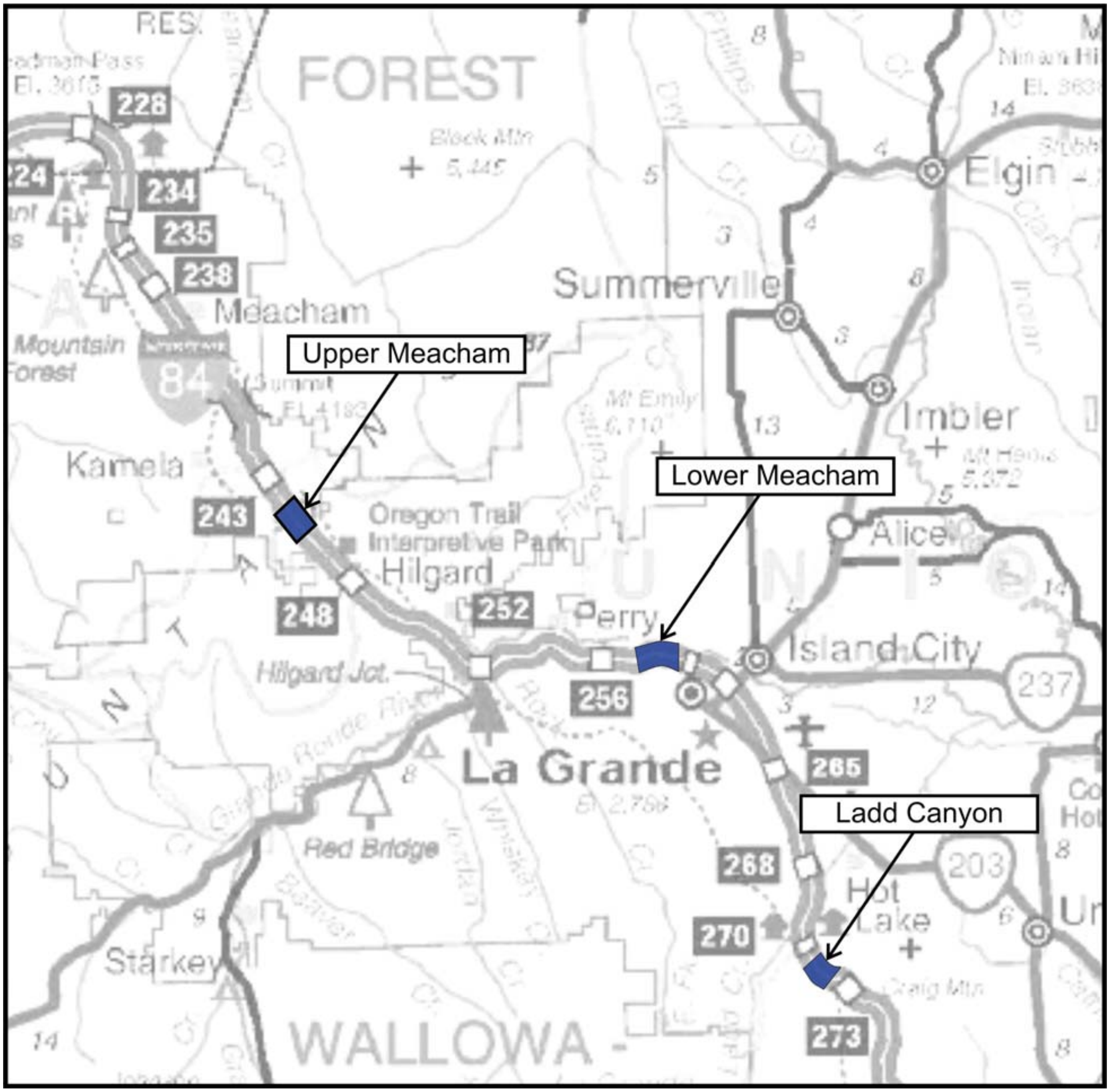

Figure 1.1: Project area locations as depicted on the Oregon Department of Transportation 2007-2009 Oregon Official State Map

2.0 BACKGROUND RESEARCH

There are many factors or variables that can affect the durability of concrete barriers. In Oregon, the standard design life of a barrier is around 30 years (*MacDonald 2007*). In theory, the amount of distress seen in a barrier will be linked to the barrier age, or number of years it has been in place. In actuality, there are several other factors that can potentially affect durability.

Variables such as the amount of moisture in the air, precipitation, and freezing and thawing events can all play a role in concrete distress and deterioration. The introduction of outside agents or chemicals, such as deicers, can present additional variables. The influence of these variables or factors is determined by the overall quality or durability of the concrete. Concrete quality can be linked to such factors as the water-to-cement ratio and the amount of entrained or entrapped air. In an attempt to correlate the cause(s) of concrete barrier deterioration in eastern Oregon, these and other variables were examined.

2.1 CONCRETE BARRIERS IN OREGON

Historically, three styles of barriers have been used in Oregon. The newest style, the Tall "F"-Shape barrier with a bolted channel, is modeled after the federal barrier design. It has been incorporated into the standard ODOT specifications as RD545 (*ODOT 2007*). The Tall "F"-Shape design represents modifications to the previous Standard "F"-Shape with pin and loop (RD500) (*ODOT 2006*). The third style of barrier, the Jersey-Style, was used prior to 1987, and was connected by tongue and groove.

The majority of ODOT median barriers are precast, Portland cement concrete (PCC). These barriers come from various approved vendors who use curing methods of either water or steam. ODOT specifications outline that each barrier be coated with at least two layers of a water base coating (*ODOT 2008*).

2.1.1 Concrete Barriers in the Project Areas

The approximate age and design of barriers from each of the three project areas is summarized in Table 2.1 below.

Table 2.1: Approximate type and age of concrete barriers sampled, grouped by project area location

Project Area Location	Barrier Design Type	Approximate Year Barrier Was Put in Place	Approximate Age of Barrier at Time of Current Study (years)
Ladd Canyon	Tall "F"-Shape	2004	3
Lower Meacham	Jersey Style	1980	27
Upper Meacham	Jersey Style	1980	27

2.2 ENVIRONMENTAL CONDITIONS OF THE PROJECT AREAS

The three project areas are generally located in eastern Oregon, in the Blue Mountain Ecological Province. The province receives, on average, around 20 inches of annual precipitation, and about 45 inches in portions closest to the project areas. In winter months, temperatures for the province generally range from 34°F to 15°F (*Anderson, E.W., Borman, M.M., and Krueger, W.C. 2008*).

The Upper Meacham project area is located at approximately MP 244 on Interstate-84, at an elevation of 4,050 feet (ft) above mean sea level (AMSL). The Ladd Canyon project area, which has similar climate characteristics to Upper Meacham, is located farther east at approximately MP 272 on Interstate-84, but at a similar elevation (3,630 ft AMSL). In these areas, the highest levels of precipitation are recorded in winter months, when the overall annual temperatures are lowest (as depicted on the temperature and precipitation chart (Figure 2.1) for Meacham) (*Western Regional Climate Center 2008*). Figure 2.2 shows the extreme temperatures recorded at the Meacham weather station from 1948 to 2007.

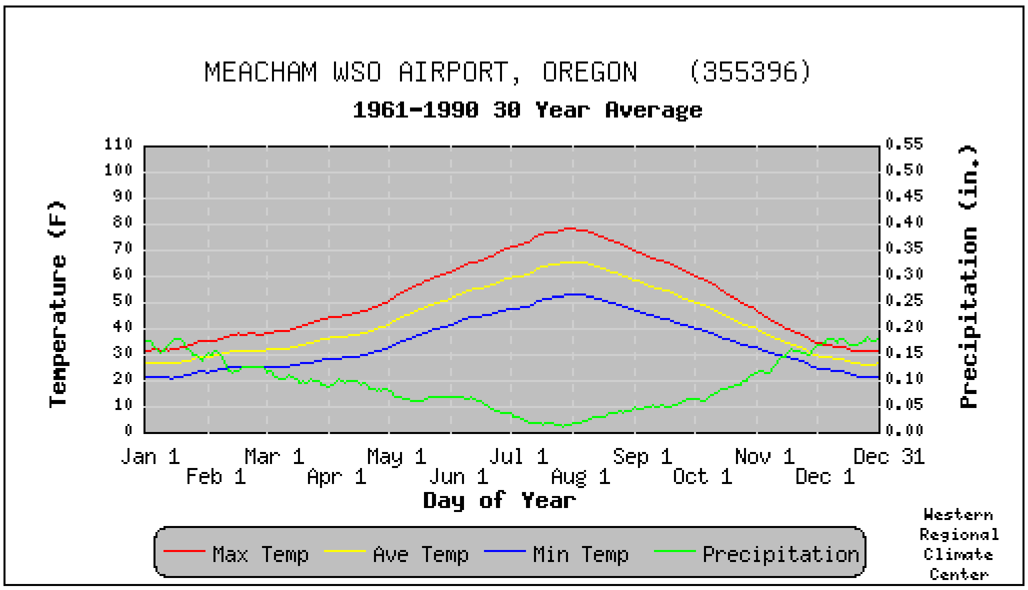

Figure 2.1: Thirty year temperature and precipitation average for the Meacham, Oregon weather station (*Western Regional Climate Center 2008*)

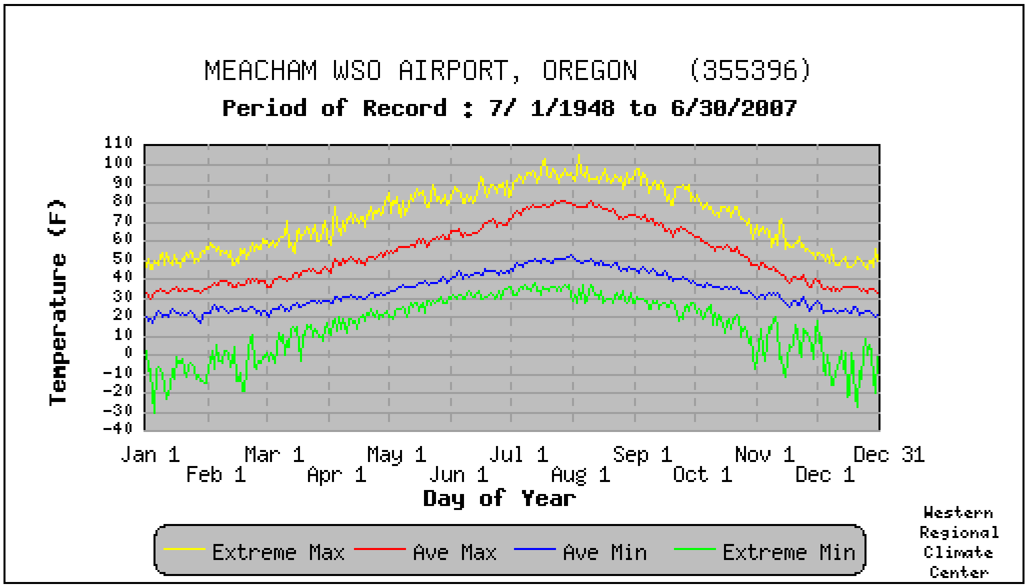

Figure 2.2: Annual extreme temperatures for the Meacham, Oregon weather station (*Western Regional Climate Center 2008*)

The third project area, Lower Meacham, located at approximately MP 258 (between Upper Meacham and Ladd Canyon) has a lower elevation, around 2,786 ft AMSL; which is similar to the elevation of the town of La Grande, Oregon. The precipitation levels in this area (Figure 2.3) are less than both Upper Meacham and Ladd Canyon, and average temperatures are 5-10ºF warmer (*Western Regional Climate Center 2008*). Figure 2.4 shows the extreme temperatures recorded at the La Grande weather station from 1948 to 2007.

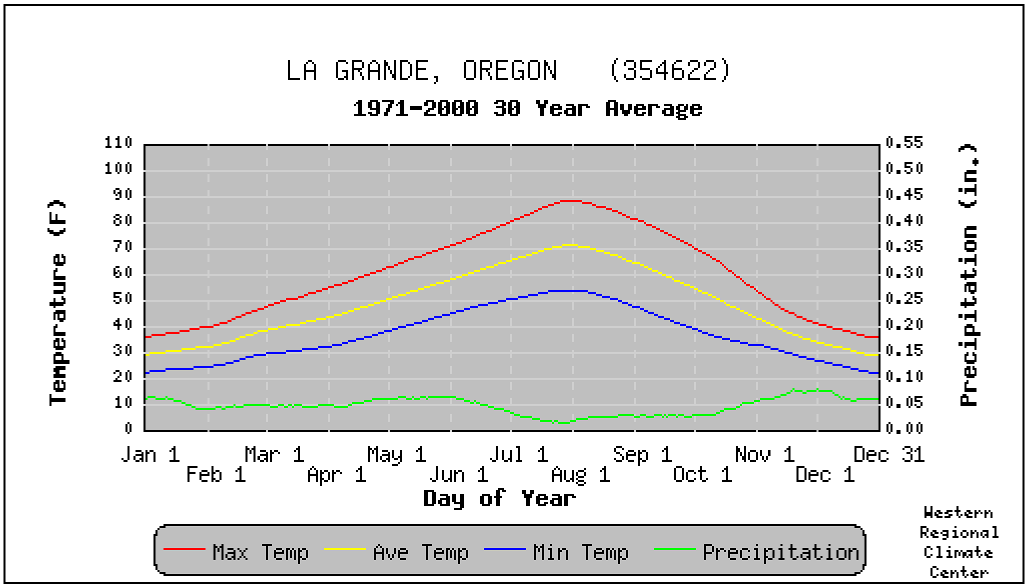

Figure 2.3: Thirty year temperature and precipitation average for the La Grande, Oregon weather station (*Western Regional Climate Center 2008*)

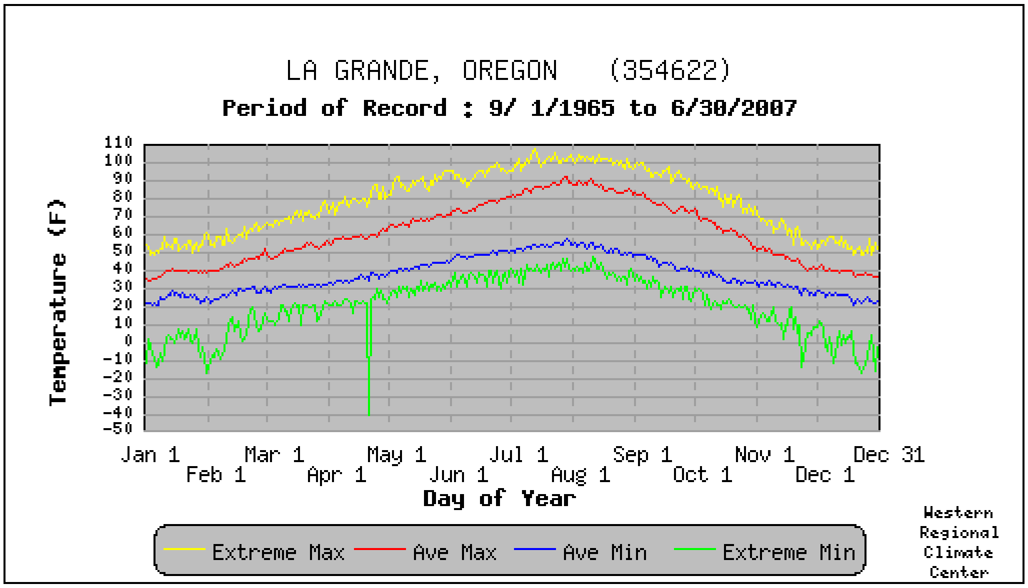

Figure 2.4: Annual extreme temperatures for the La Grande, Oregon weather station (*Western Regional Climate Center 2008*)

2.3 LITERATURE REVIEW

2.3.1 Concrete Barrier Studies

To date, there have been a limited number of research studies examining the durability of concrete barriers. These studies have focused on cast-in-place barriers, and not precast barriers (such as those found in the project areas). Some factors, such as thermal stress and the composition of the concrete, are similar in both cast-in-place and precast barriers.

According to a report published by the Michigan DOT in 2004, the primary factor affecting the durability of cast-in-place concrete barriers in Michigan was determined to be the formation of multiple full- or partial-depth vertical cracks (*Aktan and Attanayaka*). It was determined that the cracks resulted from volume changes under thermal and shrinkage load strain that developed during the cement hydration process. This has proven not to be an uncommon problem as the hydration of Portland cement is exothermic and can generate enough heat in mass to cause cracking from the thermal differential volume changes (*Winterbottom and Goodwin 2005*).

According to the findings of the Michigan study, early barrier deterioration was initiated by vertical cracking and accelerated by the presence of voids, cavities, and the overall quality of the concrete barrier (*Aktan and Attanayaka 2004*). Other distress, commonly seen in slipform barriers, includes continuous longitudinal/horizontal cracking and staining approximately four inches below the top surface of the barrier. This cracking and staining occur as the concrete is weighted under its own mass and slumps downward (*Staton and Knauff 2007*).

2.3.2 Standards in the Composition of Concrete: Freeze-Thaw Damage and Resistance

Both the Ladd Canyon and Upper Meacham project areas are repeatedly exposed to freeze-thaw cycling during winter months (see Section 2.2). Freezing and thawing conditions also exist at the Lower Meacham project area, but they occur less frequently than both Ladd Canyon and Upper Meacham. The composition of the concrete barriers in these project areas should reflect optimum standards for freeze-thaw conditions. The following literature review incorporates optimum freeze-thaw standards, where available or applicable.

As stated previously, the quality of the concrete comprising the barrier is a key factor in the durability of the system. Concrete quality is often tied to factors such as the amount of entrained air, entrapped air, the amount of cement, the water-to-cement ratio, and aggregate quality. For example, excess water, or water that is not consumed during the hydration process, will remain in the pore spaces and create tiny capillaries (*Bacho and Procopio 2007*). As the concrete freezes, water in these capillaries will be pushed through the capillaries, away from freezing sites. When these capillaries fill, hydraulic pressure is exerted creating micro cracking (*Tanesi and Meininger 2006; Bacho and Procopio 2007; Staton and Knauff 2007*). To minimize the capillary porosity, a water to cement ratio between 0.35 and 0.50 is recommended (*Bissonnette, et al. 1999*).

Freeze-thaw damage occurs when the critical saturation point is reached. This point is reached when the capillaries in the cement paste are occupied by more than 91.7 percent of water (*Powers 1945; Tanesi and Meininger 2006*). When the water inside the capillaries freeze, hydraulic pressure is exerted because the water expands in volume by approximately nine percent when it freezes (*Powers 1945; Tanesi and Meininger 2006; Petersen, et al. 2007*).

The amount of entrained air in the cement paste is also an important factor, especially in concretes exposed to freezing and thawing conditions. An air void system with a spacing factor between five and seven percent is recommended for freeze-and-thaw conditions (*Tanesi and Meininger 2006*). For the amount of entrained air, the Oregon DOT specifies 4-7 percent (*ODOT 2002*).

2.3.3 The Potential Effect of Deicing Solutions on Concrete

Barriers found in the project areas were exposed to varying amounts of liquid deicers. Both Meacham sites had been exposed to deicers for the previous 10 years, while the newer barriers in Ladd Canyon, had been exposed for the previous three years. Deicers are known to cause the following types of deterioration in reinforced concrete: corrosion of reinforced steel, advanced freeze-thaw damage, and weakening of the cement paste.

The pH level of the concrete at the steel reinforcement needs to be 8.5 or above in order to maintain passivation (*Winterbottom and Goodwin 2005*). If the passivity is lost, then the steel can actively corrode (*Winterbottom and Goodwin 2005; Mussato, et al. 2004*). Concrete typically has a pH level of 12 to 13; however, chloride ions in high enough concentration can depassivate the steel. This is important, especially where the concrete is exposed to chloride ions, such as those present in liquid deicing solutions.

Deicer solutions can be drawn into the concrete through the capillaries during freezing and thawing cycles (*Bacho and Procopio 2007*). The deicer reduces the freezing point of water, resulting in multiple freezing and thawing cycles as the concrete temperature fluctuates (*Staton and Knauff 2007*). Because the deicer latent water is super-cooled, when the water does freeze, it does so at a much faster rate, creating a greater hydraulic pressure (*Sutter 2005*).

In Oregon, magnesium chloride is used as both an anti-icer and deicer. Magnesium chloride solutions have been observed to interact and replace specific minerals in cement paste. The primary interaction that has been noted is the replacement of cementious calcium-silicate-hydrate (C-S-H), with non-cementious magnesium-silicate-hydrate (M-S-H) (*Lee, et al. 1998; Mussato, et al. 2004; Sutter, et al. 2006*). The M-S-H bond is weaker than that of C-S-H and the overall size of M-S-H is larger. The formation of M-S-H leads to expansive mineral growth, which can, at least in part, be responsible for premature deterioration (*Lee, et al. 1998*).

When M-S-H is formed, calcium is replaced by magnesium, and mobile calcium is created. This calcium can be precipitated as calcite ($CaCO_3$) and/or portlandite ($Ca(OH)_2$) in the cement paste and aggregate pores (*Cody, et al. 1996*). The newly-formed minerals may exert crystal growth pressures and initiate microcracking (*Cody, et al. 1996*).

The following microscopic characteristics of deicer stress were noted in the 1997 publication, *Ettringite: Cancer of Concrete*, by Scott Wolter of the American Petrographic Laboratories (in *Sutter 2005*):

- Microcracking propagating around aggregate particles and through the paste only;
- Aggregates relatively intact with virtually no reaction rims of silica gel observed;
- Deterioration within the paste only;
- Microcracking within the paste occurring predominantly sub-parallel to the deteriorating surface;
- Secondary deposits of ettringite within the air-void system and microcracks; and
- Less microcracking and secondary deposits as distance increases from the deteriorating surface.

3.0 FIELD METHODS AND DATA COLLECTION

Prior to the start of the research study, the ODOT Research Unit was contacted by District personnel, who had noted a recent acceleration in the distress of concrete median barriers near La Grande, Oregon. Several photographic images were taken and sent to the researchers. Initial background research was conducted prior to any field investigations.

The three areas that were selected for field analysis (Ladd Canyon, Upper Meacham, and Lower Meacham), were selected based on the initial observed amount of distress, age of the barriers, exposure level to freezing and thawing, and exposure to magnesium chloride (Table 3.1). Indicators of distress included cracks, scaling, disintegration, delamination and popouts. Advanced distress was characterized by the presence of two or more of these indicators, mostly covering the entire barrier; while minimal distress was the sporadic appearance of one or two indicators. Exposure to freezing and thawing was determined by the general climate characteristics of the project area, including elevation and average temperatures, as discussed in Section 0. Areas experiencing multiple fluctuations in daily temperatures, above and below freezing, were characterized as having a 'high' level of exposure; where temperatures varied less frequently, such as at lower elevations, exposure to freeze-thaw events was 'moderate.' Exposure level to deicers was determined by the application frequency. During winter months, areas receiving multiple applications in a single day or in a week were rated as having a 'high' exposure level, while areas where deicers were only occasionally applied were characterized as 'low.'

Table 3.1: Deterioration, age and exposure characteristics for barriers in the project areas

Project Area Location	Observed Amount of Distress	Age	Exposure Level to Freeze-Thaw	Exposure Level and Time (years) Exposed to Deicers	
Ladd Canyon	minimal	3	high	high	3
Lower Meacham	moderate	27	moderate	low	10
Upper Meacham	advanced	27	high	high	10

The condition of several median barriers, in each of the three project areas, was observed and recorded. A field form was prepared to map and record barrier distress and deterioration. The Aktan and Attanayaka (*2004*) reinforced concrete barrier distress classification scheme was utilized during field observations (Table 3.2). Completed field forms are attached to this report as Appendix A.

In addition to the observational analysis, horizontal core samples were also collected. Four-inch diameter cores were removed using a boring drill, cooled by distilled water (Figure 3.1). The cores were extracted from various locations on the barriers.

Figure 3.1: Example of core sample extraction. This core (001) was taken from barrier 001 in Ladd Canyon

Table 3.2: Reinforced concrete barrier distress classification scheme

Spall or Disintegration	A fragment, usually in the shape of a flake, detached from a larger mass; a small spall shape is roughly circular or oval or in some cases elongated, is more than 0.8 in. in depth and 6 in. in greatest dimension.	
Delamination	A separation along a plane parallel to a surface.	
Horizontal cracking	Cracks that develop parallel to the length of a member. Also referred to as longitudinal cracking.	
Corrosion	Destruction of rebar by chemical, electrochemical, or electrolytic reaction with its environment.	
Efflorescence	A deposit of salts, usually white, formed on a surface, the substance having emerged in solution from within concrete and subsequently been precipitated by evaporation.	
Vertical Cracking	Cracks that develop at right angles to the longitudinal direction of the member. Also referred to as transverse cracking.	
Map Cracking	Intersecting cracks that are near the concrete surface.	
Popouts	The breaking away of small portions of a concrete surface which leaves a shallow, typically conical, depression; small popouts leave holes up to 0.4 in. in diameter, medium popouts leave holes 0.4 to 2 in. in diameter, large popouts leave holes greater than 2 in. in diameter.	

Source: Aktan, Haluk, Ph.D, P.E. and Attanayaka, Upul. *Causes and Cures for Cracking of Concrete Barriers*: Table 2-1 Types of Distress Observed on Reinforced Concrete Barriers. Michigan Department of Transportation, Research Report RC-1448. August 2004.

3.1 LADD CANYON PROJECT AREA

Barriers in the Ladd Canyon project area measured approximately 12.5 feet in length. Minimal map cracking was observed on all barriers. The barriers were coated with a latex paint, which appeared to be in good condition on most barriers, though it had worn on some top surfaces. Where small staples appeared on the exterior surface, iron oxide leaching had occurred. Overall, the observed damage/distress of the barriers was minimal.

Four core samples were extracted from four median barriers in the Ladd Canyon project area along Interstate-84, at approximately milepost 272. The samples were taken from the westbound lanes of traffic near the highpoint of a downgrade slope. Two of the cores were sent to a lab for petrographic analysis (Cores 002 and 003).

Core 002 was extracted from the upper, eastern portion, of barrier 002 (Figure 3.2). The core was removed intact. Minimal surface map cracking was observed over the entire surface of the barrier. Approximately 5-10 low severity horizontal and transverse cracks were observed, averaging 2-6 inches in length. At the top of the barrier, small portions of the latex paint coating had come off, apparently where it had not bonded well will with the aggregate. Iron oxide was concentrated around two exposed staples.

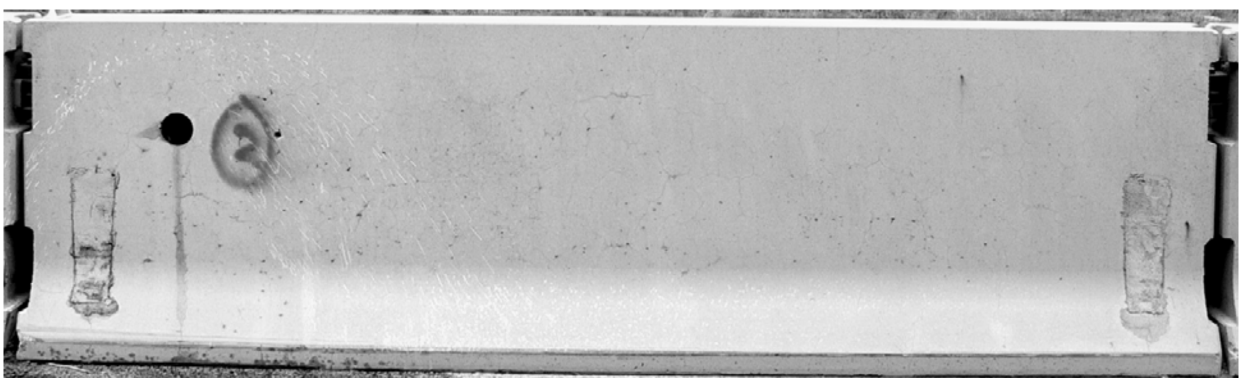

Figure 3.2: Overview photograph of barrier 002 in the Ladd Canyon project area

Core 003 was removed from the west end of barrier 003 (Figure 3.3). The core was taken intact. The surface face of the core included a staple surrounded by rust. Several reinforcing steel elements were included in the interior of the sample. Overall, this barrier had less cracking than 002, and the paint was in better condition. Aggregate was exposed in the lower, eastern, portions of the barrier. These areas were likely damaged by a snow plow.

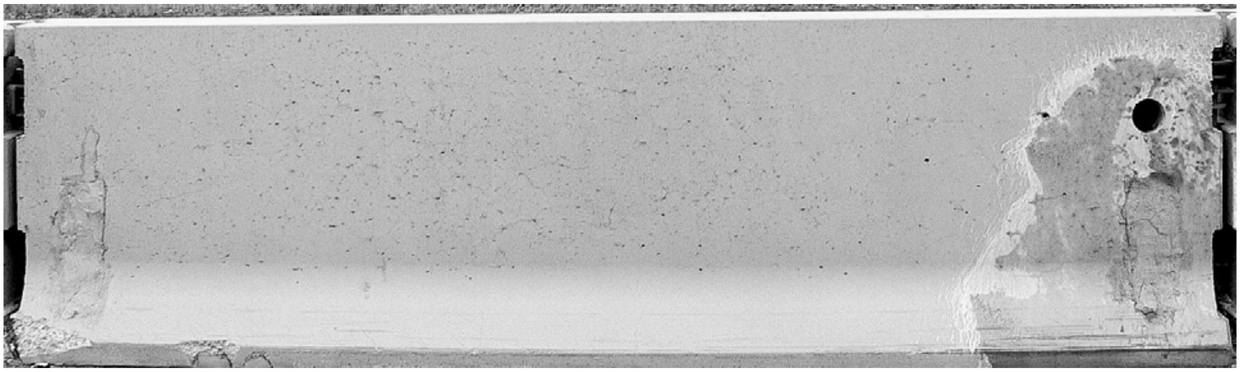

Figure 3.3: Overview photograph of barrier 003 in the Ladd Canyon project area

3.2 LOWER MEACHAM PROJECT AREA

The Lower Meacham project area was located along Interstate-84, at approximately milepost 258. The cores were extracted from the westbound lanes in a relatively flat area. The barriers were shorter in height and length than those found at the Ladd Canyon project area. The Lower Meacham barriers were Jersey-style and measured approximately 10-feet long. There was variability in the amount of map cracking between barriers, from low to moderate. The latex paint coating was in relatively poor condition on most barriers, especially on the top surfaces. Overall, the observed damage/distress of the barriers was moderate.

One core sample (005) was extracted from the Lower Meacham project area. This core sample was sent to the lab for petrographic analysis and comparison. The sample was removed intact from the western portion of the barrier, at the upper section (Figure 3.4). There was no apparent transverse or horizontal cracking on the surface of the barrier, but there were a few small map cracked areas. The lower, eastern corner of the barrier was broken off, likely by a snowplow blade.

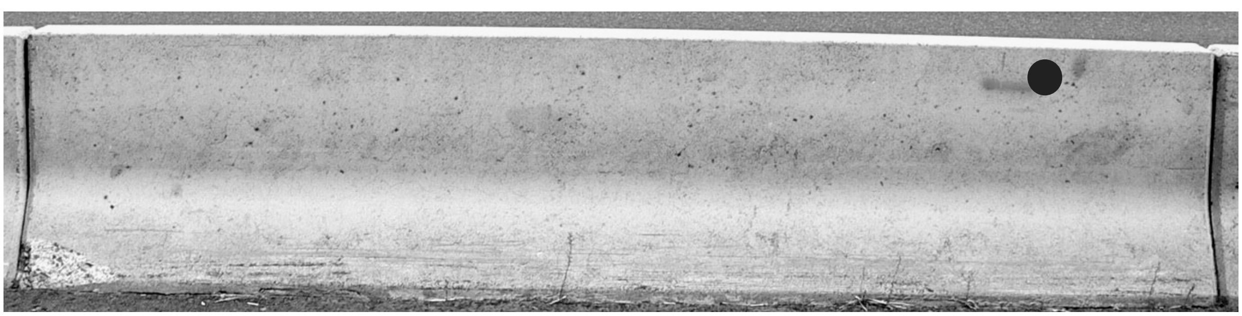

Figure 3.4: Overview photograph of barrier 005 in the Lower Meacham project area

3.3 UPPER MEACHAM PROJECT AREA

The Upper Meacham project area was located along Interstate-84 at approximately milepost 244. The cores were extracted from the eastbound lanes, along the curve of an upward grade slope. The barriers were the same size, shape and approximate age as those at the Lower Meacham site.

These barriers, however, exhibited the most advanced signs of distress seen in any of the project areas.

The barriers at Upper Meacham exhibited widely differing degrees of distress and deterioration. Some of the more advanced distress included large sections of disintegrated and missing corners and top sections, as well as full length and depth vertical cracks. Some of the more minor distress included: delamination of latex paint, minor cracking and pop-outs.

Four core samples were extracted from four different barriers at Upper Meacham. Two of the core samples (007 and 008) were sent to the lab for petrographic analysis.

The distress seen in barrier 007 was some of the most advanced noted during the field study (Figure 3.5). Several transverse cracks were observed, averaging 1 foot in length. Roughly the same number of horizontal cracks, as transverse cracks, (5-10) were also observed, but these cracks were much longer, averaging 7-10 feet. The transverse and horizontal cracks were of medium severity (width: greater than 3 mm, but less than 13 mm). Map cracking was present the entire length of the upper 6-inches of the barrier and occurred sporadically across the surface.

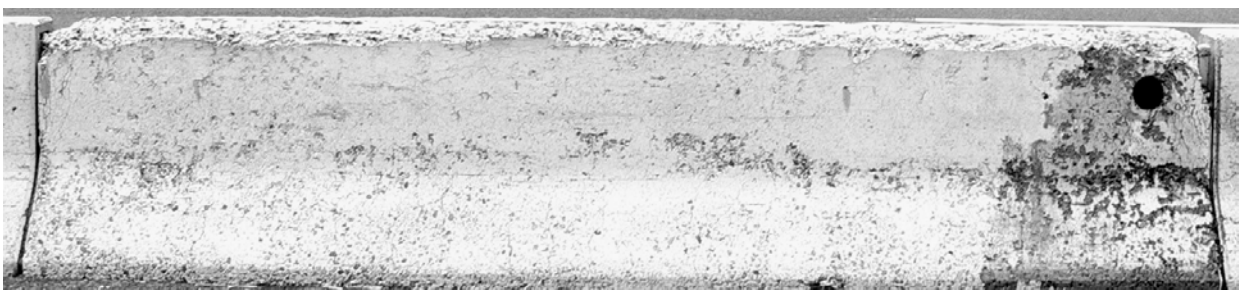

Figure 3.5: Overview photograph of barrier 007 in the Upper Meacham Project Area

Both the east and west upper corners of barrier 007 had disintegrated and were missing. Rebar was exposed in both areas. The top surface of the barrier was scaled, and the coating had worn off. The coating in other places had delaminated from the barrier surface. This was the case across the length of the barrier in the upper 6-inches. This delaminated area is depicted in Figure 3.6. The photograph was taken looking down at the top of the barrier. The scale that is depicted is abutted against the outside surface/face of the barrier. Core sample 007 included a portion of this delaminated section.

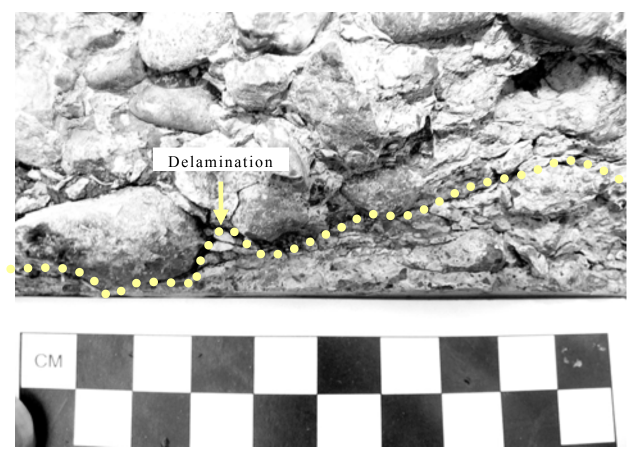

Figure 3.6: Plan view photograph of delaminated portion of barrier 007 in Upper Meacham

In the Upper Meacham project area, Core 008 was also sent in for petrographic analysis. The core was removed intact from the mid section of the east end of barrier 008 (Figure 3.7). There was little to no disintegration of the corners of this barrier. The severity of horizontal cracking was low, though many horizontal cracks (10-20) were present. Transverse cracking, on the other hand, was abundant (25-30), and was of medium severity. Map cracking appeared to be particularly severe in the eastern portion of the barrier, but occurred throughout the entire surface. Much of the surface coating was worn and aggregate was exposed.

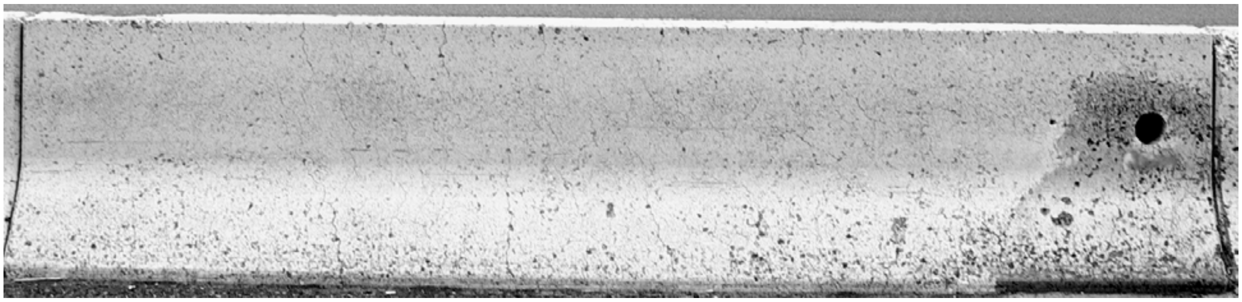

Figure 3.7: Overview photograph of barrier 008 in the Upper Meacham Project Area

4.0 RESULTS

Nine horizontal cores were extracted from concrete barriers in eastern Oregon. Five of those cores were submitted to a petrographic laboratory for analysis. The project area location and core identification number for the lab samples is summarized in Table 4.1.

Table 4.1: Core sample number and location

Core	Location
002	Ladd Canyon
003	Ladd Canyon
005	Lower Meacham
007	Upper Meacham
008	Upper Meacham

The laboratory results that are summarized in this section were provided to ODOT by Dominion Consulting, Inc., of La Grande, Oregon (*Glasheen 2007*). All cores were examined using American Standard Test Method (ASTM) C 865, *Standard Guide for Petrographic Examination of Concrete*. This test was used to obtain estimates for the water to cement ratio, air-void system, degree of paste carbonation, presence of microcracking and presence of secondary deposits. An additional test, a Gel Fluorescence Test, was conducted on only two of the core samples to determine presence of alkali-silica reactivity (ASR). The ODOT Materials Lab conducted total chloride testing on all cores. Samples for the chloride testing were extracted from the cross-cut center of the core at a depth of approximately ½ inch from the surface face of the barrier core.

The polished outer surface of each core was examined with the unaided eye and a stereomicroscope (16-80X) (Figure 4.1). General aggregate and paste characteristics were noted. Thin-sections were then prepared from each of the core samples. The thin-sections were ground and polished to 25 microns. Thin sections were examined using a polarizing microscope (40-400X).

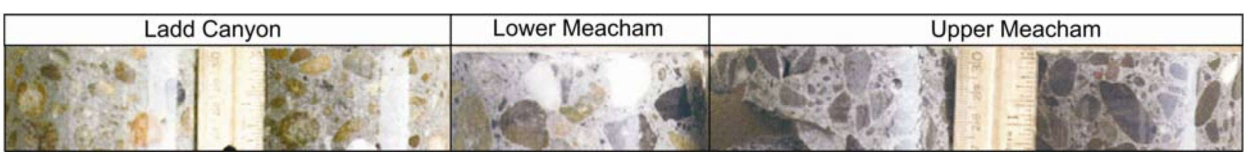

Figure 4.1: Polished outer surfaces of cores from Ladd Canyon, Lower Meacham and Upper Meacham

Each core sample contained at least some portion of reinforcing steel. Upon closer examination, it was observed that none of the steel fragments were corroded with rust. While the surrounding hardened cement paste at ¼ inch and deeper ranged in alkalinity from 11 to 13 in all core samples, surface alkalinity varied. Overall the pastes were well hydrated. Water to cement ratio generally ranged from 0.40 to 0.45. The mineral Portlandite was noted as a secondary deposit, partially infilling microcracks on all core samples.

4.1 LADD CANYON CORE SAMPLES

Cores 002 and 003, from Ladd Canyon, were examined. The cores exhibited overall good paste hardness. The samples were bound with Portland cement and fly ash (Figure 4.2). The presence of fly ash in these cores prompted additional testing for alkali-silica reactivity (ASR). A Gel Fluorescence Test of Core 003 yielded no ASR gel products.

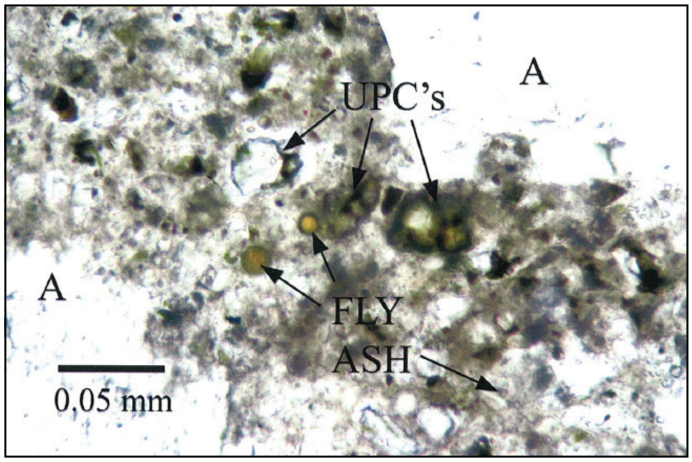

Figure 4.2: Micrograph thin-section of Core 003 showing fly ash spheres, aggregate (A), and un-hydrated Portland cement particles (UPC's)

Both core samples were well hydrated and had an interpreted water to cement ratio of 0.40 to 0.45. Minimal cracking was noted with the unaided eye and some fine microcracking was observed in the thin-sections. The pH level and air-void system varied for both samples. Core 002 had a pH of 6-8. The pH of Core 003 was slightly higher, at 7-8. The amount of entrained air in Core 002 was uneven at 3-4 percent, while air voids in Core 003 were mostly even, at 4-5 percent. Chloride testing was done on both samples. Total chloride tests yielded small quantities of chloride; 0.005 percent in Core 002, and 0.011 percent in Core 003.

Overall, the uneven air void system and lower percentage of entrained air in Core 002 had little quantifiable effect on the interior of the barrier. Few differences in the amount and severity of cracks and microcracks were noted between Cores 002 and 003. Field observations noted that more surface cracking was apparent on Core 002. The exact cause for this is unknown, but it may be due to freeze-thaw damage caused by differences in the air void system and amount of entrained air.

4.2 LOWER MEACHAM CORE SAMPLE

Core 005, from Lower Meacham, was examined. The sample was bound with Portland cement only. The cement was moderately well hydrated and had an interpreted water to cement ratio of 0.40-0.45. Few to some microcracks, similar to those seen in Ladd Canyon samples, were observed in the Lower Meacham core. The air void system was well developed (evenly at 5-6%), and minimal surface damage was noted. The pH level was 7-8, and chloride levels were at 0.010 percent.

4.3 UPPER MEACHAM CORE SAMPLES

Cores 007 and 008, from Upper Meacham, were examined. While the surface face of the core samples from both Ladd Canyon and Lower Meacham was relatively smooth, visible signs of distress (cracking, delamination, popouts, and disintegration) were immediately evident on the surface faces of Cores 007 and 008 (Figure 4.3).

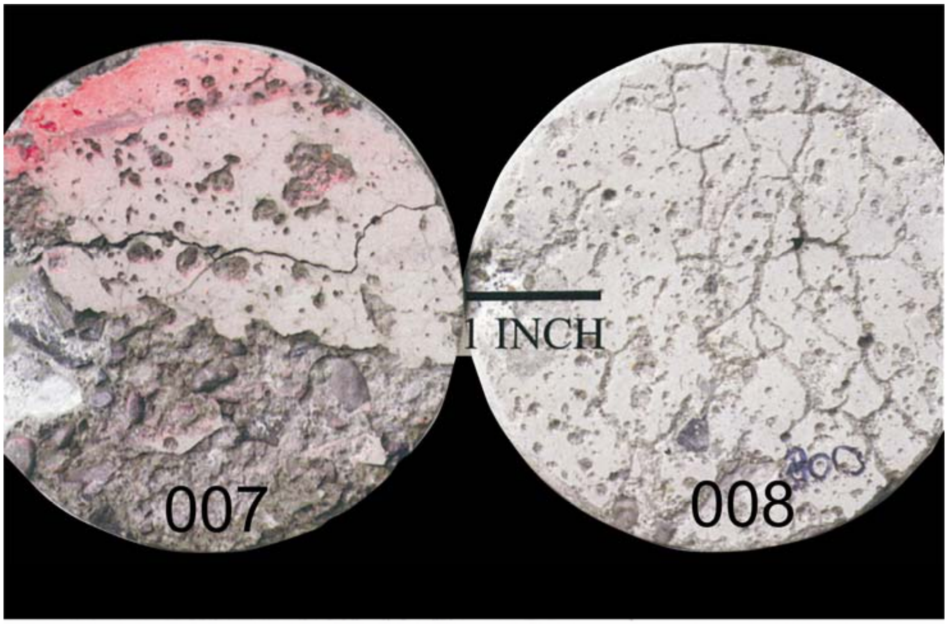

Figure 4.3: Exposed surface face of core samples 007 and 008

The Upper Meacham cores exhibited advanced signs of distress. Abundant cracks were observed with the unaided eye, and an abundant amount of additional fine microcracks were noted (Figure 4.4). These cracks mostly paralleled the exterior vertical surface of the cores and passed through the paste. A few cracks were noted to propagate through the aggregate as well. The widths of the cracks varied from 0.001 to 0.005 inch wide. Vertical cracks in Core 007 were up to 2 inches deep and were 1 inch deep in Core 008.

The air void system in both samples was uneven and was well below the 4-7 percent prescribed in ODOT specifications (*2002*) – 1-2 percent in Core 007, and 2-3 percent in Core 008. Water to cement ratios were consistent with samples from both Ladd Canyon and Lower Meacham (0.40-0.45). The deepest level of carbonation, ½ inch, was seen in Core 007, with a pH of 4-7. The pH for Core 008 was 7-8. A Gel Fluorescence test was done on Core 008 to check for ASR gel products, and none were detected. Total chloride concentrations for Cores 007 and 008 were low, 0.003 percent and 0.008 percent respectively.

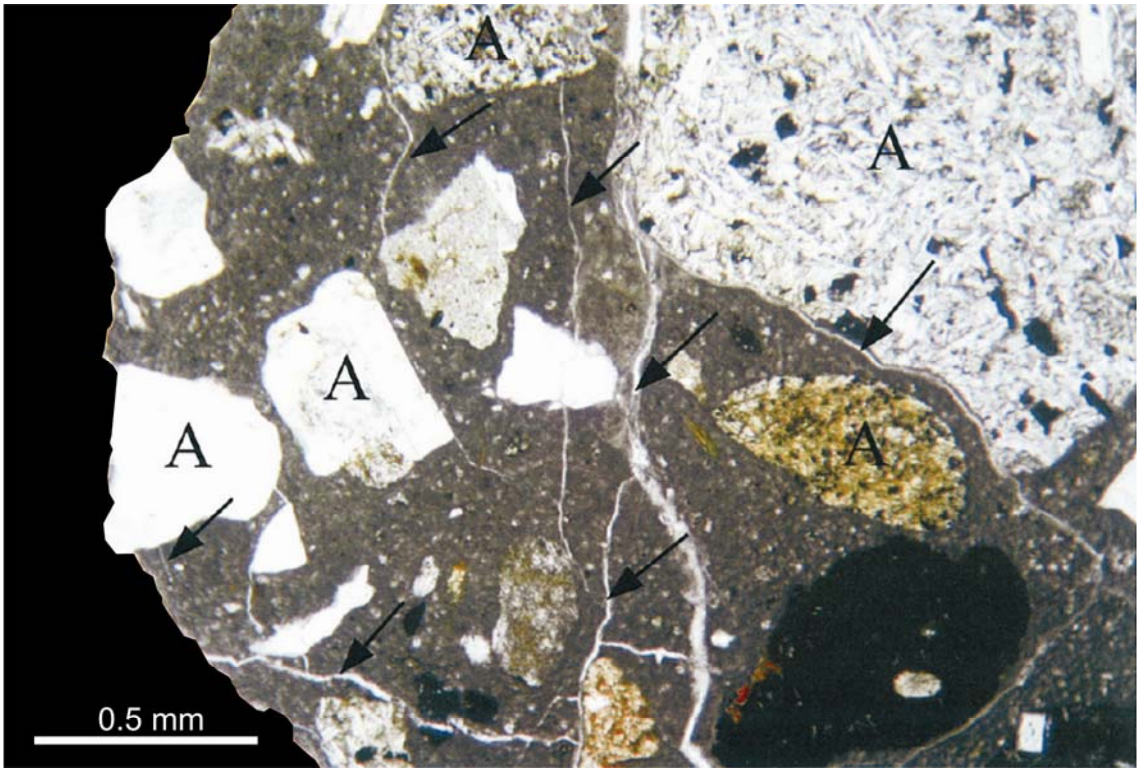

Figure 4.4: Micrograph thin-section of Core 007 showing cracks (indicated by arrows) and aggregate (A)

5.0 SUMMARY AND CONCLUSION

Several concrete barriers in La Grande, Oregon were observed to be deteriorating at an accelerated rate. Field inspection of the barriers in the La Grande area resulted in the designation of three distinct project areas: Ladd Canyon, Lower Meacham, and Upper Meacham. All three project areas consisted of median barriers located along portions of Interstate-84. Barriers in these project areas were examined in the field, and signs of distress were observed and recorded. Core samples were extracted from nine barriers, and five of these were sent to a lab for petrographic analysis.

All barriers were precast. Barriers from each of the three project areas represented unique construction times, type designs and compositions. The newer design – Tall "F"-Shape barrier – was found in the Ladd Canyon area, while the older, Jersey style was present in the Lower and Upper Meacham areas. The Ladd Canyon barriers were constructed approximately 3 years prior to the study, while those in the Lower and Upper Meacham areas were much older, around 27 years of age at the time of the study. All barriers were composed of Portland cement, and only those at the Ladd Canyon site contained a fly ash additive.

Barriers in all project areas experienced at least some exposure to freezing and thawing conditions during winter months. The highest levels of exposure occurred at the Ladd Canyon and Upper Meacham project areas. These areas also received larger quantities of magnesium chloride deicing solutions during adverse conditions of snow and ice.

Laboratory analysis of the core samples showed that all had good paste hardness and were well hydrated. The water to cement ratio was consistently interpreted as 0.40 to 0.45. The presence of a secondary deposit, Portlandite, was noted in each core. Cracks and microcracks were observed in all samples.

5.1 THE EFFECTS OF DEICING SOLUTIONS ON CONCRETE BARRIERS IN LA GRANDE

Secondary deposits of Portlandite were observed to partially fill some microcracks in all cores. Portlandite has been noted to occur when calcium is replaced by magnesium, creating mobile calcium (*Cody, et al. 1996*). This typically occurs with the introduction of an external source of magnesium, such as that found in liquid deicers, specifically magnesium chloride. Because magnesium chloride is used in Oregon, and in abundance in portions of the project areas, it was hypothesized that magnesium chloride might be a contributing factor. The presence of Portlandite may support this hypothesis but is not conclusive alone. Thus secondary testing was needed.

The ODOT Materials Lab conducted total chloride testing on all core samples. Chloride levels ranged from 0.003 to 0.011 percent, but there was no correlation with the amount of deterioration observed in the core samples. Therefore, there was no conclusive evidence that magnesium chloride contributed to the distress of concrete barriers in La Grande, Oregon.

5.2 CONCLUSIONS

Barriers in all project area locations exhibited at least some signs of visible distress. The most advanced distress, as observed in the field, was evident in barriers at the Upper Meacham site. Further laboratory analysis substantiated field observations. Cracks running mostly parallel to the vertical surface were consistent with damage from freezing and thawing events. Poor amounts of entrained air likely exacerbated freeze-thaw damage by not allowing for the expansion of water molecules during crystallization.

Though the Upper Meacham and Lower Meacham barriers were constructed at roughly the same time, those barriers in Upper Meacham exhibited more advanced distress. The Lower Meacham barriers had a better developed air void system than those in Upper Meacham and were exposed less to extreme cold temperatures and freeze-thaw conditions.

Observed field distress strongly paralleled distress seen in the laboratory examinations. Barrier age (years since construction) proved not to be a factor of deterioration. Those samples with inadequate entrained air volumes (less than 4%) exhibited the most advanced signs of distress, especially in freeze-thaw conditions.

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APPENDIX A:
LA GRANDE, OREGON CONCRETE BARRIER FIELD FORMS