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BRIDGE DECK FOGGING SYSTEM: EVALUATION OF FIELD IMPLEMENTATION OF FOGGING SYSTEM USED DURING CONCRETE BRIDGE DECK CONSTRUCTION

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16. Abstract
The objective of this research was to implement and evaluate a fogging system used to provide initial cure for a concrete bridge deck construction project. To accomplish this, Bridges 5500 and 5701 along NM26 were selected. Bridge 5500 was placed using the fogging system and Bridge 5701 was placed using conventional curing methods. Since weather conditions influence evaporation rate, weather conditions were monitored throughout the construction processes. A windbreak was erected to reduce the wind speed during the placement and fogging of Bridge 5500. Visual inspections of cracks were conducted 7, 14, 21, 28 and 56 days after the construction of each bridge. Bridge 5500 exhibited substantially more cracks than Bridge 5701. The additional cracking in Bridge 5500 is attributed to more severe evaporation conditions during placement and inefficiencies associated with the fogging system. Cracking occurred in both bridges to concrete that was exposed to evaporation rates that exceeded 0.1 lb/ft^2/hr.

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PREFACE

The research reported herein evaluates the field implementation of a fogging system used during concrete bridge deck construction. The purpose of this work was to investigate the effectiveness of fogging during construction as a method for mitigating shrinkage cracking. To accomplish this objective, Bridge decks 5500 and 5701 were selected along NM26. Bridge deck 5500 was placed using the fogging system and Bridge deck 5701 was placed using conventional curing methods. The bridges were compared based on the weather conditions during placement and visual inspection of cracks in the weeks following the construction of the bridges.

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ABSTRACT

The objective of this research was to implement and evaluate a fogging system used to provide initial cure for a concrete bridge deck construction project. To accomplish this, Bridges 5500 and 5701 along NM26 were selected. Bridge deck 5500 was placed using the fogging system and Bridge deck 5701 was placed using conventional curing methods. Since weather conditions influence evaporation rate, weather conditions were monitored throughout the construction processes. A windbreak was erected to reduce the wind speed during the placement and fogging of Bridge 5500. Visual inspections of cracks were conducted 7, 14, 21, 28 and 56 days after the construction of each bridge. Bridge deck 5500 exhibited substantially more cracks than Bridge 5701. The additional cracking in Bridge 5500 is attributed to more severe evaporation conditions during placement and inefficiencies associated with the fogging system. Cracking occurred in both bridges to concrete that was exposed to evaporation rates that exceeded 0.1 $lb/ft^2/hr$.

METRIC CONVERSION FACTORS PAGE

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	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	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 (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
ºF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	ºC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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INTRODUCTION

Concrete is one of the major construction materials in the civil engineering industry. Even though concrete is widely used to construct bridges in North America, shrinkage cracks are a common problem for concrete bridge decks. In 2001, after construction of the Big-I (intersection of I-25 and I-40) in Albuquerque, shrinkage cracks were observed in 18 out of 56 newly constructed bridge decks. Such cracking is common in North America and can result in accelerated deterioration of a bridge and potential structural problems at later ages[1]. After the Big-I project, NMDOT began funding research to find effective methods for reducing cracking in bridge deck construction.

Shrinkage in concrete is the result of complex volume changes such as chemical shrinkage, drying shrinkage and thermal shrinkage. Tensile stresses are developed due to these volumetric changes at an age when the concrete has low strength. Development of shrinkage cracks begins just after concrete placing and it may continue through the life of the concrete.

Curing is the most important parameter directly related to shrinkage and thermal cracking of concrete. Fogging and sprinkling water are excellent curing methods when temperatures are above freezing and there is low humidity[2]. The current project is the result of two phases investigating the effectiveness of fogging to reduce shrinkage. The first phase focused on laboratory testing using different curing methods. That work indicated that misting can reduce early-age shrinkage in concrete by as much as 85%[3]. The second phase focused on design issues related to fogging under field conditions.

The objective of this research was the evaluation of a misting system intended to reduce early age shrinkage in bridge deck construction. This evaluation consisted of implementing the fogging system on a bridge deck construction project and comparing the project with the construction of another bridge constructed using conventional curing methods.

BACKGROUND AND LITERATURE REVIEW

Concrete is a durable and effective construction material that is widely used all over the world. The durability of concrete is defined as “the ability of the material to remain serviceable”[4]. However, cracks often develop in concrete that cause reduced service life. A shrinkage crack that occurs due to moisture loss is one common type of crack. Consequently, shrinkage is a major issue in producing a durable structure. If early-age cracking of concrete could be eliminated, concrete bridge deck life would be extended and the cost of repairs would be reduced.

Durability and other concrete properties are significantly influenced by curing since it is largely responsible for hydration of cement[5]. Fogging is one of the most effective ways to reduce drying shrinkage at early ages, because it reduces the evaporation of water from concrete substantially.

CRACKS IN CONCRETE

Many concrete bridge decks in America have cracked after construction, and a 1995 survey of all 50 states indicated that more than 100,000 bridges had developed early-age cracking [6]. The early-age cracks may not be considered critical in the beginning, but they can cause serious problems as time passes[7]. These cracks allow moisture and other chemicals to penetrate into the concrete. Which may cause corrosion of reinforcing steel in concrete, spalling of the concrete deck, and deterioration of the bridge super structure[8]? Many researchers have investigated early-age concrete cracking and have identified numerous factors that influence cracking. Basically these factors can be classified into three major categories; design based parameters, material based parameters and construction related parameters.

Design based parameters

A number of design concepts influence cracking of concrete structures. End restraints and support have substantial influence on cracks in bridge decks. For example, simply supported elements show less cracking compared to continuous members[9]. Also, roller supports prevent thermal cracks in bridge elements such as beams, slabs and pre-cast elements. Another design provision that influences cracks is providing transverse, temperature and shrinkage steel in concrete structures. Practically, this provision has little influence on cracking because most designs already provide temperature and shrinkage steel.

Material based parameters

Many studies have found that material based parameters have substantial influence on cracking[9]. Examples of material related parameters are cement type, admixtures, water-cement ratio and aggregate properties. Some of these material based parameters affect material properties such as creep and shrinkage. These properties are also affected by construction related parameters. For example, shrinkage and creep are affected by curing methods and other environmental factors.

Construction related parameters

Construction related parameters also have considerable effects on the formation of cracks in concrete. Examples of construction related parameters are air temperature, weather conditions, curing methods, curing period, vibration methods and finishing procedures. Weather conditions include wind speed and relative humidity[9].

SHRINKAGE

The general definition of shrinkage is “reduced in amount or value”. Shrinkage in concrete is defined as a decrease in either length or volume of the material resulting from temperature changes, loss of water or chemical changes[2]. Shrinkage plays a major role in early-age cracking in concrete.

Types of shrinkage

Shrinkage occurs in two distinct stages; early-age and long term shrinkage. Early-age is generally defined as shrinkage occurring during the first 24 hours after placing and long term refers to shrinkage that occurs after 24 hours[10]. Figure 1 illustrates the different types of shrinkage and how they contribute to the total shrinkage.

Autogenous shrinkage

Autogenous shrinkage is the result of water consumption during the hydration process. It reduces relative humidity in the concrete, which is referred to as self-desiccation and increases the surface tension in the capillary water. This shrinkage can occur even if there is no moisture exchange between concrete and the environment (i.e. the entire surface of the concrete specimen is sealed) [11]. Low water-cement ratio concrete mixtures tend to exhibit greater autogeneous shrinkage.

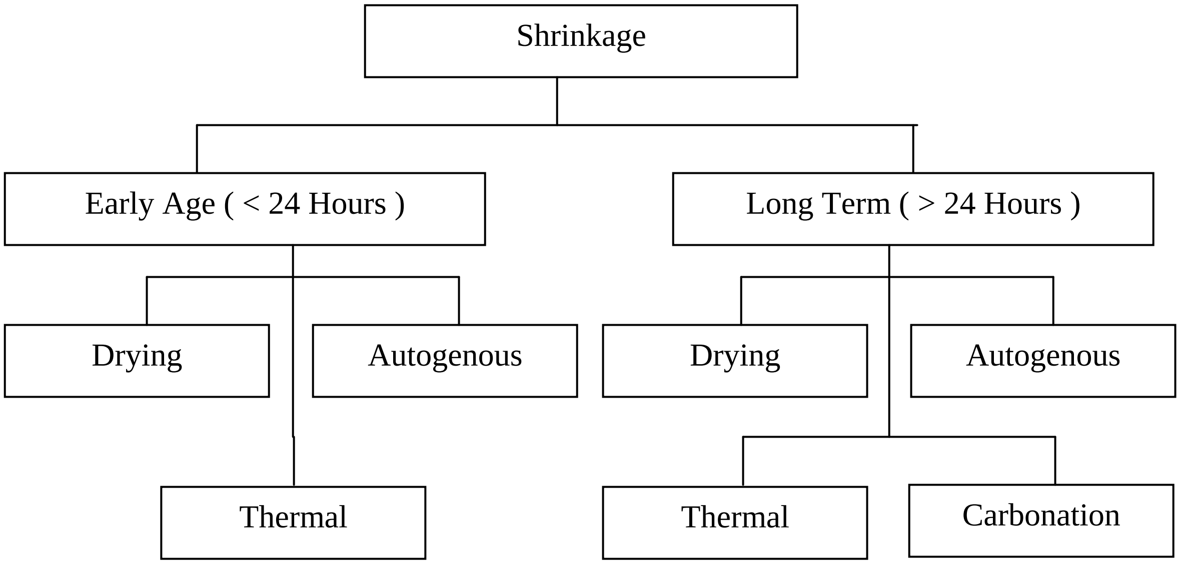


FIGURE 1 Diagram of shrinkage types and stages[10].

Drying shrinkage

Drying shrinkage is a reduction in the volume of concrete due to loss of water from concrete to the environment[11]. Drying shrinkage can occur at early ages and long term. Some researchers have referred to early-age drying shrinkage as “plastic shrinkage”. The use of fogging or misting during curing is an efficient way to reduce early-age drying shrinkage[2].

Thermal shrinkage

Thermal shrinkage is a result of temperature changes in the concrete. Cooling after the peak temperature during the hydration process contributes to thermal shrinkage[10]. Generally, rapid temperature changes are the primary cause of thermal cracks.

Carbonation

Carbonation occurs in hardened concrete due to a chemical reaction between cement hydration products and carbon dioxide. This type of shrinkage occurs in the paste near the surface[2]. This type of shrinkage occurs over several years and falls in the long term shrinkage category.

Factors influencing shrinkage

Concrete shrinkage is influenced by many internal and external factors such as weather, choice of concrete materials, admixtures and type of curing. The following sub-sections provide brief descriptions of these factors.

Hydration

The chemical reaction between water and the chemical compounds in cement is called hydration[2]. Since the products of this reaction occupy less space than the reactants, this reaction causes chemical shrinkage in concrete. Additionally, this reaction generates heat that causes thermal expansion. Cooling from the peak temperature during the hydration process causes thermal shrinkage.

Weather conditions

Weather is also an important factor when considering concrete shrinkage. Weather conditions include wind speed, air temperature, and relative humidity. Weather conditions significantly affect the evaporation rate of water from concrete. Shrinkage cracks often occur when the evaporation rate exceeds the concrete bleeding rate. In normal practice, concrete placing is avoided during windy conditions to reduce the cracking of concrete because wind increases the evaporation rate of water. The evaporation rate can be calculated using Menzel's[12] nomograph presented in Figure 2. The variables used in the nomograph are relative humidity, temperature, air temperature and wind velocity. Evaporation rate is determined in lb/ft^2/hr.

Water-cement ratio

Water-cement ratio is the most important factor when considering the quality of concrete. An excessively high or low water-cement ratio can cause autogenous shrinkage, about 80 percent of which occurs at early ages according to many studies. High-performance concretes with low water-cement ratios increase the possibility of excessive autogenous shrinkage[13].

Admixtures

Admixtures can have substantial influence on concrete shrinkage. Shrinkage reducing admixtures have been shown by numerous investigators to reduce drying shrinkage. Accelerators that increase the heat of hydration to accelerate the setting time of concrete can also increase shrinkage in concrete[14].

Curing

Curing is another important factor influencing concrete shrinkage. Different methods of curing are applied to concrete depending on the purpose and location of the construction. This topic is discussed in the next section in greater detail.

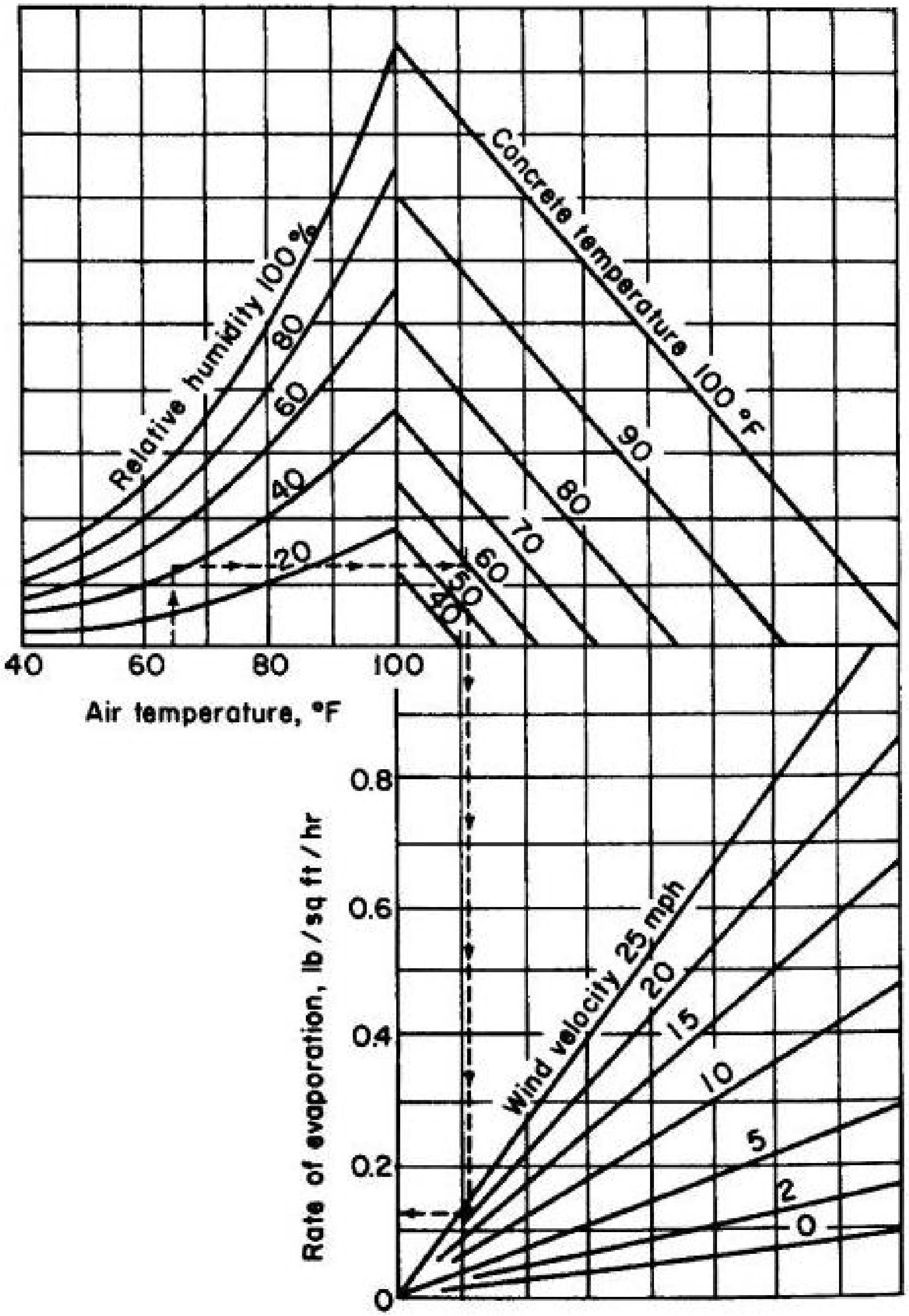


FIGURE 2 Menzel's[12] nomograph[2].

Cement type

The chemical compositions of various types of portland cement produce different peak temperatures during hydration and have different chemical shrinkage characteristics. Consequently, the choice of cement type will influence the overall shrinkage of the concrete. Supplementary materials also influence shrinkage of concrete. Pozzolanic materials generally reduce concrete shrinkage. However, this effect is small compared to the effects of other parameters[15].

Aggregate properties

Aggregate properties also influence shrinkage since concrete is a composite material composed of cement, fine aggregate and coarse aggregate. Larger coarse aggregate top size and higher aggregate contents reduce shrinkage because aggregates are the material that shrinks the least in concrete[11].

CURING OF CONCRETE

Curing is defined as the maintenance of sufficient moisture in the concrete for the first several days after placement[2]. Curing prevents moisture loss from the concrete. Complete hydration occurs when proper curing is provided to concrete[16]. The extent of hydration has a major influence on hardened concrete properties such as strength, permeability, abrasion resistance, volume stability, and resistance to freezing and thawing[16].

Curing methods and materials

Concrete should be kept moist at a favorable temperature using the following recommendations[2]:

a. Maintain the presence of the mixing water in the concrete. This is generally accomplished by ponding or immersion, spraying or fogging, and saturated coverings.

b. Reduce the loss of mixing water from the concrete. This can be accomplished by covering the concrete with a plastic sheet, other impervious paper, or a membrane-forming curing compound.
c. Accelerate strength gain by supplying additional water or heat to the concrete. This is usually accomplished by using steam curing, heating coils or electrically heated forms or pads.

Ponding and immersion

Ponding is a common practice and an easy way to cure flatwork. Ponding is an ideal method for preventing moisture losses from concrete and it also effectively maintains a uniform temperature along the concrete surface[2]. Ponding does require more labor and supervision, so it is not frequently used on large scale projects[2]. Immersion is not a common method of curing in industry because of practical issues, but it is commonly used in laboratories.

Fogging and sprinkling

Fogging or sprinkling is an effective method of curing when ambient temperatures are above freezing[16]. Fogging increases the relative humidity of the air over the concrete, which significantly reduces evaporation of water from the concrete[2]. Fogging is a good way to reduce plastic shrinkage cracking. The cost of a fogging system can be the main disadvantage. The system requires an ample supply of water and good supervision[2]. If the sprinkling is applied in intervals, concrete must be kept moist and prevented from drying between two applications using wet burlap or similar materials[16].

Wet coverings

Moisture can be held by burlap, cotton mats or other coverings of absorbent materials on horizontal and vertical surfaces. These materials must not contain harmful substances, such as sugar, fertilizer or any other materials that can react with concrete or concrete constituents[16]. There should be considerable care taken in applying these coverings since dry burlap can wick water from the concrete.

Methods based on moisture retention

Sheets or liquid membrane-forming compounds that can reduce or minimize evaporation losses of water from concrete are also a common curing method[16]. These methods have the following advantages:

a. They do not need a water source, but it is necessary to ensure that they do not absorb water from the concrete.
b. They require less labor than burlap.
c. They can be applied earlier than other methods.

Numerous products are available in practice such as plastic film, reinforced paper, and liquid membrane-forming compounds[16].

Curing period and temperature

Curing should be continued until the concrete achieves 70% of the specified 28 day strength[16]. Table 1 provides minimum recommended curing periods for different types of concrete mixtures.

Table 1. Recommended minimum curing durations[16].

	Minimum Curing Period
ASTM C 150 Type I	7 Days
ASTM C 150 Type II	10 Days
ASTM Type III or when accelerators are used to achieve results demonstrated by testing to be comparable to those achieved using ASTM C 150 Type III cement	3 days
ASTM C 150 Type IV or Type V Cement	14 Days
Blended cements, combinations of cement and other cementitious materials of various types in various proportions in accordance with ASTM C 595, C 845 and C 1157.	Variable

EXPERIMENTAL METHODS

This research focused on the evaluation of the field implementation of a fogging system used during concrete bridge deck construction. Two bridges were selected for this research; one bridge was placed using the fogging system and the other was placed using conventional curing methods. This chapter describes the site locations of the two bridges, the fogging system that was used, and the evaluation methods used in this study.

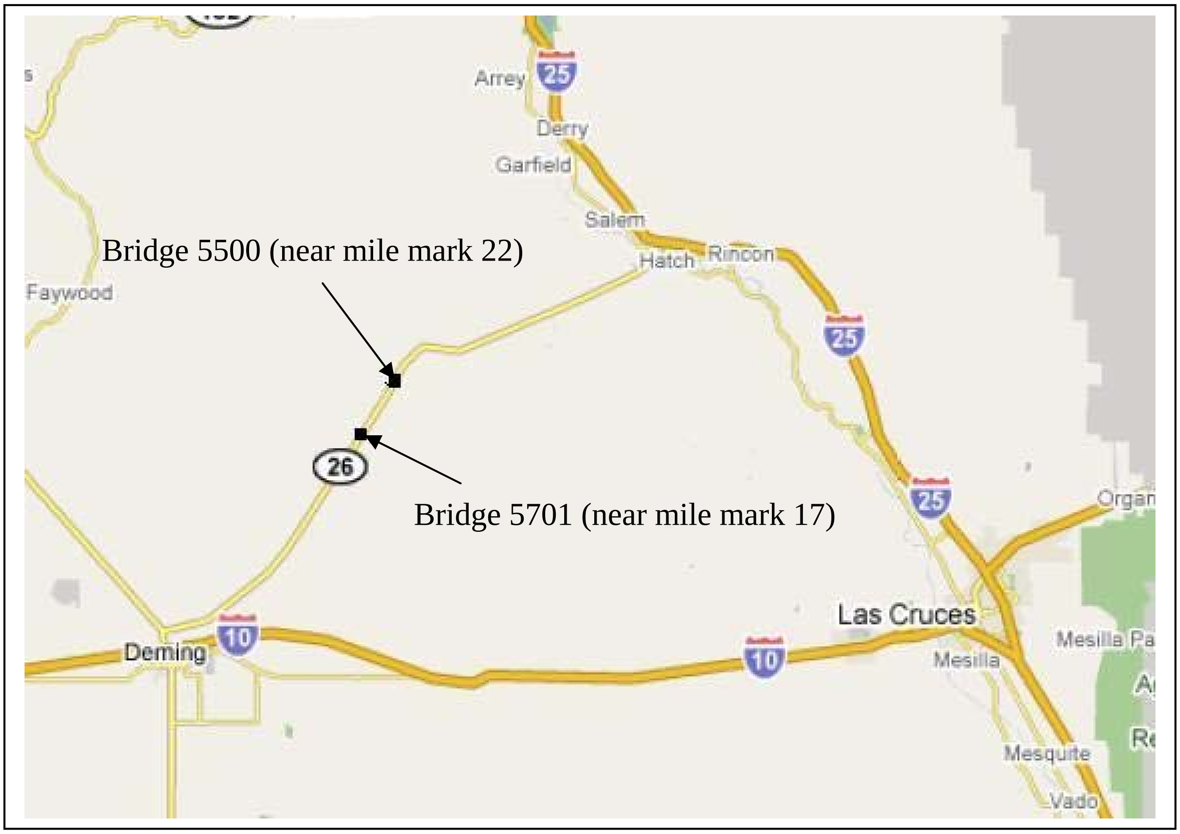
SITE LOCATION AND DESCRIPTION

Bridges 5701 and 5500 on New Mexico state highway 26 were selected for this study. The bridges are located along NM26 near mile markers 17 and 22, respectively, in Luna County, New Mexico and were reconstructed as part of NMDOT project AC-GRIP-(TPM)-026-1(11)30, contract no: CN-G3131. The location of Bridge 5701 is from STA889+30.91 to STA 890+80.86 and the location of Bridge 5500 is from STA 1198+33.50 to STA 1199+49.75. Figure 3 shows the location of the bridges. Overall dimensions of Bridges 5500 and 5701 are approximately 99’-6” x 43’ and 149’-06” x 43”, respectively.

Geometric data for both bridges are summarized in Table 2. Bridge 5500 was placed using the fogging system designed by NMSU, and Bridge 5701 was placed using conventional curing methods.

FOGGING SYSTEM

A fogging system was designed based on discussion with the technical panel for this project. The technical panel decided to suspend the fogging system from longitudinal cables over the bridge. The fogging system was installed on Bridge 5500. The fogging system was composed of 0.5” inside diameter PVC pipes fitted with cone jet TXWS-1 nozzles at two feet spacings.



Bridge 5500 (near mile mark 22)

Bridge 5701 (near mile mark 17)

FIGURE 3 Bridge locations on NM26 (Google Map 2008).

The nozzles were arranged such that adjacent nozzles sprayed water in opposite directions. The fogging system was fixed 10’-6” above the top of the bridge deck to provide enough head room for workers and still provide appropriate mist distribution. All of the pipes were tied to cables using steel wires. Clamps were used to connect the wires to the cables and to prevent slipping of

Table 2. Geometric data for the bridges.

	Bridge 5500	**Bridge 5701**
Length	99’ - 06”	149’- 00”
Width	43’ -00”	43’ - 00”
Number of spans	4	6
Interior span length	25’ - 00”	25” - 00”
End span length	24’ - 09”	24’ - 09”

the pipes along the cables. The three segments of the fogging system are illustrated in Figure 4. Each segment was approximately 33 feet long and had four rows of misting nozzles, each of which was controlled individually. All of the pipes were connected to pumps using hoses. Pressure gauges were attached to the pumps to measure and control system pressure. Figure 5 shows a plan view of the fogging system and nozzle layout and Figure 6 presents a schematic arrangement of the cable system used to support the fogging system. Figure 7 shows a photograph of the system installed at Bridge 5500. As soon as concrete finishing passed each segment, fogging was initiated; fogging continued until the concrete was covered with burlap.

WATER PUMPS/ WATER TANKS / PRESSURE GAGES

Simer MOD.2825ss model water pumps were used to pump water with adequate pressure through the pipes. One pump was used for each 33 ft segment of the fogging system. The pumps and water tanks are shown in Figure 8. The maximum possible pressure supplied by the pump was 80 psi. The fogging rate was selected based on the expected evaporation rate of water from concrete determined using Menzel's12 nomograph. The fogging rate used in this study was 0.40 lb/ft^2/hr. This fogging rate is substantially greater than the maximum expected

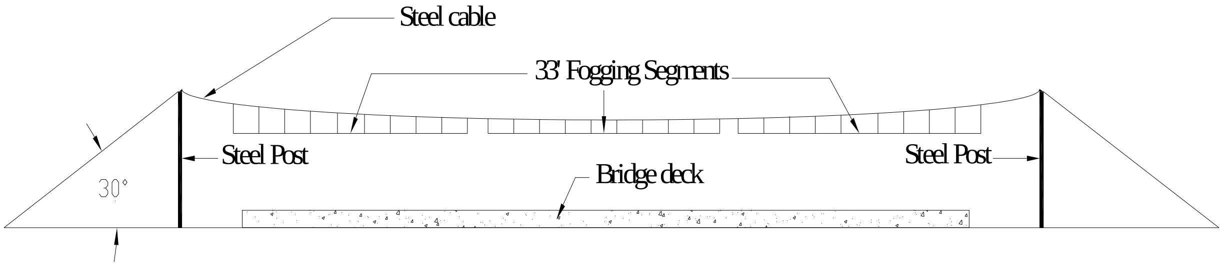


FIGURE 4 Typical cross section of the fogging system.

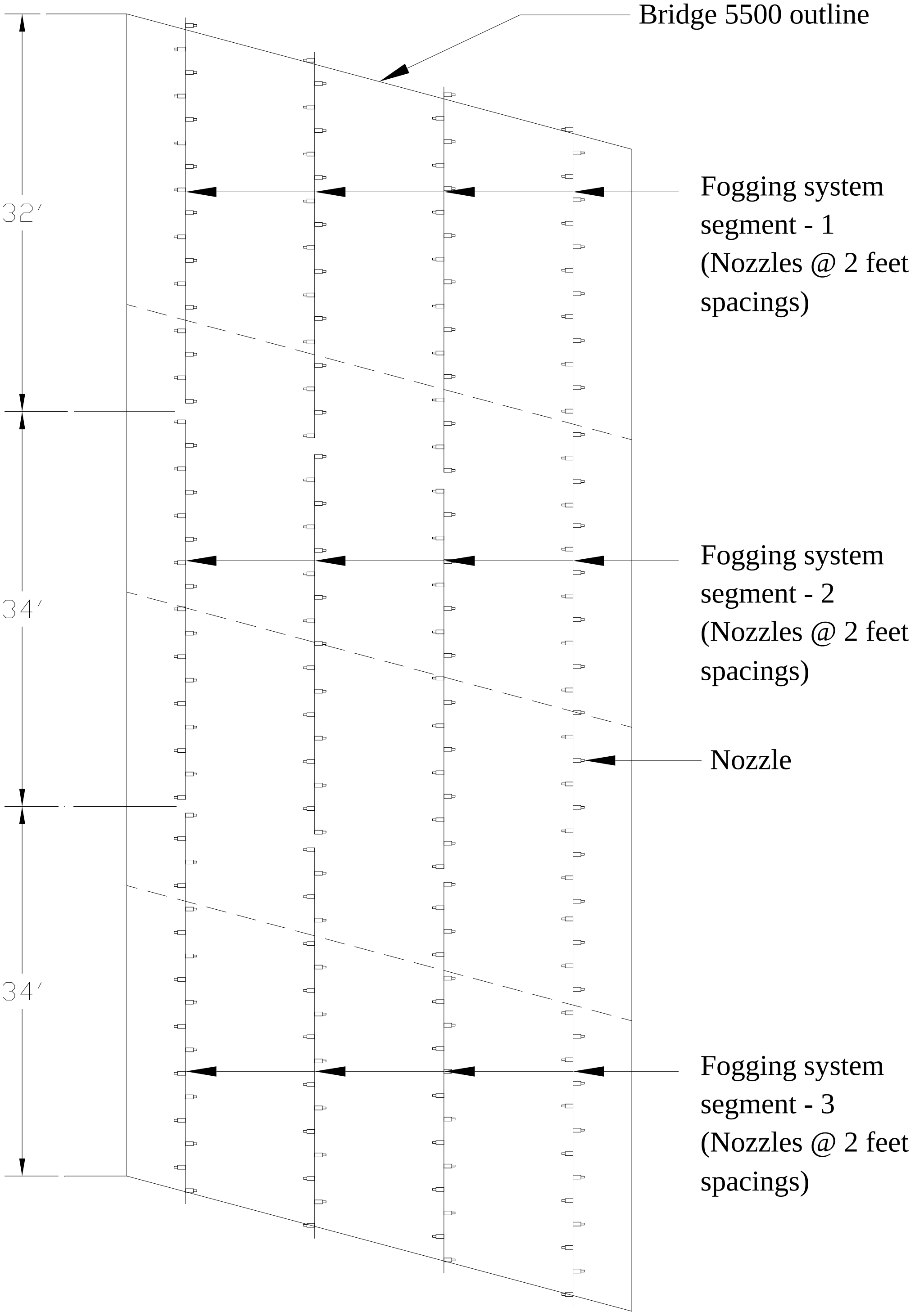


FIGURE 5 Plan view of fogging system.

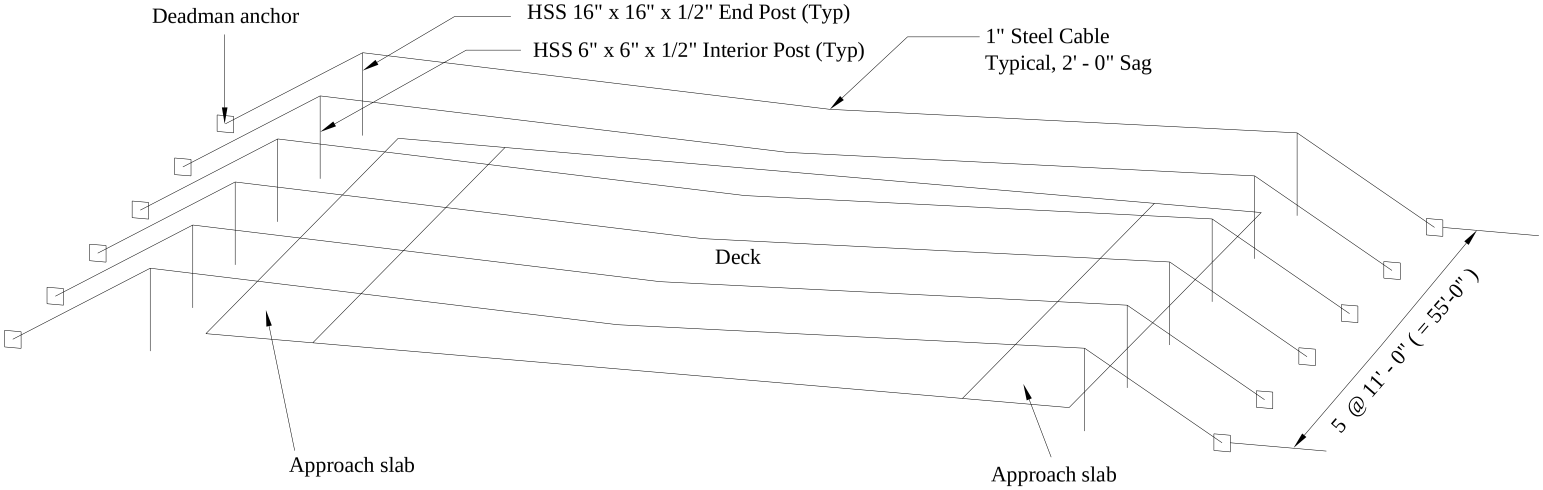


FIGURE 6 Fogging support schematic.

FIGURE 7 The fogging system installed at Bridge 5500.

evaporation rate (0.2 lb/ft^2/hr) to allow for losses to wind at the top of the windbreak and to address the fact that the path of the mist cannot be finely controlled from a height of 10’-6”. The fogging rate was adjusted by using valves and back flow of water from the pump to the tank to control the pressure in the pipes. The pump pressure was maintained at 40 psi to produce the fogging rate of 0.40 lb/ft^2/hr over the bridge deck.

WINDBREAK

The windbreak was installed around the bridge by hanging it from the exterior cables, and its height averaged about 12’-9” above the top of the bridge deck. The windbreak was installed at

FIGURE 8 Water tank, water pumps and pressure gauges for the fogging system.

the bridge site by the contractor. Windbreak fabric by PAK INC. - E.11 GC was used as the windbreak material and holes were made by the contractor for access. Additional openings in the windbreak were caused by the Bid-well machine. Figure 9 shows a photograph of the windbreak installed at Bridge 5500.

WEATHER MONITORING INSTRUMENTATION

A Kestrel 3000 pocket weather meter, as shown in Figure 10, was used to measure wind velocity, relative humidity and temperature at 15 minute intervals during the construction of both bridge decks. The Kestrel 3000 can measure current wind speed, maximum wind speed, average wind speed, air temperature, wind chill, relative humidity, heat stress index and dew point [17].

FIGURE 9 Windbreak at Bridge 5500.

FIGURE 10 Kestrel 3000 pocket weather meter[17].

In this work, wind velocities were measured as the average wind speed during a three second period. Relative humidity and air temperature were also monitored.

CURING COMPOUND

Kurez vox white pigmented curing compound was used on Bridge 5701. It is a water based and membrane forming curing compound. The membrane helps concrete to retain sufficient water to gain the design strength while providing reflectivity to reduce the heat produced by direct sun light. This curing compound was only applied to Bridge 5701. Specifications for Kurez vox White Pigmented curing compound include[18]:

a. Drying time – 1 hour @ 73°F and 50% RH.
b. Solid content - 25%.
c. Moisture loss - < 0.1127 lb/ft^2 (0.55 kg/m^2).
d. Foot traffic – 2 to 4 hours.
e. Wheel traffic – 6 to 10 hours.

The manufacturer also states that this compound covers about 300 ft^2/gal for smooth concrete and 200 ft^2/gal for textured concrete.

CONSTRUCTION OBSERVATIONS

Even though early-age cracking can be reduced by fogging and weather conditions, other environmental factors also have significant influence on cracking. Therefore, weather conditions and construction progress were monitored for both bridges. The following measurements were recorded on the day of placing deck on Bridge 5500 using the Kestrel 3000 pocket weather meter:

a. Wind speed inside the windbreak and outside the windbreak.
b. Relative humidity inside the windbreak and outside the windbreak.

c. Temperature inside the windbreak and outside the windbreak.
d. Concrete placement time for each of the fogging segments.
e. Bid-well finishing time for each fogging segment.
f. Burlap covering time for each fogging segment.
g. Plastic sheet covering time for each fogging segment.

Bridge 5701 deck was placed with conventional curing methods; on the day of placement, wind speed, relative humidity and air temperature were measured at 15 minute intervals.

CRACK OBSERVATION

The first visual inspections for cracks were conducted on the day that the burlap was removed, and then subsequently at 14, 21, and 28 days. Location of crack, crack length and width of the crack, were measured and mapped. In addition, observations were made on how the cracks were developing with time; observations were made for both bridges.

BRIDGE DECK CONSTRUCTION

This chapter presents the observations made for the days of deck placement on the two bridges along NM26. Weather conditions including temperature, relative humidity and wind speed were monitored throughout the placement of concrete for both bridges since weather conditions have a major influence on cracking. In addition, fogging starting and ending times, Bid-well finishing times, and burlap and plastic sheet covering times were recorded for both bridges.

CONSTRUCTION SEQUENCE MONITORING

The construction sequence was monitored throughout the construction of both bridges. The following activities were monitored and recorded:

a. Placement time of each segment.
b. Bid-well finishing time for each segment.
c. Burlap coving time.
d. Plastic sheet covering time.
e. Curing compound application time.

The observations for the construction and fogging sequences for Bridge 5500 are summarized in Figures 11 and 12. Similar observations for Bridge 5701 are presented in Figure 13. In Figure 12, two stoppages are listed for the fogging system. These stoppages were to allow the contractor to repair footprints left during burlap coverage. NMDOT specifications state that the rate of forward progress of the finishing machine shall be 20ft/hr over the entire width of the slab bridge being placed. Finishing durations for Bridges 5500 and 5701 were 7 hours and 10.5 hours, respectively. The rate of forward progress for Bridges 5500 and 5701 was about 14 ft/hr. The forward progress rate was slower than the rate specified by NMDOT. Other authors have

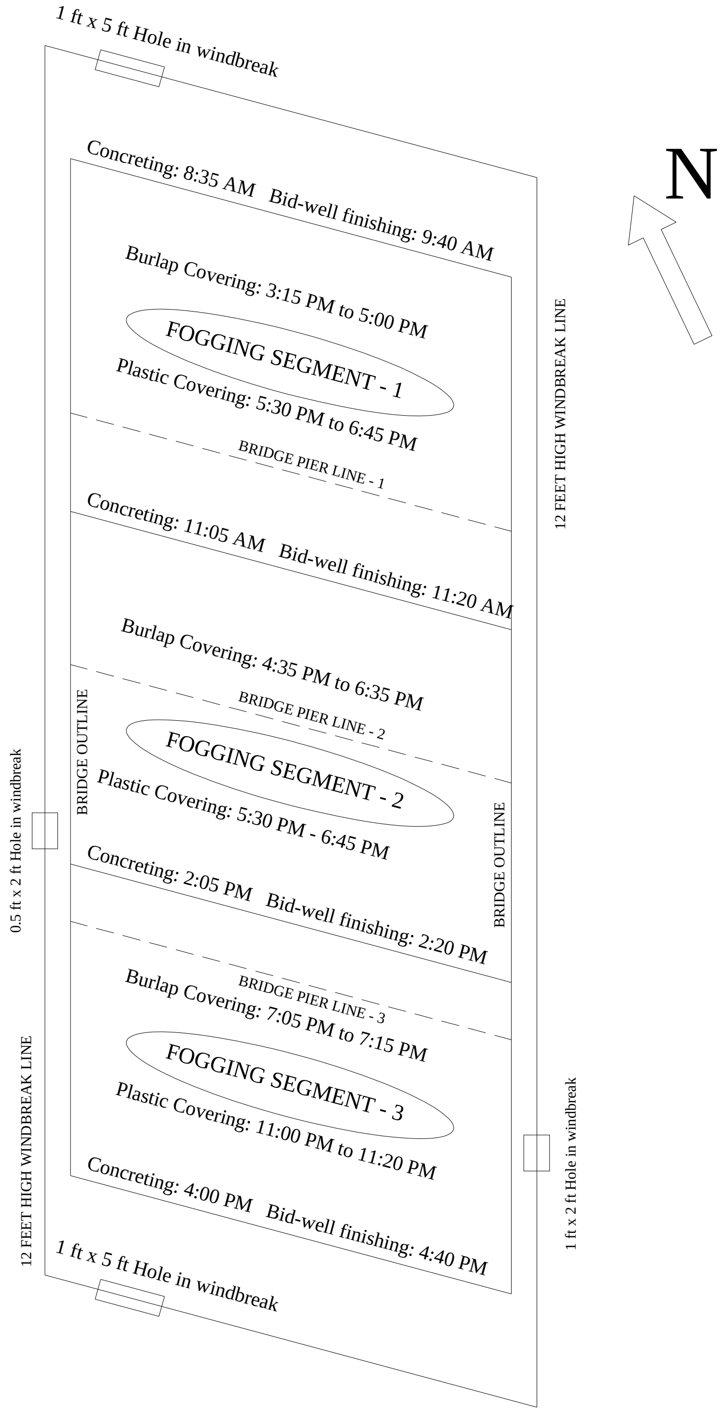


FIGURE 11 Bridge 5500 construction sequence observations and wind break openings.

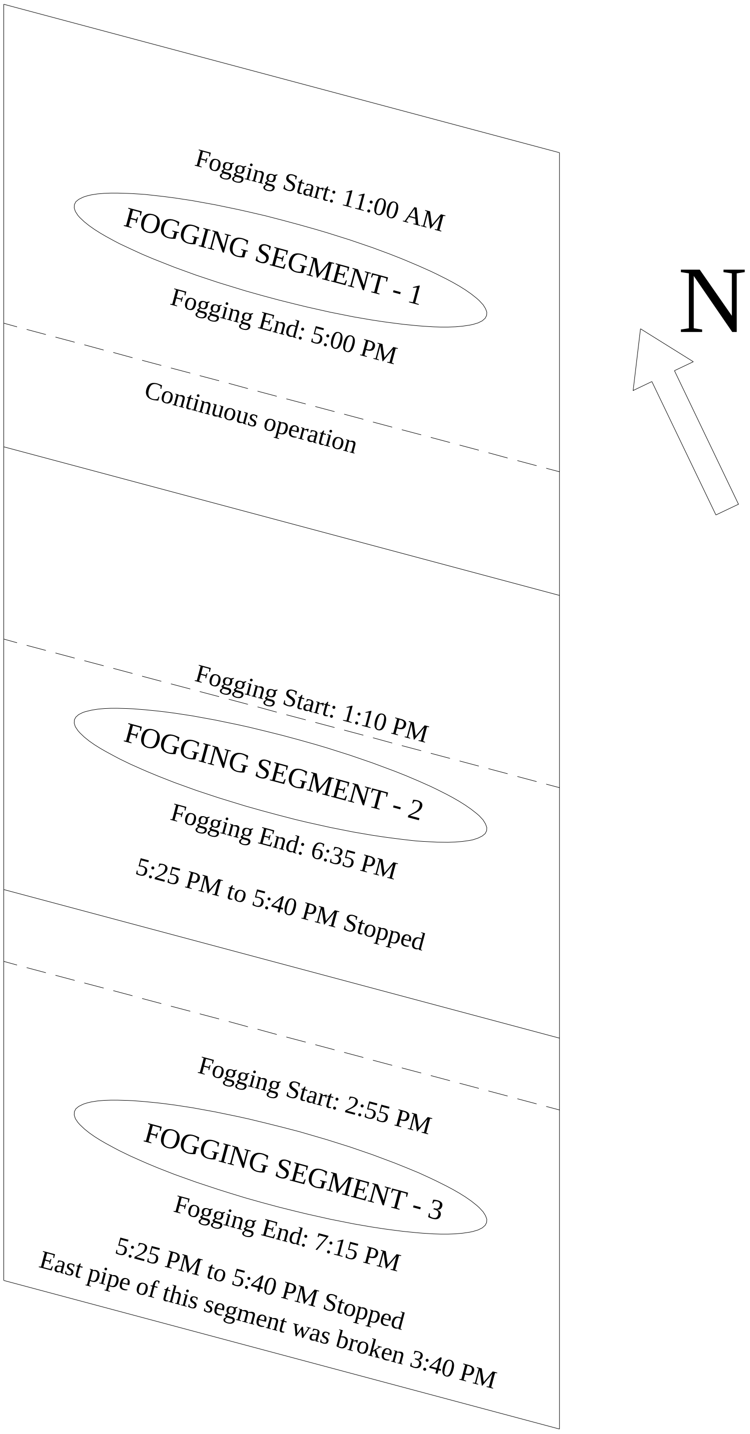


FIGURE 12 Bridge 5500 fogging observations.

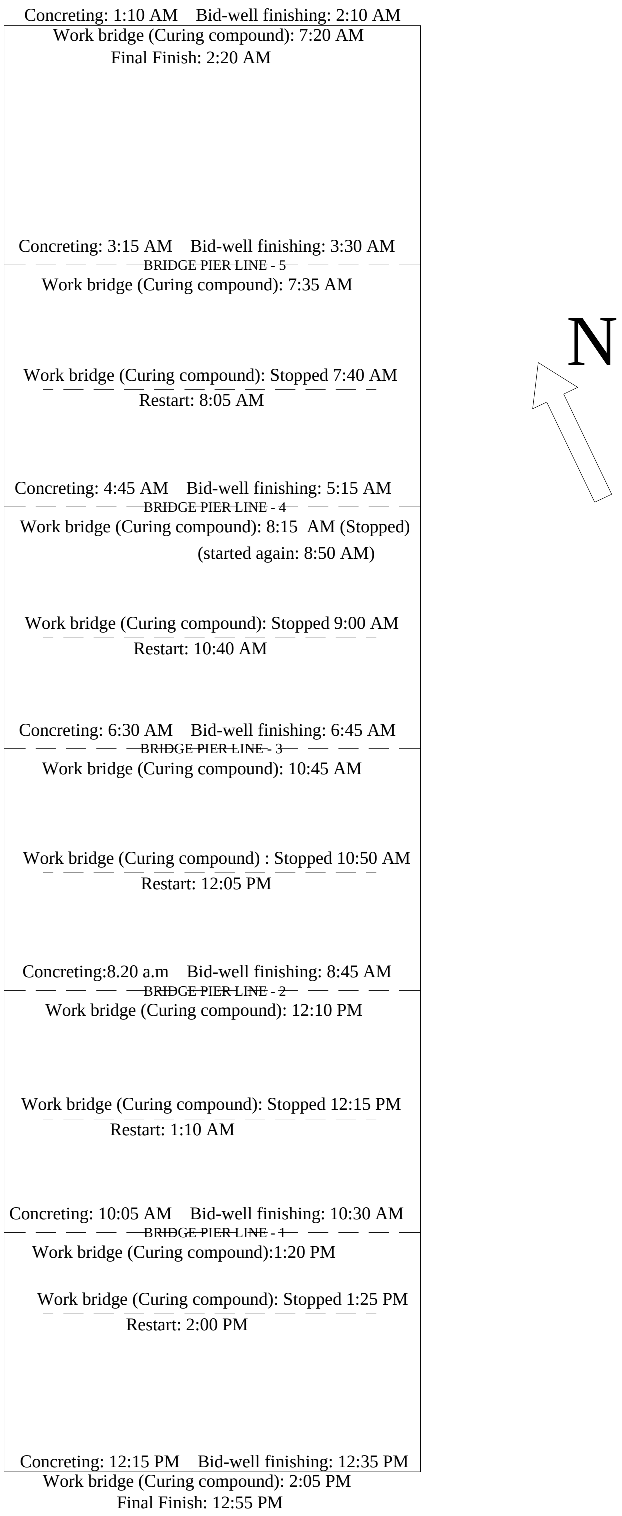


FIGURE 13 Bridge 5701 construction sequences observations.

recommended that placement speed not be less than 0.6 span/hr (about 15 ft/hr)[19]. A slow placement speed lead to more evaporation occurring before fogging is initiated.

WINDBREAK

A windbreak was erected for the Bridge 5500 site to reduce the wind speed at the concrete surface, which reduces the evaporation rate and allows proper fogging operation. There were two openings in the windbreak that were made by the contractor for access to the inside of windbreak, and the Bid-well machine damaged the windbreak in two places. All of those holes in the windbreak are documented in Figure 11.

WEATHER MONITORING

Weather conditions including temperature, wind speed and relative humidity were monitored throughout placement of concrete at fifteen minute intervals using a Kestrel-3000 pocket weather meter. For Bridge 5500, measurements were taken inside and outside the windbreak. All of the weather data for Bridges 5500 and 5701 are presented in Tables 3 and 4, respectively.

Wind speed is the most important factor for evaporation rate which strongly influences early-age cracking. The windbreak for Bridge 5500 reduced the wind speed by 60-65% inside the windbreak compared to the outside wind speed. Even though a windbreak was not erected at Bridge 5701, wind velocity was low on the night and morning of deck placement on Bridge 5701. Wind speeds present during the construction of both bridge decks are plotted in Figure 14. Even though the windbreak was erected for Bridge 5500, Bridge 5701 experienced lower wind speeds than Bridge 5500.

Air temperature is another important factor for evaporation. The windbreak and fogging did not influence the air temperature at the concrete surface for Bridge 5500. This is apparent from the similarity of the temperatures inside and outside the windbreak presented in Figure 15.

Table 3. Bridge deck 5500 weather data.

Date of casting		March 26, 2008				
Time	Wind Speed		Temperature		Relative Humidity	
	Inside the Windbreak (MPH)	Outside the Windbreak (MPH)	Inside the Windbreak (°F)	Outside the Windbreak (°F)	Inside the Windbreak (%)	Outside the Windbreak (%)
8:30 AM	0.0	1.2	56.5	53.0	20	20
8:45 AM	0.0	1.6	57.7	54.0	21	20
9:00 AM	0.0	3.5	58.1	56.3	20	17
9:15 AM	0.0	3.8	61.0	60.0	17	16
9:30 AM	0.0	2.5	63.5	62.3	17	16
9:45 AM	0.5	3.5	64.3	64.2	15	14
10:00 AM	0.6	4.0	70.5	67.0	16	14
10:15 AM	0.0	4.3	73.7	69.2	16	13
10:30 AM	2.8	7.3	73.2	74.3	11	10
10:45 AM	2.5	7.8	74.3	76.5	10	9
11:00 AM	2.0	5.5	73.6	74.0	10	9
11:15 AM	2.7	8.1	75.5	77.8	13	10
11:30 AM	1.7	11.7	75.7	76.0	14	7
11:45 AM	4.8	14.8	70.6	74.7	13	8
12:00 PM	4.0	10.3	76.5	76.9	14	9
12:15 PM	2.4	10.0	72.7	78.9	16	9
12:30 PM	2.2	9.5	77.3	80.7	16	8
12:45 PM	4.2	12.7	73.7	74.2	13	7
1:00 PM	4.8	15.0	72.6	75.0	12	8
1:15 PM	4.4	16.5	78.7	77.2	9	7
1:30 PM	6.5	14.3	72.2	77.2	11	6
1:45 PM	8.0	11.9	72.0	77.3	11	6
2:00 PM	4.2	11.5	76.6	77.4	11	7
2:15 PM	2.7	19.0	74.0	79.1	14	6
2:30 PM	2.8	13.2	76.2	76.5	9	6
2:45 PM	3.2	9.5	75.2	78.8	12	7
3:00 PM	6.3	9.5	73.1	79.4	15	8
3:15 PM	3.2	13.5	81.1	79.1	10	6
3:30 PM	3.8	18.6	76.5	78.1	11	6
3:45 PM	6.0	14.6	75.0	80.2	13	6
4:00 PM	3.5	9.9	77.4	78.6	10	6
4:15 PM	3.4	9.5	78.5	79.5	13	7
4:30 PM	5.5	11.5	74.5	77.7	15	6
4:45 PM	6.2	12.3	74.7	78.2	13	7
5:00 PM	2.0	11.5	80.8	78.2	9	7
5:15 PM	2.0	9.6	78.8	77.5	10	6
5:30 PM	1.6	9.6	78.2	80.3	8	6
5:45 PM	1.4	7.8	76.9	76.6	8	7
6:00 PM	1.0	12.0	80.1	76.1	8	7
6:15 PM	3.6	11.6	75.6	74.5	8	7
6:30 PM	4.3	12.9	71.7	74.2	11	7
6:45 PM	3.4	13.6	72.6	72.2	10	8
7:00 PM	3.4	15.9	70.4	71.9	10	8
7:15 PM	3.8	15.2	73.0	69.8	10	9

Table 4. Bridge deck 5701 weather data.

Date of casting		May 9, 2008	
Time	Wind Speed (MPH)	Temperature (^{o}F)	Relative Humidity (%)
1:15 AM	0.6	67.3	13
1:30 AM	0.6	59.3	17
1:45 AM	1.2	63.1	14
2:00 AM	1.2	57.1	16
2:15 AM	0.6	61.5	13
2:30 AM	0.6	61.2	12
2:45 AM	0.6	59.9	12
3:00 AM	0.6	63.0	13
3:15 AM	1.0	61.0	14
3:30 AM	1.1	62.3	12
3:45 AM	0.8	60.5	13
4:00 AM	1.2	58.0	12
4:15 AM	0.8	61.0	12
4:30 AM	1.5	54.5	13
4:45 AM	0.6	65.5	11
5:00 AM	0.0	60.1	13
5:15 AM	0.6	62.0	11
5:30 AM	1.0	59.8	11
5:45 AM	1.2	59.0	12
6:00 AM	1.1	61.0	12
6:15 AM	1.0	62.0	11
6:30 AM	0.6	65.0	10
6:45 AM	1.3	58.0	13
7:00 AM	1.1	61.0	13
7:15 AM	1.2	60.0	15
7:30 AM	1.6	60.0	14
7:45 AM	1.0	63.0	14
8:00 AM	1.0	67.2	12
8:15 AM	1.9	61.6	14
8:30 AM	0.6	67.3	12
8:45 AM	0.8	67.0	12
9:00 AM	0.0	68.6	14
9:15 AM	0.6	70.1	12
9:30 AM	1.2	75.3	9
9:45 AM	2.9	74.0	10
10:00 AM	4.0	73.7	10
10:15 AM	4.0	74.7	10
10:30 AM	4.2	74.9	10
10:45 AM	2.8	78.6	8
11:00 AM	1.8	80.0	8
11:15 AM	4.5	78.9	10
11:30 AM	2.2	81.5	10
11:45 AM	3.8	80.4	8
12:00 PM	3.2	81.0	8
12:15 PM	6.5	80.7	8
12:30 PM	4.5	81.2	8
12:45 PM	3.5	85.4	9
1:00 PM	8.4	87.2	9
1:15 PM	7.2	86.3	8
1:30 PM	6.3	87.9	9

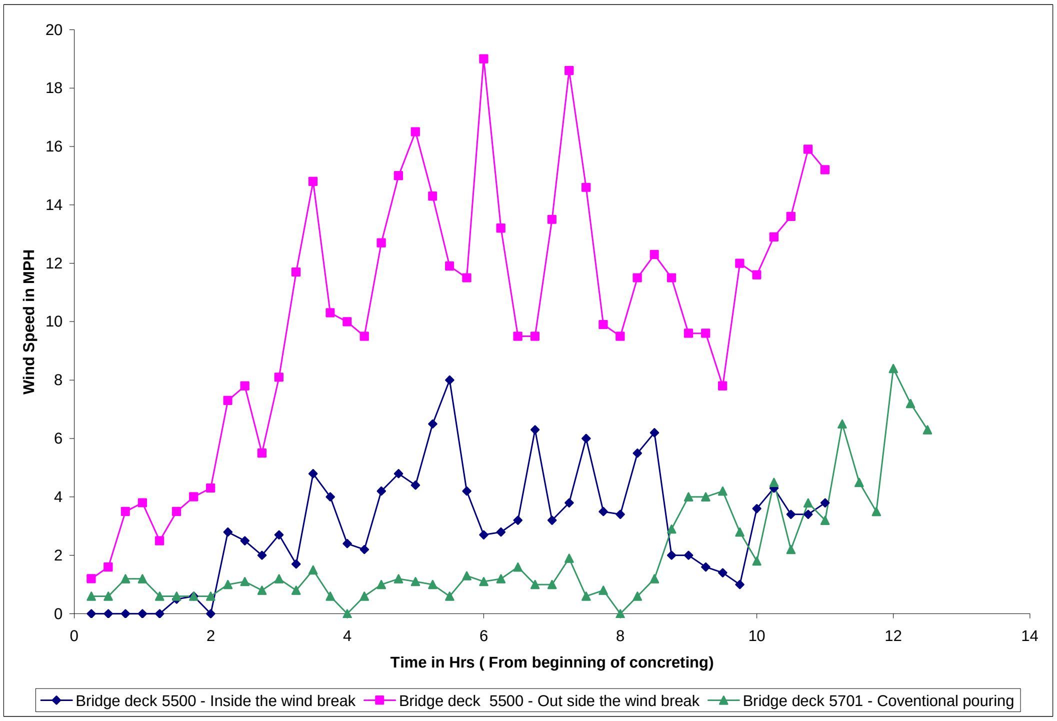


FIGURE 14 Wind speed variation during the concrete placement for both bridges.

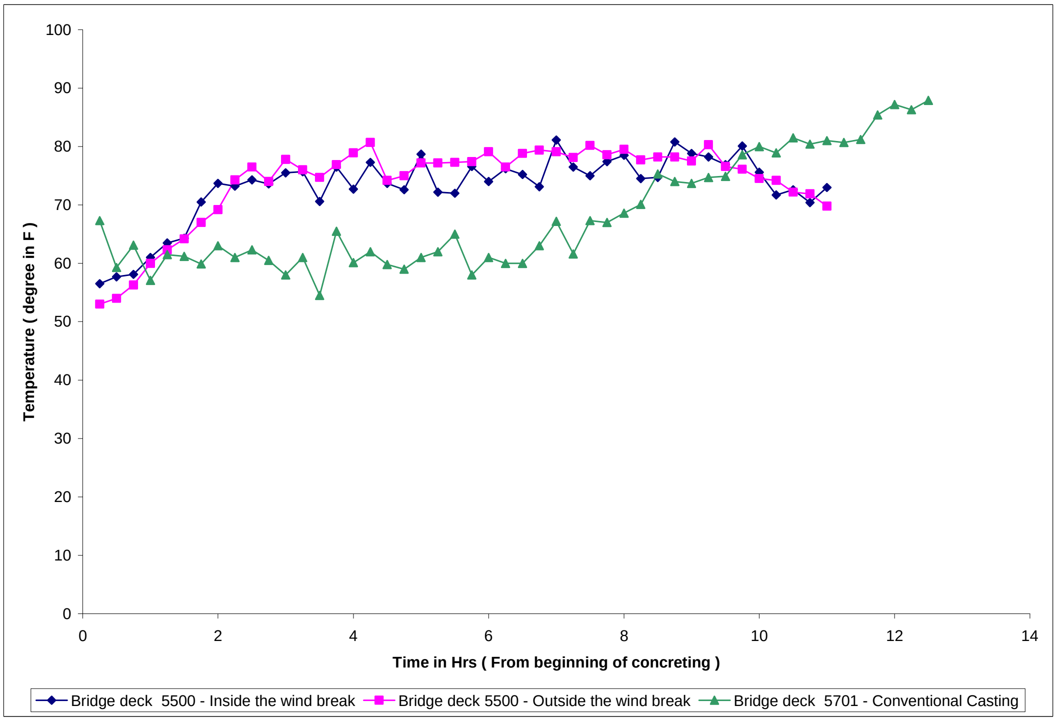


FIGURE 15 Temperature variation during concrete placement for both bridges.

Air temperature during the placement of Bridge deck 5701 was good for the first eight hours. Maximum and minimum recommended temperatures for placing concrete are 80°F and 45°F [20]. The air temperature was near the upper end of this recommended range during the Bridge 5500 placement, but near the middle of the range for most of the Bridge 5701 deck placement.

Relative humidity is another weather condition that influences evaporation. Fogging increases the relative humidity and reduces the amount of water that evaporates from concrete. The plotted relative humidity values in Figure 16 show that fogging increased the relative humidity by 70-80% over the concrete surface for Bridge 5500. This elevated relative humidity for Bridge deck 5500 was approximately equal to that observed for Bridge deck 5701 without fogging. Bridge deck 5701 experienced higher relative humidity because the concrete was placed at night. It should be noted that fogging provides moisture over the concrete surface, but doesn't

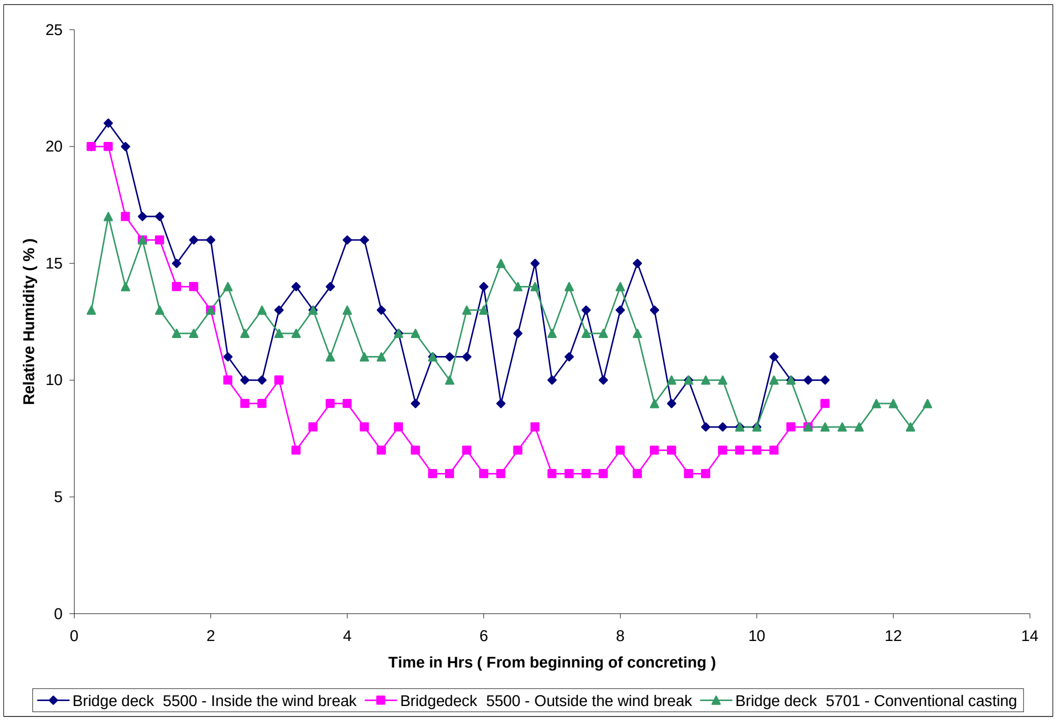


FIGURE 16 Relative humidity variation during concrete placement for both bridges.

necessarily raise the relative humidity measurement to 100%. Fogging produces water particles in the air, but the relative humidity measurement doesn’t capture individual water droplets; however, the droplets provided by fogging provide a source of water that will evaporate before water evaporates from the concrete.

EVAPORATION RATE

Evaporation rate is a primary source of cracking in concrete. Air temperature, concrete temperature, relative humidity and wind speed all influence the rate of evaporation. Using Menzel’s[12] equation, with assumed concrete temperatures of 74^{o}F for Bridge deck 5500 and 68^{o}F for Bridge deck 5701, evaporation rates were computed for the weather conditions presented in Tables 3 and 4. The calculated evaporation rates are plotted in Figure 17. Normally, shrinkage cracks are expected when the evaporation rate exceeds 0.2 lb/ft^2/hr.

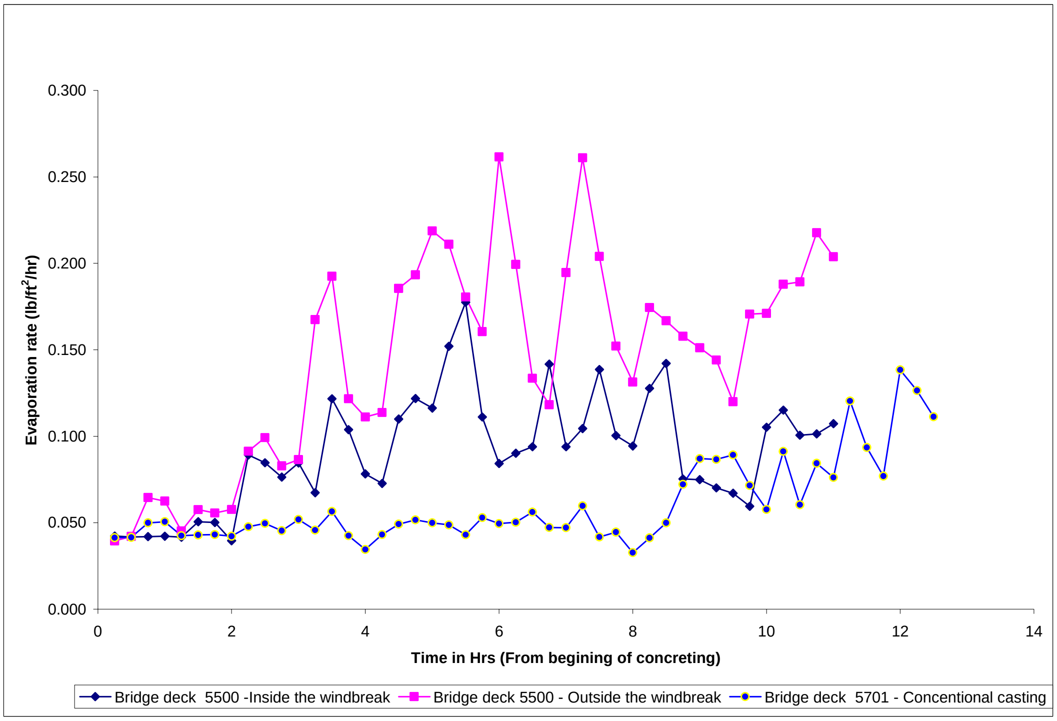


FIGURE 17 Evaporation rate variation during concrete placement for both bridges.

When the evaporation rate is between 0.2 lb/ft^2/hr and 0.1 lb/ft^2/hr, plastic shrinkage cracks may still occur[21]. However, if the evaporation rate is less than 0.1 lb/ft^2/hr, plastic shrinkage cracks are not expected.

FOGGING SYSTEM OPERATION OBSERVATION

The fogging system was operated on the Bridge 5500 site until the deck was covered with burlap. The fogging system was arranged as three segments with each segment approximately 33 foot long. Fogging was started once final finishing passed the end of each of the segments. All three segments of the fogging systems were individually controlled and each segment's operation was monitored separately. Operation times for each segment of the fogging system are provided in Figure 12.

CRACK OBSERVATIONS

This chapter presents the observations made for Bridge decks 5500 and 5701 after construction. These observations are used to evaluate the field implementation of the fogging system on Bridge deck 5500.

OBSERVATIONS AND ANALYSIS

Observations of the two bridge decks were made after construction at age 7, 14, 21, 28 and 56 days. Comparisons of the observations of the bridges are not ideal since the bridge decks were placed on different days with different weather and environmental conditions. However, there are some comparisons that can be made from the observations.

Crack observations

Cracks were observed and mapped for both bridges at age 7, 14, 21, 28 and 56 days. All visible cracks were identified by location, length and crack width. Crack maps for both bridges are presented in Figures 18-26.

Observation of cracks at 7 days

Both bridges were covered by burlap and plastic sheets for 7 days. The first visual inspection was made on the seventh day. For Bridge deck 5500, thirteen small cracks were observed on the seventh day (Figure 18). Most of the cracks are located near pier line 2 on the east side of the bridge. The first span and last span were observed to be in good condition. For Bridge deck 5701, five small cracks were observed at 7 days (Figure 19). Three cracks were located in the span between the abutment and pier line 5 and the other two cracks were near pier line 5. Spans 1 through 4 were in good condition.

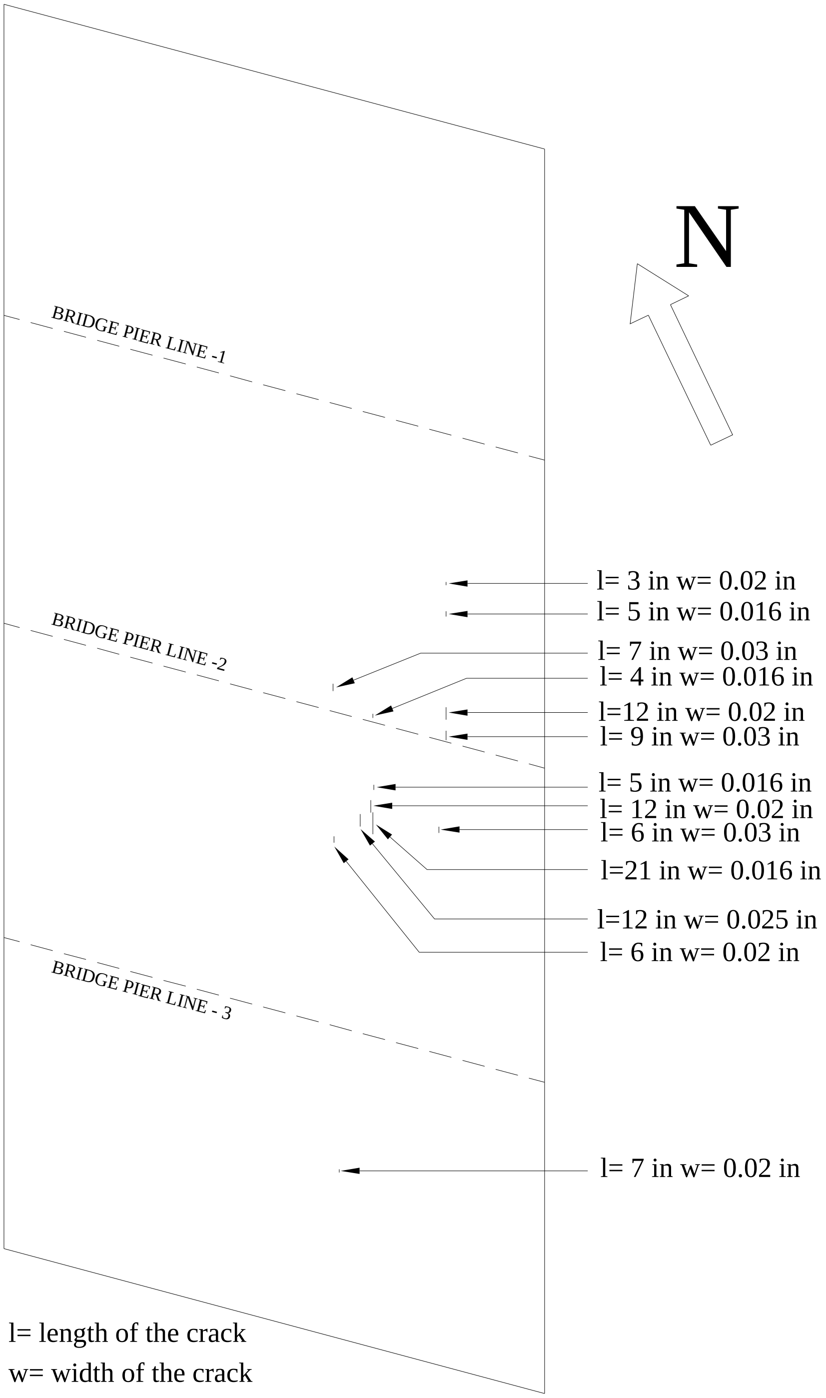


FIGURE 18 Bridge deck 5500 crack map at 7 days.

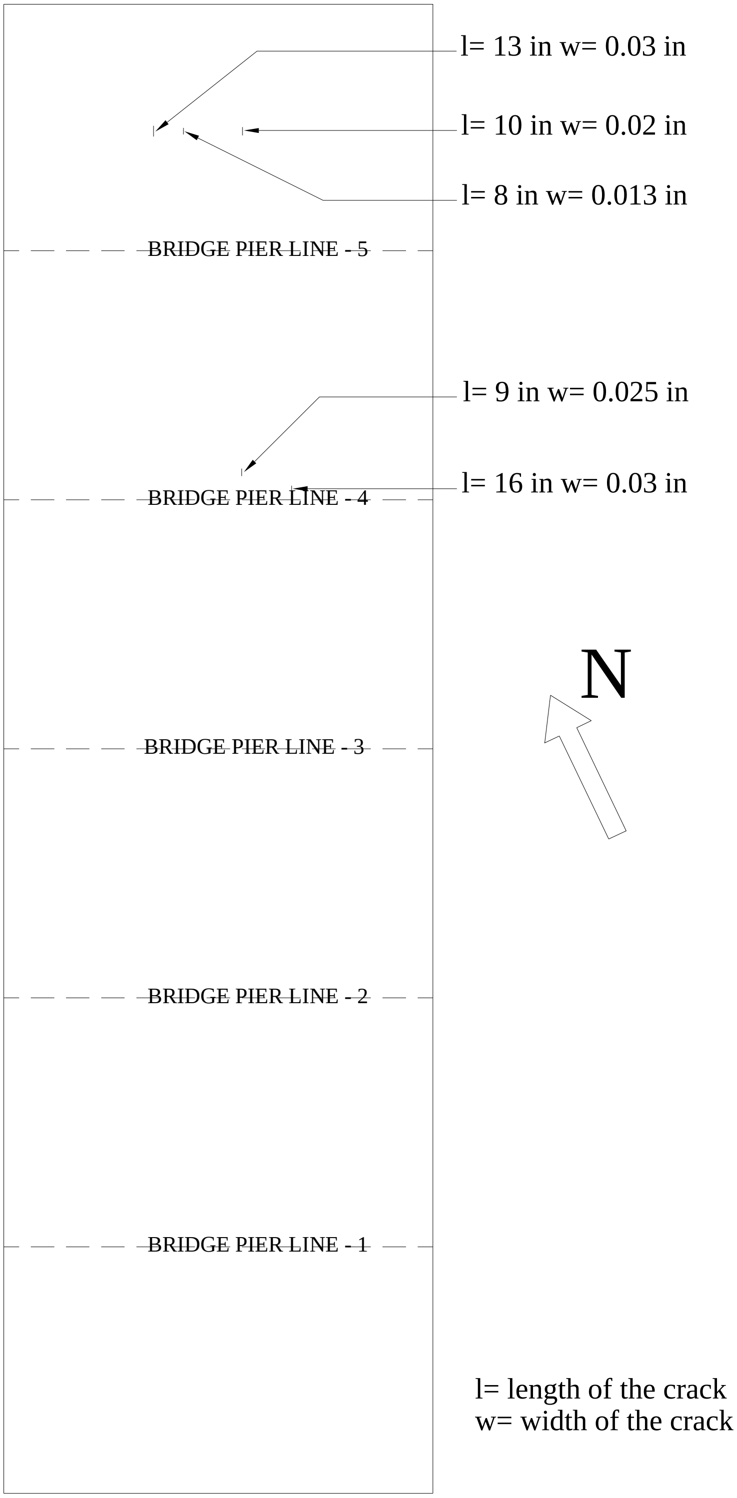
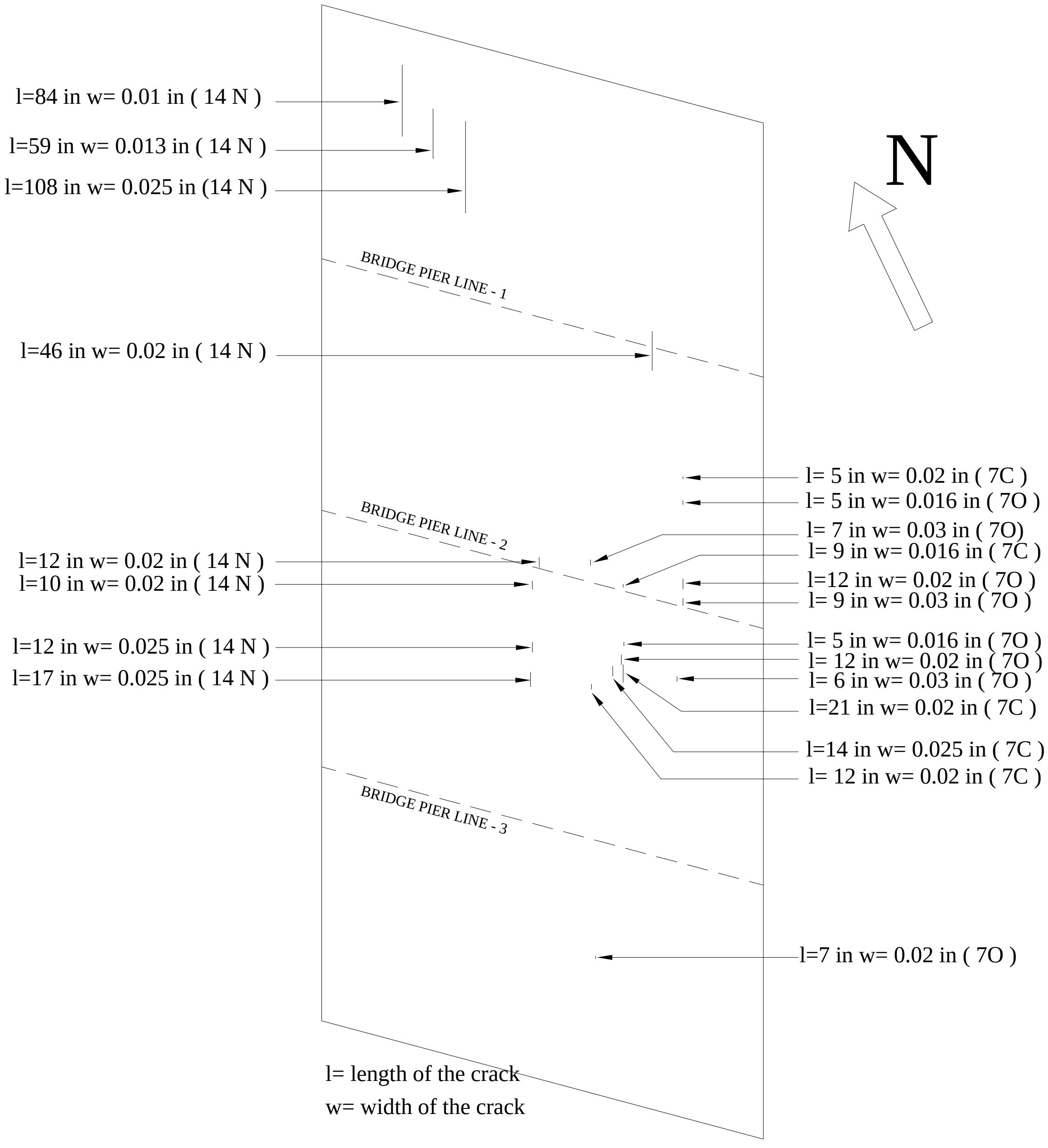
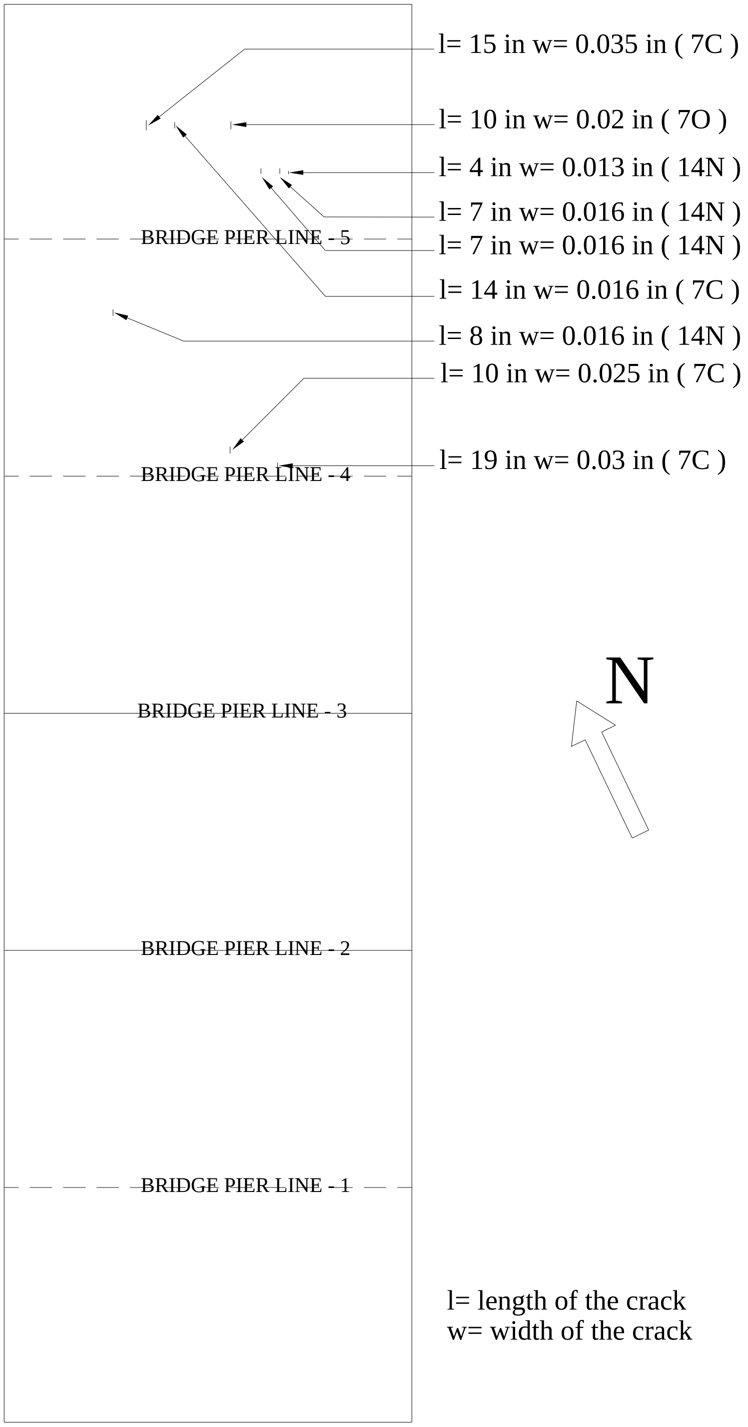


FIGURE 19 Bridge deck 5701 crack map at 7 days.



(7C) Indicates changed cracks from 7 days
(7O) Indicates unchanged cracks from 7 days
(14N) Indicates new cracks at 14 days

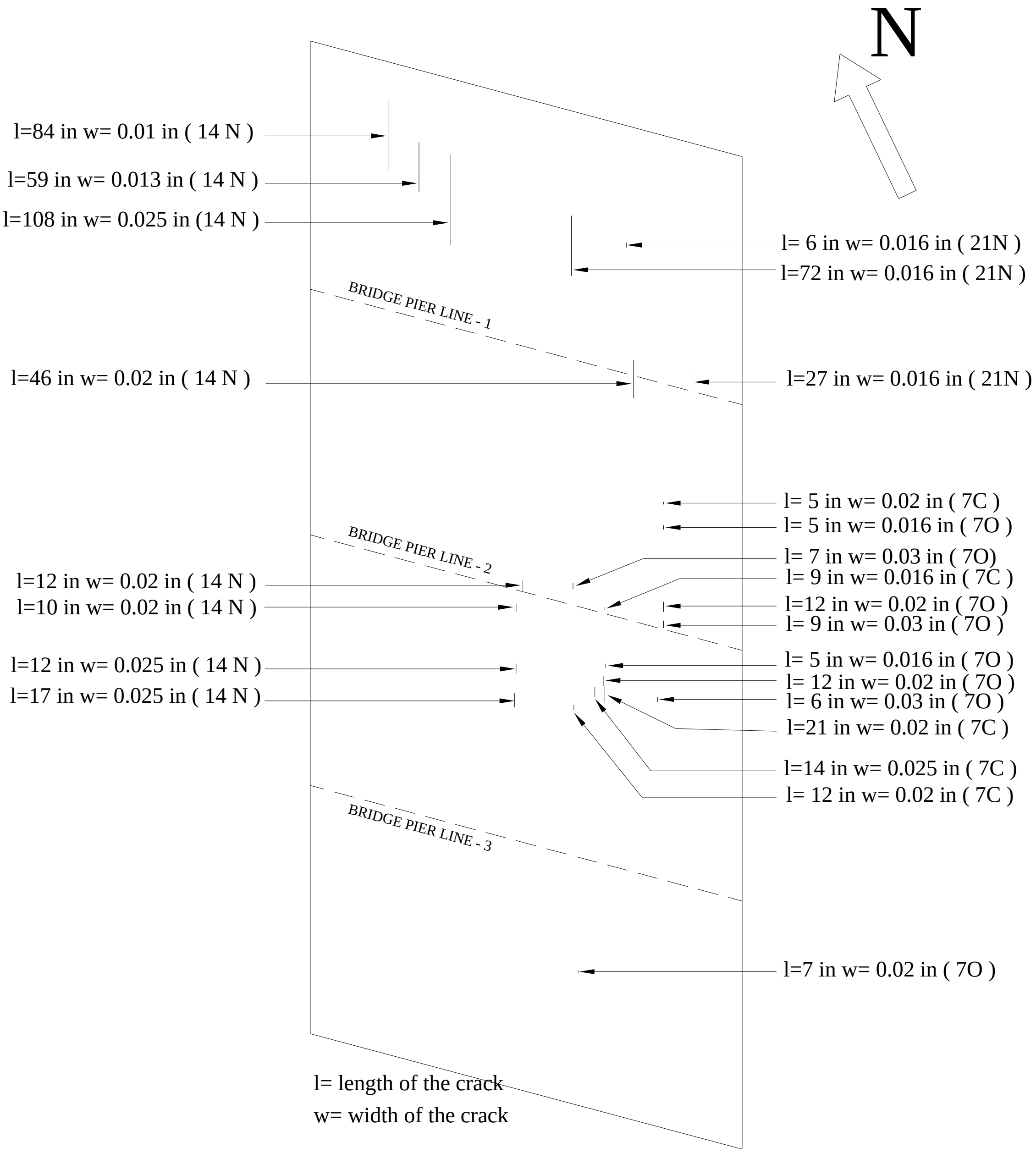
FIGURE 20 Bridge deck 5500 crack map at 14 days.



l= length of the crack
w= width of the crack

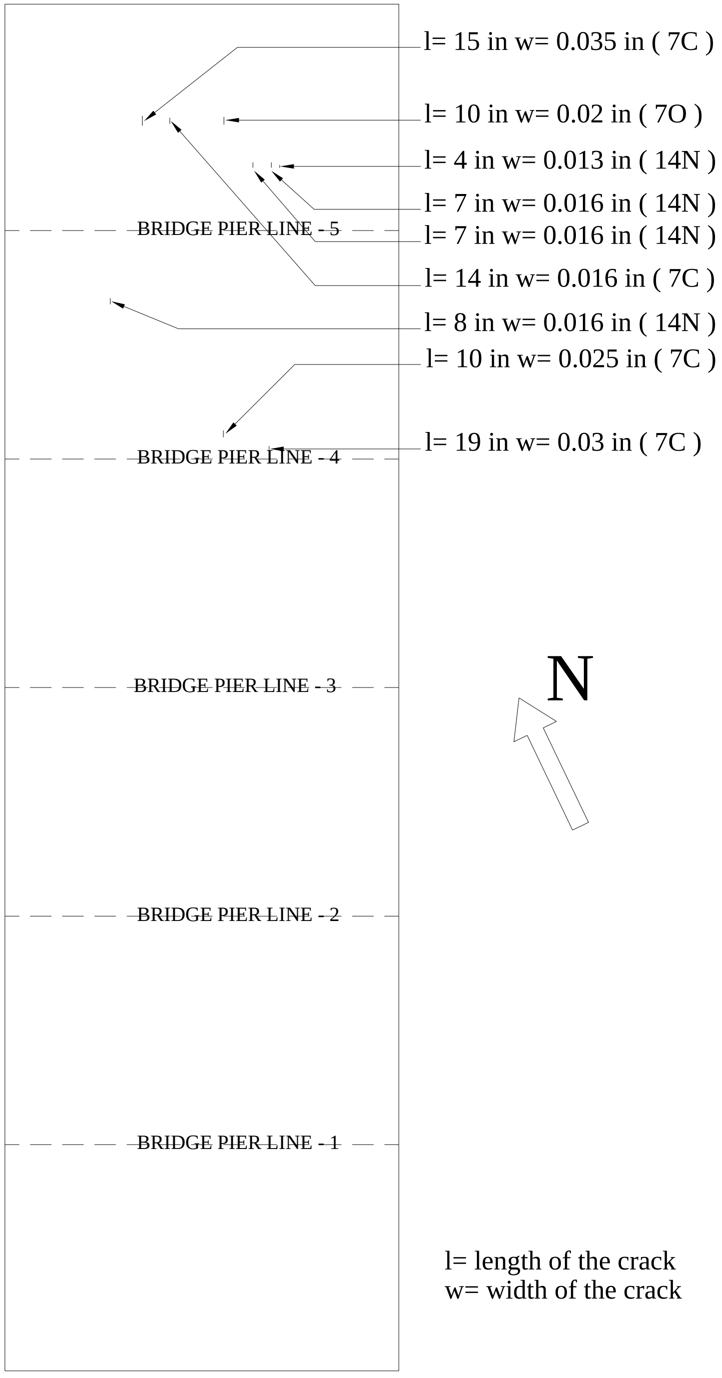
(7C) Indicates changed cracks from 7 days
(7O) Indicates unchanged cracks from 7 days
(14N) Indicates new cracks at 14 days

FIGURE 21 Bridge deck 5701 crack map at 14 days.



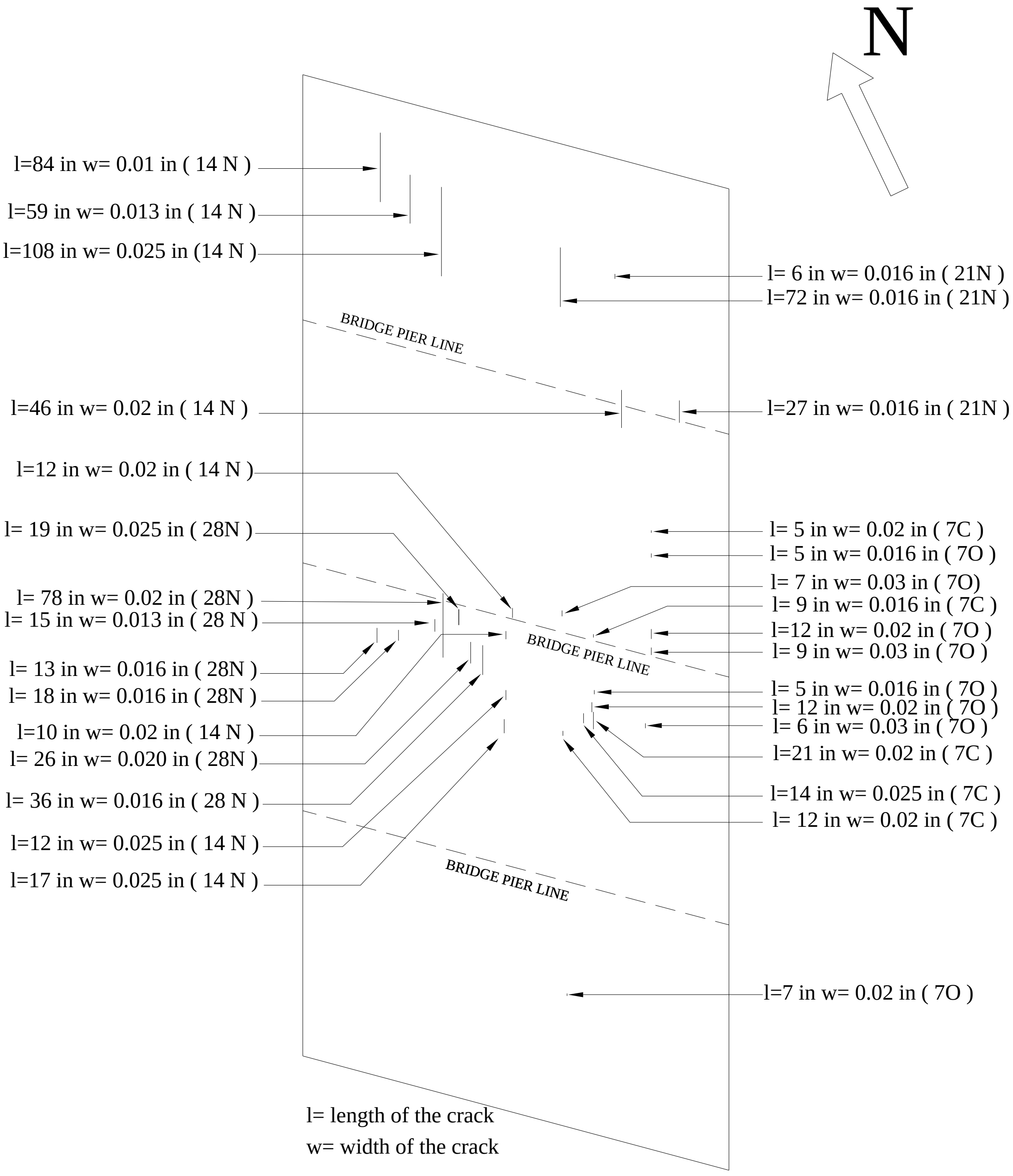
(7C) Indicates cracks that changed between 7 days and 14 days
(7O) Indicates unchanged cracks from 7 days
(14N) Indicates new cracks at 14 days that remain the same at 21 days
(21N) Indicates new cracks at 21 days

FIGURE 22 Bridge deck 5500 crack map at 21days.



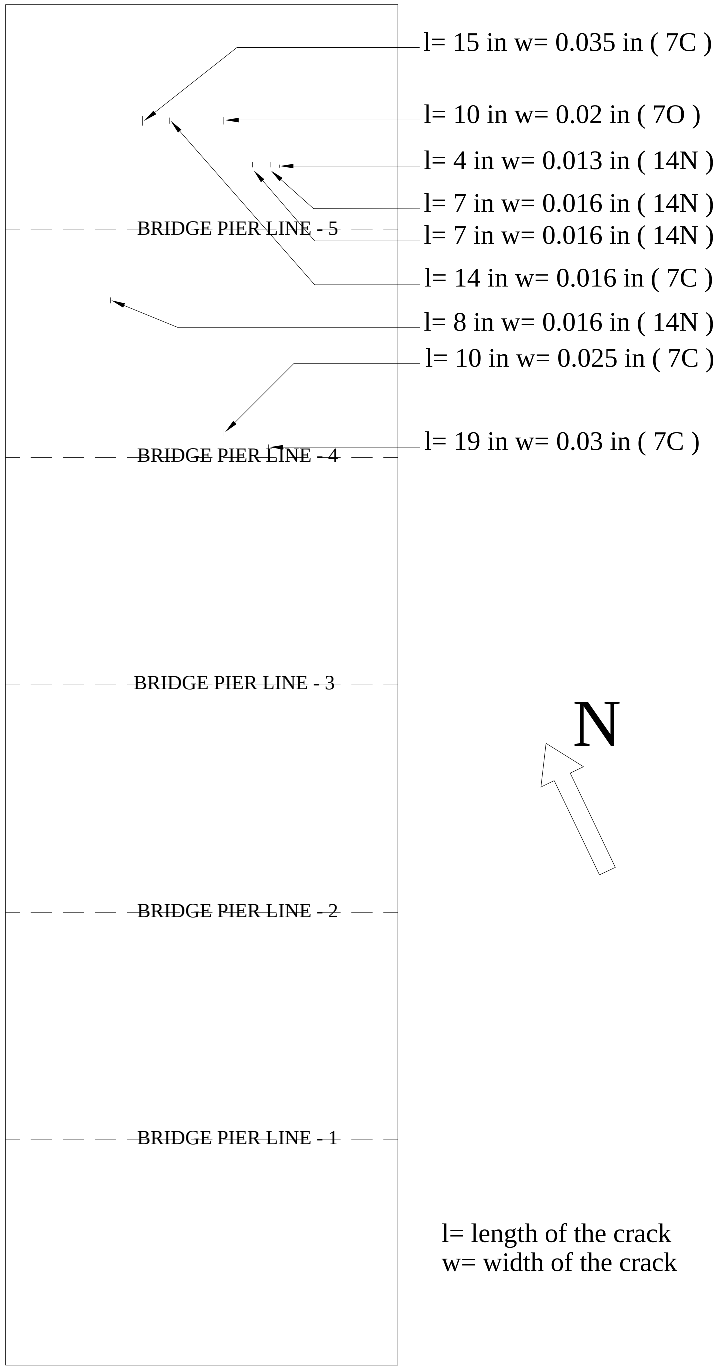
(7C) Indicates cracks that changed between 7 days and 14 days
(7O) Indicates unchanged cracks from 7 days
(14N) Indicates new cracks at 14 days that remain the same at 21 days
(21N) Indicates new cracks at 21 days

FIGURE 23 Bridge deck 5701 crack map at 21 days.



(7C) Indicates cracks that changed between 7 days and 14 days
(7O) Indicates unchanged cracks from 7 days that remain at 28 days
(14N) Indicates new cracks at 14 days that remain the same at 28 days
(21N) Indicates new cracks at 21 days that remain the same at 28 days
(28N) Indicates new cracks at 28 days

FIGURE 24 Bridge deck 5500 crack map at 28 days.



(7C) Indicates cracks that changed between 7 days and 14 days
(7O) Indicates unchanged cracks from 7 days that remain at 28 days
(14N) Indicates new cracks at 14 days that remain the same at 28 days
(21N) Indicates new cracks at 21 days that remain the same at 28 days
(28N) Indicates new cracks at 28 days

FIGURE 25 Bridge deck 5701 crack map at 28 days.

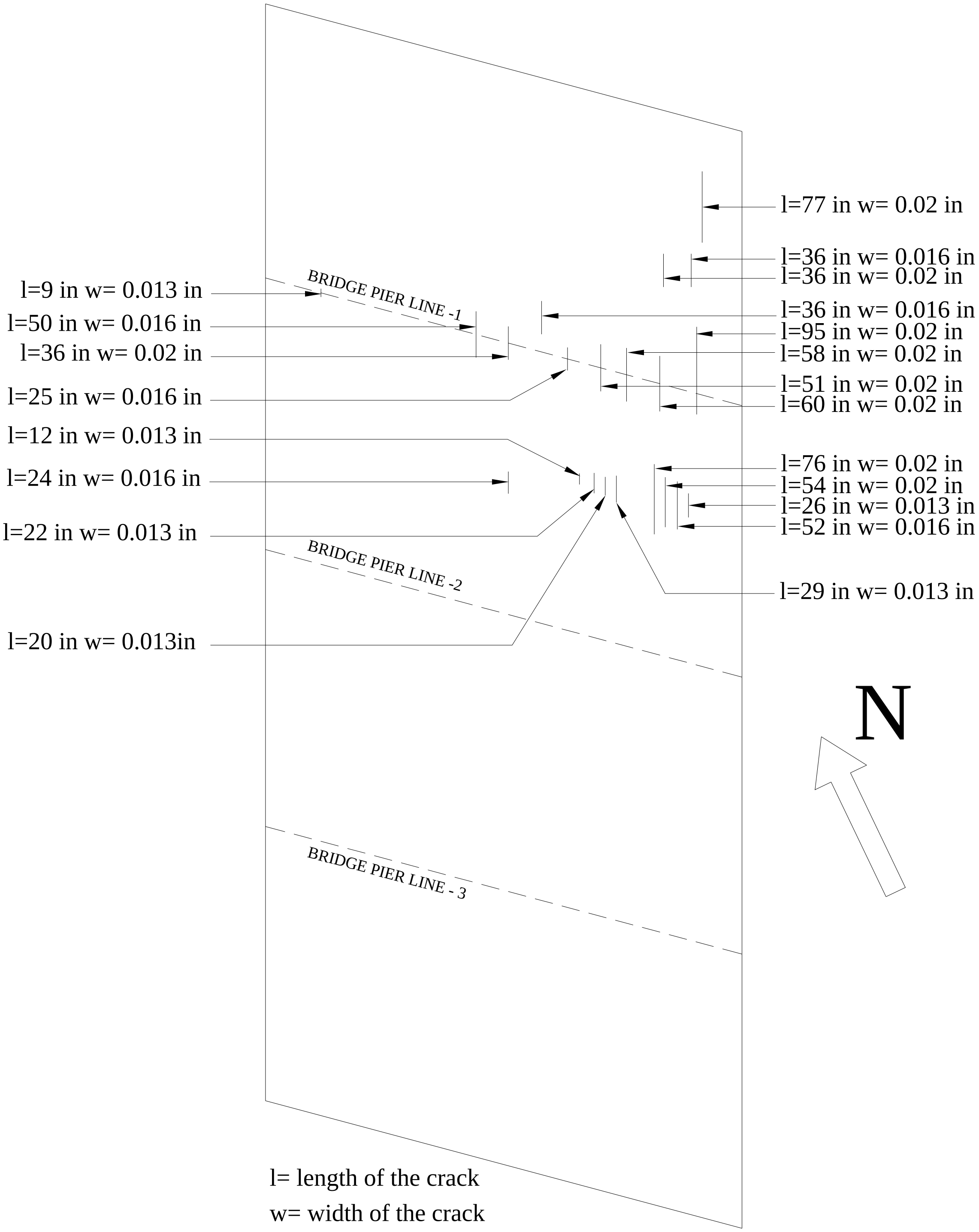


FIGURE 26 Bridge deck 5500 new cracks between 28 and 56 days.

The more extensive cracking on Bridge 5500 appears to be largely due to the greater evaporation rate experienced during placement. It should also be noted that the cracks in Bridge 5500 were in the location of a stoppage in placement. The cracks in Bridge 5701 occurred in concrete that was placed with an elevated evaporation rate.

All of the observed cracks in both bridges were oriented in the longitudinal direction. This could indicate that restraint in the transverse direction contributed to the cracking.

Observation of cracks at 14 days

For Bridge deck 5500, eight new cracks were observed at 14 days (Figure 20). Four cracks were located in first span between the abutment and pier line 1, one was located on pier line one, and the others were located near pier line 2. The span between pier line 3 and the abutment looked very good at 14 days. For Bridge deck 5701, four new cracks were observed at 14 days (Figure 21); three were located in the last span between pier line 5 and the abutment and the other was located on the fifth span between pier lines 4 and 5. The first four spans were observed to be in good condition.

Again, all of the cracks were oriented in the longitudinal direction indicating that transverse restraint may be playing a role in cracking, and all of the cracks occurred in concrete that had been exposed to an evaporation rate near or exceeding 0.1 lb/ft^2/hr.

Observation of cracks at 21 days

For Bridge deck 5500, three new cracks were observed in the first span between pier line one and the abutment at 21 days (Figure 22). Two were located in the middle of the first span and the other was located over the first pier line. For Bridge deck 5701, there were no new cracks observed at 21 days (Figure 23).

Observation of cracks at 28 days

For Bridge deck 5500, seven new cracks were observed at 28 days (Figure 24). All of these cracks were located near pier line 2. For Bridge deck 5701, there were no new cracks observed at 28 days (Figure 25).

Again, the new cracks appeared in concrete that was exposed to an evaporation rate exceeding 0.1 lb/ft^2/hr and were oriented longitudinally.

Observation of cracks at 56 days

For Bridge deck 5500, several new cracks were observed in spans one and two at 56 days (Figure 26). Most of the cracks were observed along pier line one and at midspan between pier lines 1 and 2. However, there were several minor cracks located in the second span.

At the time that this report was prepared, Bridge deck 5701 had not reached an age of 56 days. Consequently, no 56 day observations are presented here.

Possible reasons for cracks

This section presents a discussion of the observed cracks and possible causes for the cracks.

Placement duration

The rate of progress of concrete placement has a significant impact on deck cracking. As discussed in the Bridge Deck Construction section, both forward progress rates were slower than NMDOT specifications allow. Slow placement allows to more evaporation to occur before fogging is initiated. The portion of Bridge deck 5500 under fogging segment 2 was observed to have the majority of the cracking at 7 days. This portion of the deck required more than three hours of forward progress and other two segments required approximately two hours.

Weather conditions

Weather conditions are a major factor influencing bridge deck cracking. Bridge deck 5500 was placed during the daytime and Bridge deck 5701 was placed at night and early morning. The night time weather conditions during the Bridge deck 5701 placement were favorable for concrete placing.

Wind conditions were very good for Bridge deck 5701 since there was little wind until the last two hours of concrete deck placement. Even though the windbreak was erected for Bridge deck 5500, Bridge deck 5701 experienced slower wind speed than Bridge 5500 (Figure 14).

Relative humidity is another weather condition that influences evaporation. Fogging increases the relative humidity and reduces the evaporation of water from the concrete. As discussed in the Bridge Deck Construction section, relative humidity was approximately the same for both bridges, even though fogging increased relative humidity by 70-80% at Bridge deck 5500.

Air temperature is another important parameter for evaporation. The windbreak and fogging did not influence the air temperature above the concrete surface for Bridge deck 5500. Bridge deck 5701 experienced milder air temperatures for most of the placement. Most of the cracks observed on Bridge deck 5701 were in the last span which was placed when the air temperature was approximately 80°F and the relative humidity was 8-9%.

Evaporation rate

NMDOT specifications state that concrete shall not be placed unless the combinations of weather and environmental conditions produce an evaporation rate less than 0.2 lb/ft^2/hr. Neither bridge experienced an evaporation rate greater than 0.2 lb/ft^2/hr. However, both bridges experienced cracking in concrete that was exposed to an evaporation rate of 0.1 lb/ft^2/hr. For Bridge 5500, the evaporation rate approached 0.2 lb/ft^2/hr five to six hours into the placement (Figure 17).

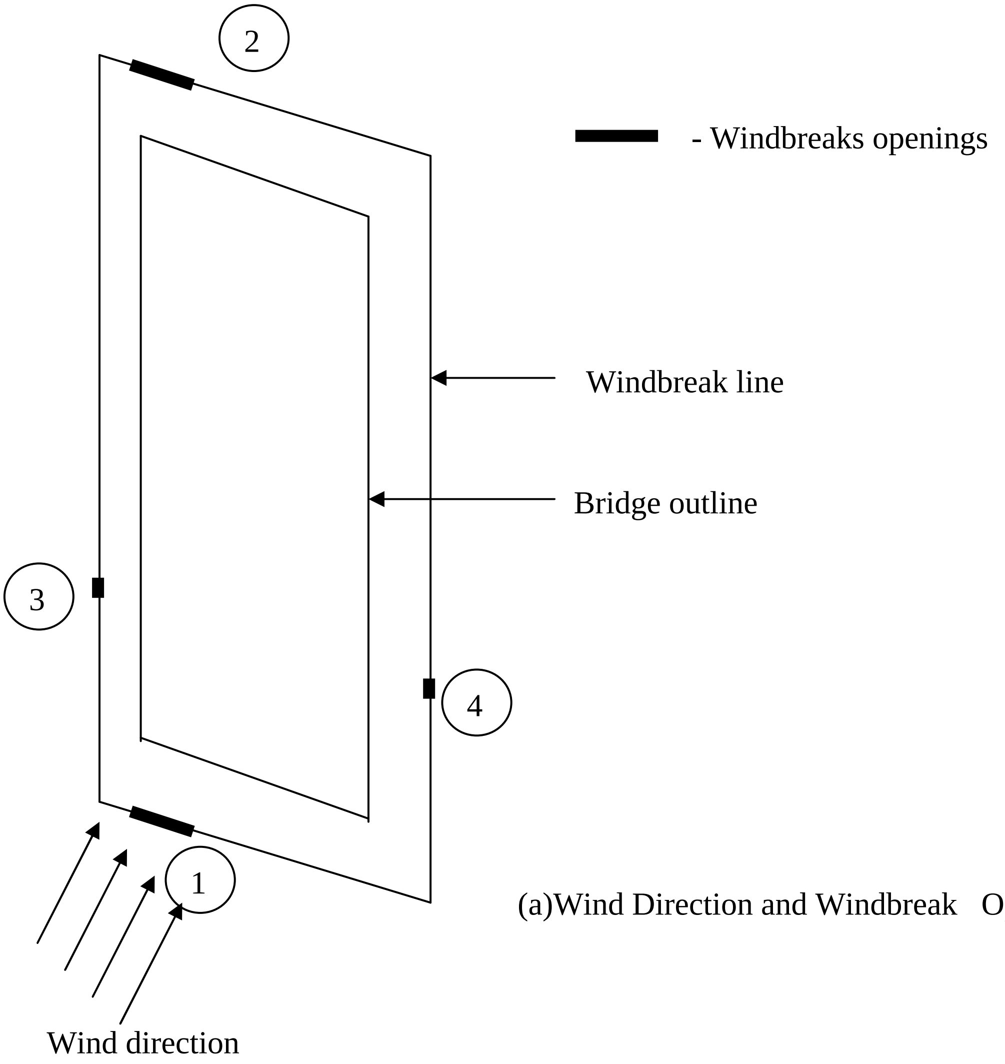
Windbreak

As discussed in Bridge Deck Construction section, the windbreak reduced the wind speed 60-65% inside the windbreak compared to the outside wind speed. As shown in Figure 27, four openings were present in the windbreak on the day of placement. Openings 1 and 2 were made for access to the bridge site and openings 3 and 4 were made by the Bid-well machine. Idealized wind flow over the windbreak is illustrated in Figure 27(b). Since the fogging system and windbreak were nearly the same height, about 10.5 to 12.75 ft, some of the misting water was carried outside the windbreak by the wind.

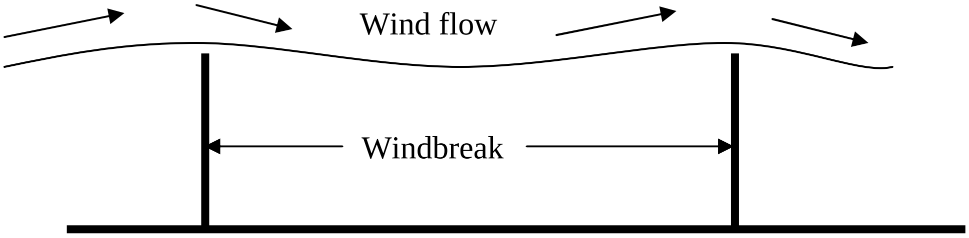
If the windbreak was 3-4 ft higher than the fogging system, that would improve the efficiency of the windbreak. Also, if the access openings were located on the leeward side of the windbreak, the windbreak efficiency would increase.

Other reasons

Other than the reasons listed above, there are other possible causes for the observed cracks. For Bridge deck 5500, formwork for span 1 was removed during the 7-14 day period. The removal of formwork may have caused some tensile stresses or movement in the first span of Bridge deck 5500. Three long cracks were observed in the first span of Bridge deck 5500 on the 14th day. In the week following the placement of Bridge deck 5701, weather conditions were overcast in southern New Mexico. This also provided a favorable environment for Bridge deck 5701 placement.



(a)Wind Direction and Windbreak Openings.



(b) Wind flow diagram.

FIGURE 27 Wind direction, windbreak openings and wind flow diagram.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the observations made during this work, the following conclusions are drawn:

1. Using a fogging system that was suspended from longitudinal cables was not an efficient system. There were a number of drawbacks that included:
    a. The support system consisting of cables, steel posts, deadman anchors, and windbreak fabric was expensive to install. The contractor's bid for the installation of this hardware on the Bridge 5500 site was approximately $75,000.
    b. It was extremely difficult to ensure that a uniform mist of known quantity was delivered to the concrete because it was being delivered from more than 10 feet above the surface of the concrete.
    c. Even crude control of the fogging system required a large windbreak.
2. Fogging at a rate that was double the evaporation rate did not alleviate all of the cracking in Bridge deck 5500. Using curing compound in combination with the fogging would probably have helped. However, the mist still needs to be delivered with more control than was provided by the suspended system.
3. Concrete in both bridge decks that was exposed to an evaporation rate greater than 0.1 lb/ft^2/hr was susceptible to cracking. The location on Bridge deck 5500 where the placement and finishing operations were particularly slow was more prone to cracking.
4. All of the cracks observed in the two bridge decks were oriented in the longitudinal direction. This seems to indicate that transverse restraint contributed to the cracking.

RECOMMENDATIONS

For implementing fogging systems on future projects, the following recommendations are provided:

1. The fogging system should be installed on a work bridge that follows the Bid-well. This will allow the mist to be applied close to the concrete with much better control.
2. Curing compound should be used in combination with fogging.
3. Fogging should be initiated as soon as possible after placement.
4. Concrete should be placed while the evaporation rate is less than 0.1 lb/ft^2/hr. Practically, this requires placing concrete at night for most projects in New Mexico.

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APPENDIX A: USER'S MANUAL

The purpose of this user's manual is to provide detailed instructions for the assembly, installation, and operation of the fogging system. In addition to the fogging system described in the user's manual, hardware described in the report needs to be installed on-site by the contractor. The hardware is referred to as "site specific hardware."

PARTS LIST

The fogging system used for this study consisted of:

1. 400 feet of 0.5 inch inside diameter PVC pipes.
2. 200 cone jet TXWS-1 nozzles.
3. 288 hose clamps for 3 inch hoses.
4. 300 feet of 17 gauge wire.
5. Four Simer MOD.2825ss model water pumps.
6. Four sediment filters.
7. Four pressure gauges.
8. 1000 feet of reinforced garden hose.
9. 16 flow tees.
10. One 325 gallon water tank.
11. One 425 gallon mobile water tank.

In addition to the above items, there is site specific hardware that must be installed at a site by the contractor. This hardware is used to support the fogging system and to provide a windbreak for the fogging operations. This hardware consists of steel posts, deadman anchors, steel cables and windbreak fabric as described in the body of the report.

ASSEMBLY

The fogging system has been preassembled in 11 foot sections of 0.5 inch inside diameter PVC pipes fitted with cone jet TXWS-1 nozzles spaced two feet apart. The nozzles are arranged such that adjacent nozzles spray water in opposite directions. Each of the nozzle fittings is assembled as shown in Figure A1, using Teflon tape on all threaded connections.

Each segment of the fogging system consists of four lines (one on each cable), each approximately 33 feet long, and each 33 foot line is produced by connecting three 11 foot

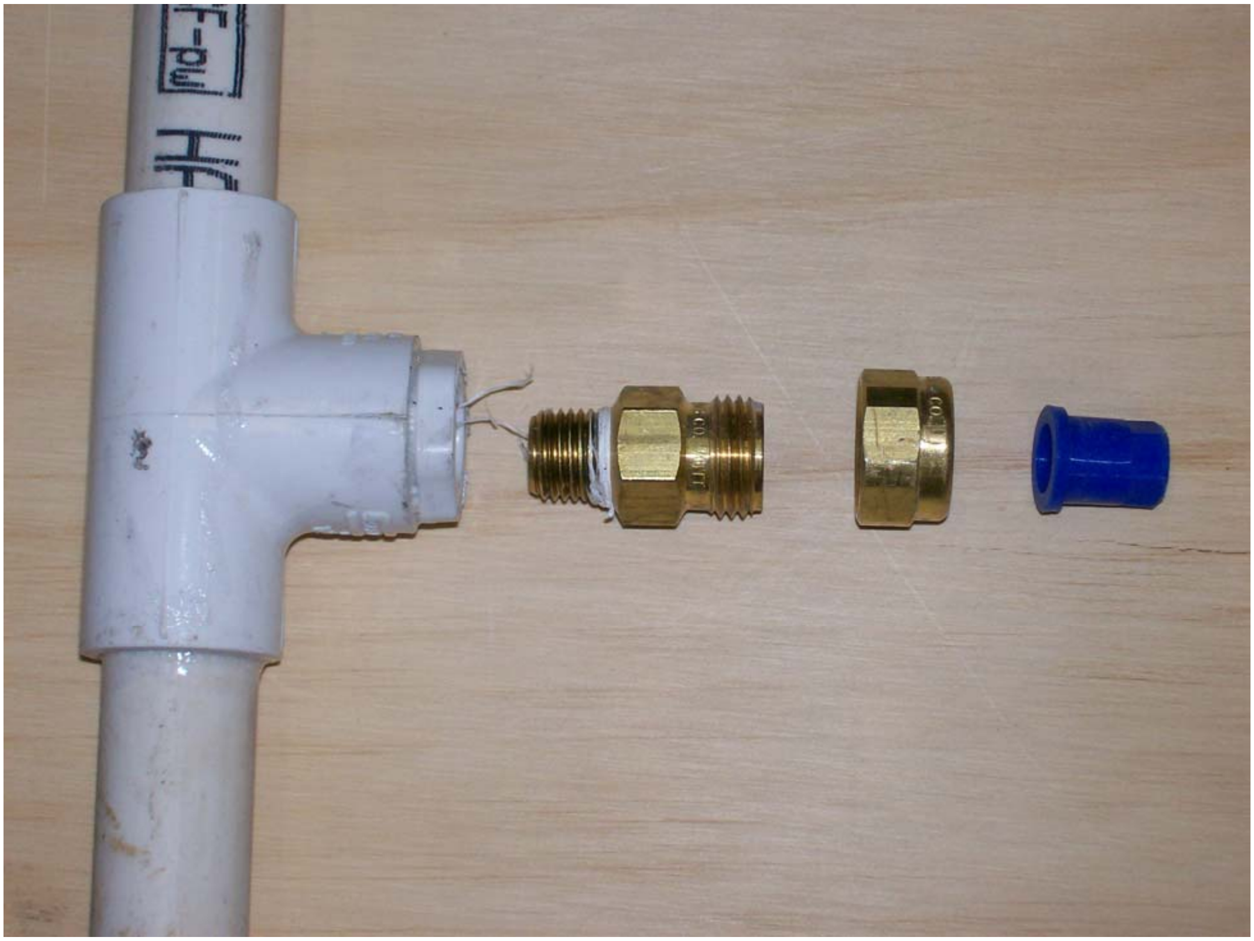

FIGURE A1 Nozzle fitting assembly.

sections. The section nearest the pump has one end with hose fitting, and one end with a compression connection. An end with a hose fitting is shown in Figure A2. A compression connection is shown in Figure A3. Although there is a threaded coupler on the compression connection, no Teflon tape is necessary. The connection is sealed by compressing a rubber gasket. The middle section of each line has compression connections at each end, and the section furthest from the pump has one end capped.

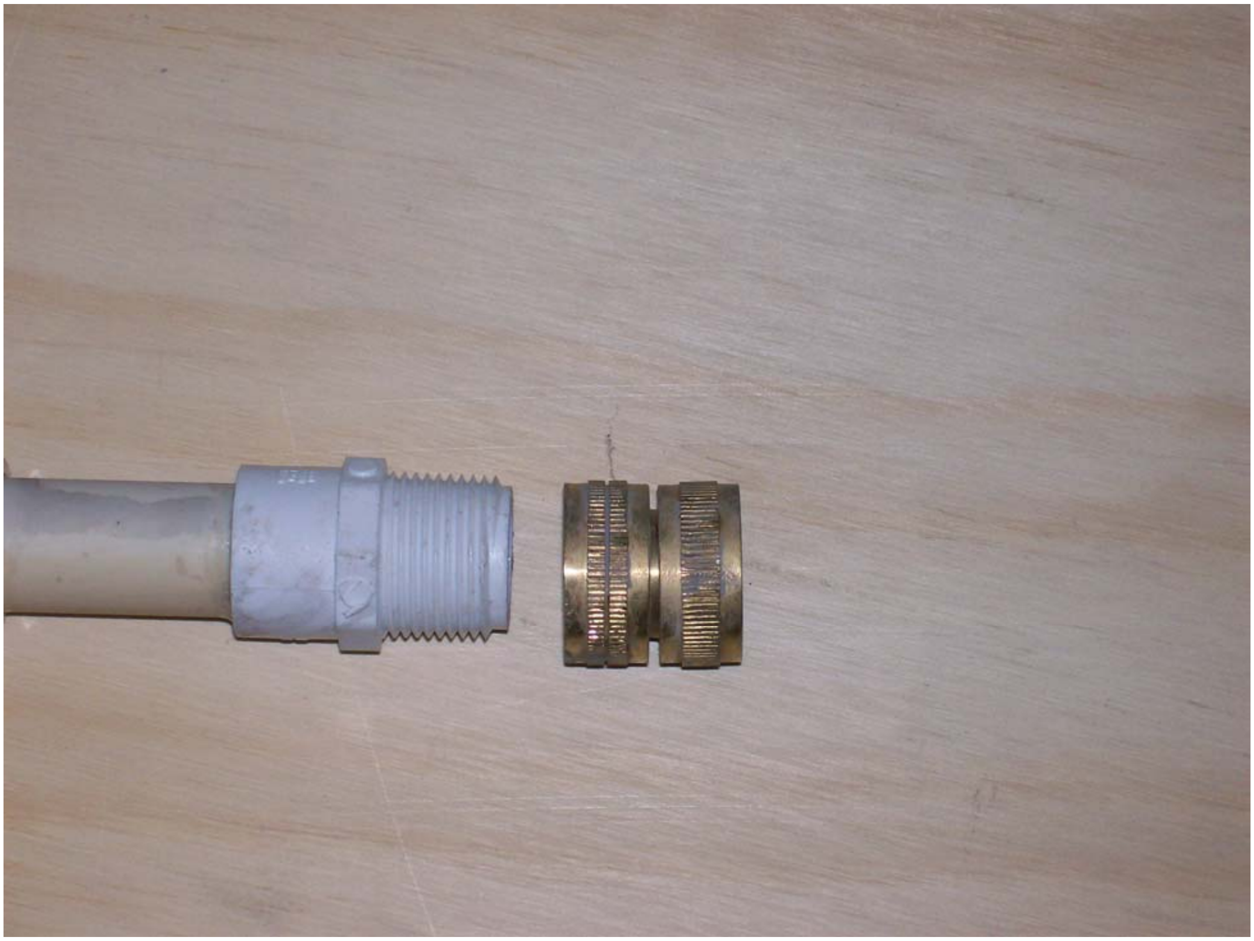

FIGURE A2 Hose fitting at end of fogging segment.

FIGURE A3 Compression connection.

INSTALLATION

All site specific hardware must be in place prior to field installation. It is recommended that installation be performed from the end of the fogging system furthest from the pumps to the end nearest the pumps. To begin the installation, the fogging system should be laid out directly under the cable system used for support. The installers should ensure that all items are present and that the fogging system has proper dimensions to extend just beyond each end of the bridge deck to be placed.

Each 11 foot section of one 33 foot line in a fogging segment should be installed individually. To install a section, four hose clamps should be attached to the cable at 4 foot spacings above the final location of the section. Placement of these clamps should be selected such that the outer clamps are near the ends of the section, and that none of the clamps will interfere with the operation of a nozzle. Four additional hose clamps should be attached to the PVC section at locations that correspond to those of the clamps attached to the cable. The pipe section should then be lifted into place and 17 gauge wire should be used to connect the hose clamps as shown in Figure A4. The wire should be tightened as needed to adjust the elevation of the section. Once the section is in place, the hose clamps on both the cable and the pipe and any connections to previously installed sections should be tightened.

After installing all of the sections in each line for the first segment of the fogging system, the hoses should be connected to this segment. As the proceeding segments are installed, the hoses for the first segment can be tied to the cable using plastic or wire ties. Tying the hoses to the

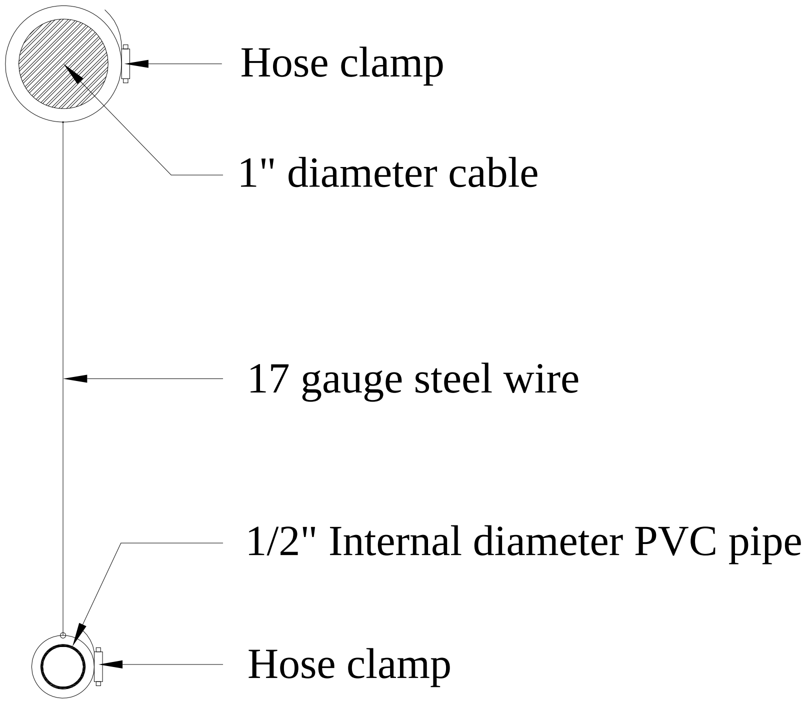

FIGURE A4 Wire connection to cable.

cables insures that the hoses do not sag and interfere with the fogging operation of the other segments.

After all of the sections have been installed, the fogging system attached to each cable should appear as shown in Figure A5.

The hoses should be tied to the cable to a point adjacent to the windbreak and then draped over the windbreak to the ground. The hose for each line of each segment should be connected to a flow tee, such as the one shown in Figure A6, so that the line can be shut down if necessary during operation. The arrangement of the hoses, pumps and tank is shown in Figure A7. It should be noted that one pump is required for each segment of the fogging system.

The pumps and tank should be arranged outside the windbreak to avoid interference with construction operations.

OPERATION

Operation of the fogging system consists primarily of ensuring that a fogging rate of 0.4 lb/ft^2/hr is being produced. The fogging rate is controlled primarily by the pressure in the system. A pressure of 40 psi will produce the desired fogging rate (based on an 11 foot cable spacing). The fogging rate can be adjusted within a range of 0.35 to 0.45 lb/ft^2/hr by adjusting the system

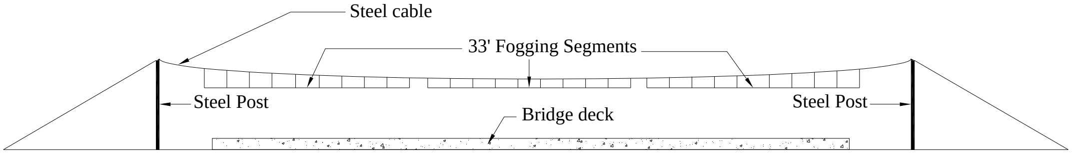

FIGURE A5 Fogging segments on an individual cable.

FIGURE A6 Flow tee.

pressure. This is accomplished by increasing or decreasing the backflow to decrease or increase the fogging rate, respectively. Adjustment outside this range of fogging rates requires changing either the size of the nozzles, the spacing of the nozzles, or the spacing of the cables. Pressure gauges are attached to the pumps to measure the system pressure as shown in Figure A8. The hose line rising vertically from the pump is the backflow line, and the bulbous apparatus attached to the main line is a sediment filter to capture sediment that could plug nozzles. The pumps require electrical power for operation, so generator will be needed at most sites.

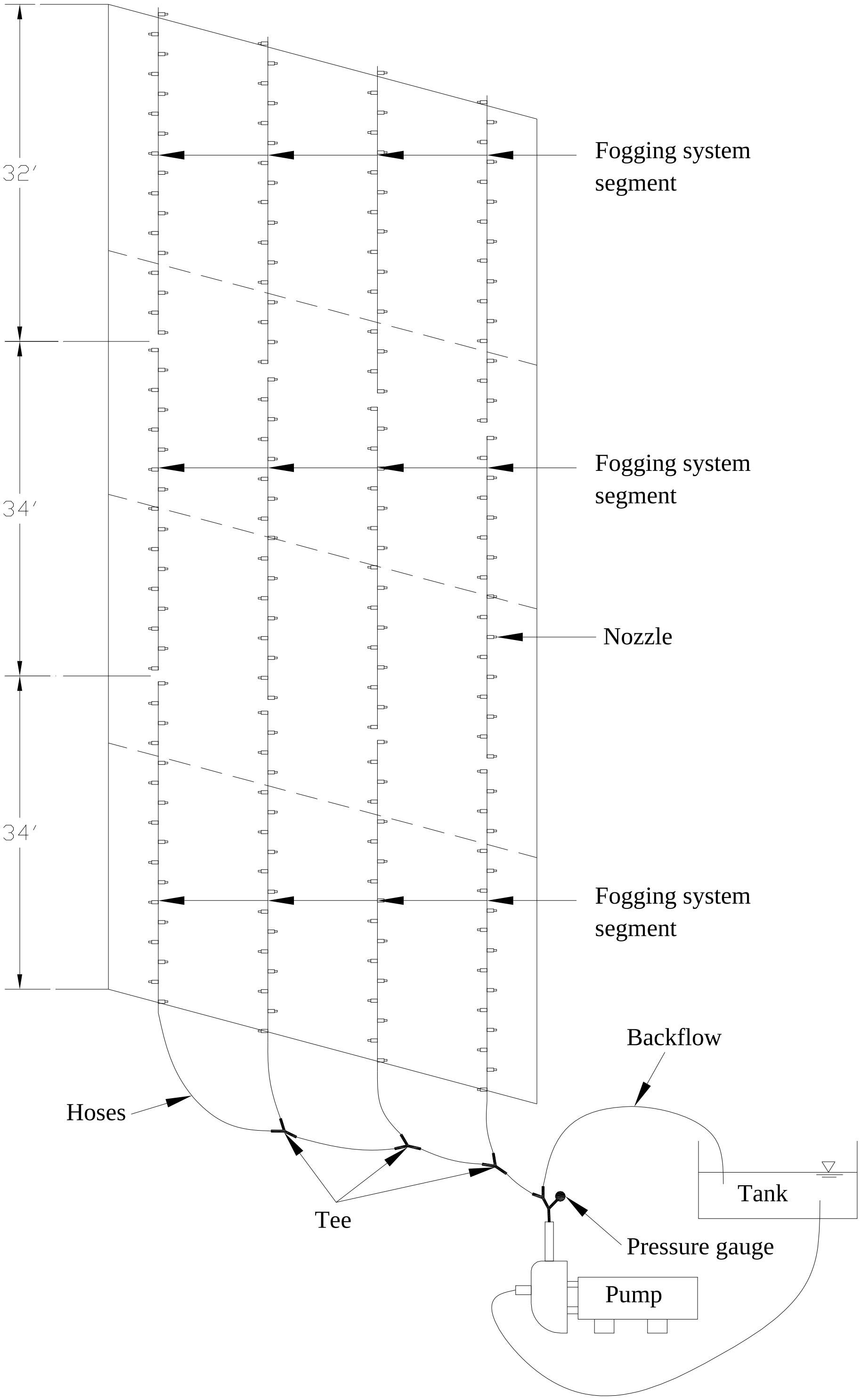

FIGURE A7 Hose, pump and tank arrangement.

FIGURE A8 Pump with pressure gauge.

Fogging should be initiated as soon as the finishing operation passes the end of a segment. For example, the first segment of the fogging system should be turned on as soon as the Bid-well machine has progressed to the beginning of the second segment. Fogging should continue until the concrete is covered with either burlap or curing compound.

The 325 gallon capacity tank provides enough water for approximately four hours of continuous operation of this system. The 425 gallon tank is mounted on a trailer to facilitate refilling the 325 gallon tank.

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