

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS DIVISION - STRUCTURAL CONCRETE SUBDIVISION

Report of Bridge Cores Taken On
Barnet-St. Johnsbury I 91-2 (59) C/3 I 91/U.S. Route 5

On September 12th and September 15th cores were extracted from both the northbound and southbound bridges over U.S. Route 5 on Interstate Project Barnet-St. Johnsbury I 91-2 (59) C/3.

Numerous transverse cracks have been observed in the southbound deck. The northbound deck appears to be relatively free of these cracks even though both bridges are very similar in design. Both structures are two span bridges.

The following information has been compiled in an effort to help determine the cause of these cracks. The information contained, herein, will hopefully be reviewed by the Bridge Division, and the Construction Division. Comments as a result of any review of this information is desired.

A sketch of the two bridges is enclosed. Cores have been numbered and located on the sketch. The pour sequence has been shown along with the direction in which the pours were made.

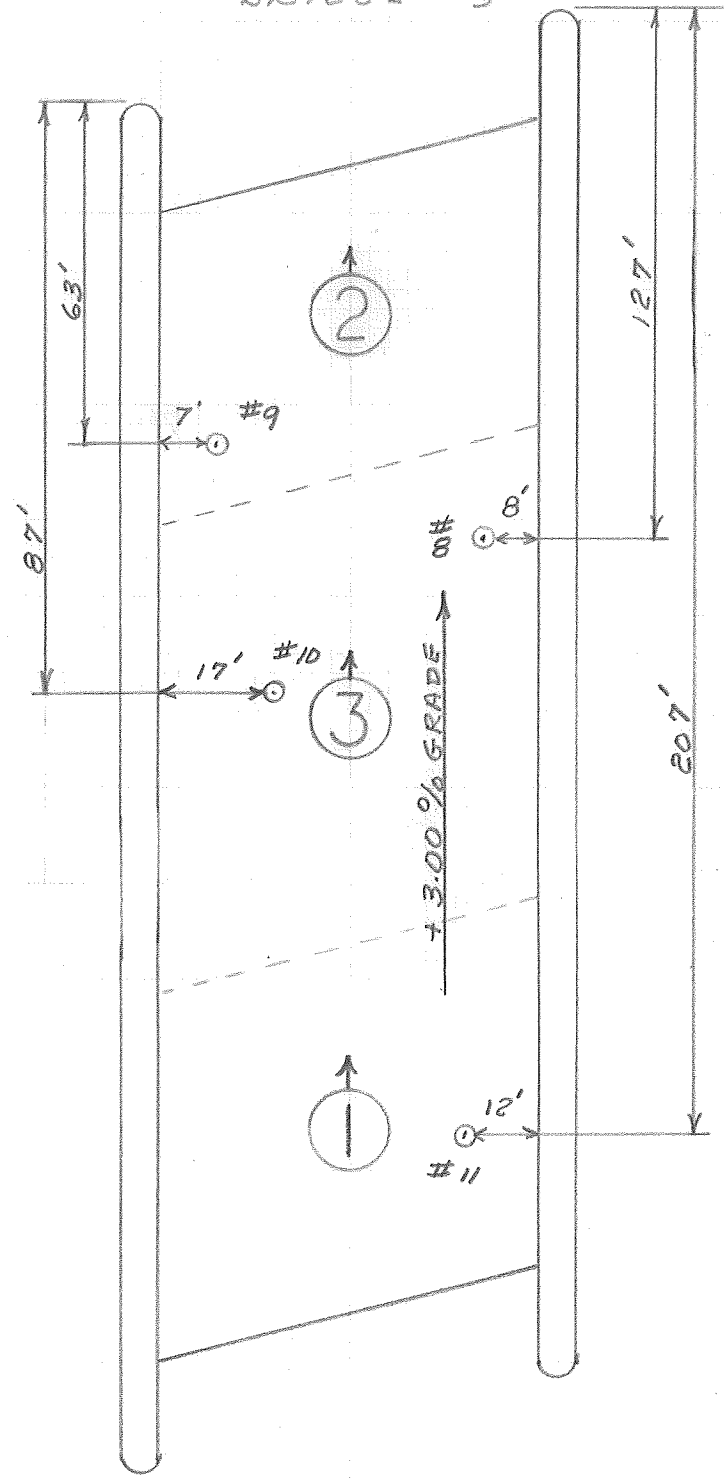
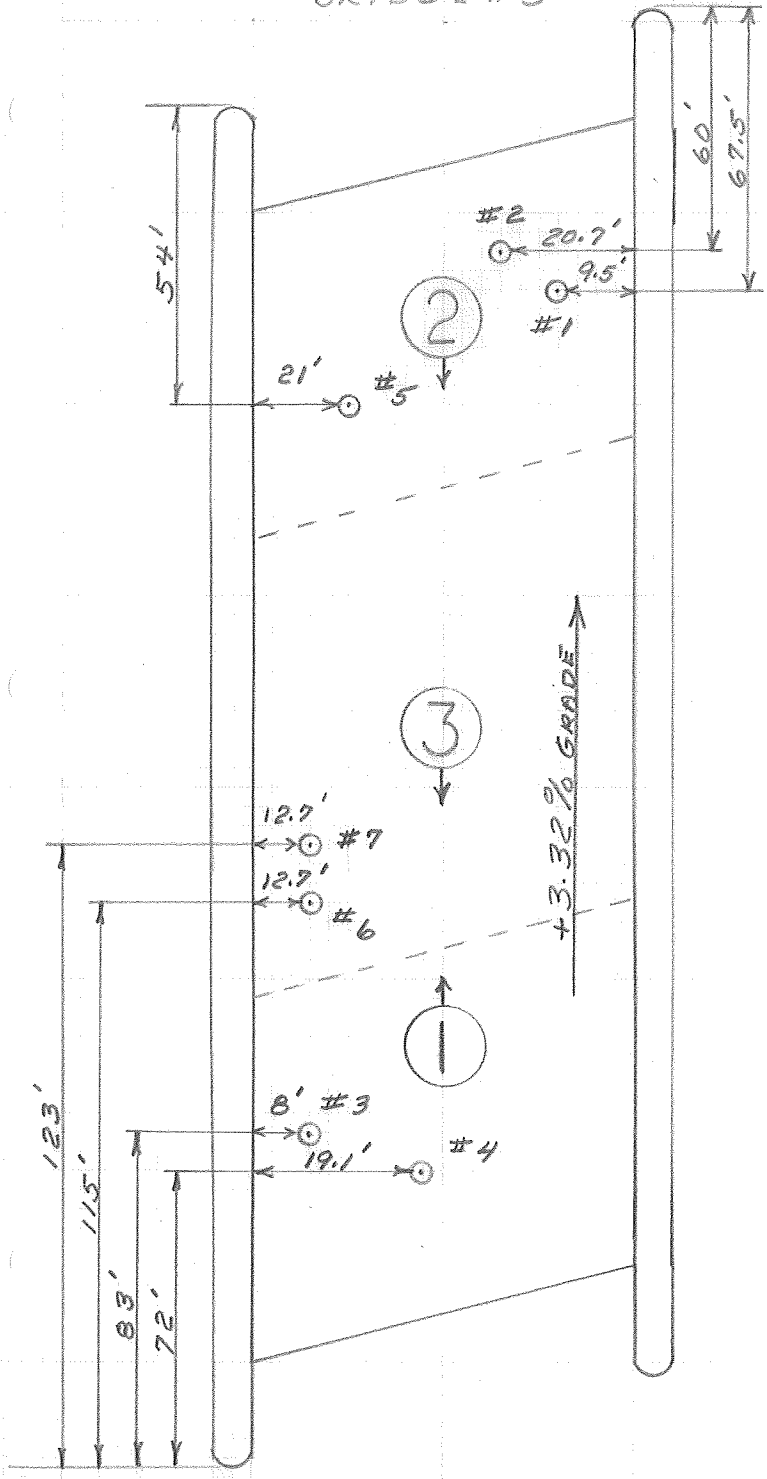
The percent of grade has been labeled on each structure.

CORE LOCATIONS

BY J. TALBOT
9-16-77
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SB
BRIDGE #3

NB
BRIDGE #3



○ CORE LOCATION & NO.
③ POUR SEQUENCE & DIRECTION OF POUR

State of Vermont
Agency of Transportation
Materials Division-Structural Concrete Subdivision

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BRIDGE CORE RESULTS

I 91-2 (59) C-3 Barnet-St. Johnsbury
I 91/U.S. Route 5

CORE NO.	BRIDGE	POUR SEQUENCE	DECK CRACKED	MAXIMUM DEPTH OF CRACK	DEPTH OF COVER OVER TOP MAT OF STEEL
1	SB	2	Yes	3 3/4 inches	1 5/8 inches
2	SB	2	Yes	5 inches	2 1/4 inches
3	SB	1	Yes	1 1/4 inches	1 1/4 inches
4	SB	1	No	-	1 5/8 inches
5	SB	2	Yes	1 5/8 inches	1 5/8 inches
6	SB	3	Yes	1 1/2 inches	1 5/8 inches
7	SB	3	No	-	2 3/8 inches
8	NB	3	Yes	1 1/2 inches	2 inches
9	NB	2	No	-	1 5/8 inches
10	NB	3	No	-	2 3/16 inches
11	NB	1	No	-	2 inches

SEQUENCE OF EVENTS

SOUTHBOUND BRIDGE - POUR SEQUENCE NO. 1

Checking Out the Finishing Machine

The finishing machine was checked for alignment, grade, and depth of cover over the top mat of reinforcing steel at six locations over the pour length of 60 feet. Depths of cover over the reinforcing steel at the back of the roll varied from 1 5/8" to 2 3/4". The average depth exceeded 2" but several readings were taken indicating areas where 2" of clearance was not obtained.

Direction of Pour

The pour was made in a northerly direction with an increase in the positive grade as the pour continued.

Conditions On The Day of The Pour

Date of Pour: June 23, 1977
Time of Day: 12:10 PM till 5:00 PM
Yardage Poured: 104 c.y.±
Weather: Overcast, cloudy, light wind
 ambient temperatures 65^o F. to 60^o F.
 concrete temperatures 71^o F. to 75^o F.
% of Air in Mix: 5.0 to 7.1% - Average 6.12%
Slump: 2 1/4 to 3 1/2 inches Average: 2.89 inches
Water Cement Ratio: 0.39
Retarder Schedule: Daratard HC 6 oz/sack used during entire pour
Compressive Strength: 28 day standard cured cylinders
Load #2 - Lab. Report #C7700572 4297 Ave. psi
Load #11 - Lab. Report #C7700596 5292 Ave. psi
Load #11 - Lab. Report #C7700595 4611 Ave. psi

Curing Procedures

Wetting of this portion of the deck did not occur until the morning of June 24, 1977. Periodic wetting occurred the morning of June 24, 1977 up until the time of covering with Burlene, approximately 10:00 AM. The cure continued for 10 days.

Condition of the Deck at the Time Cores Were Taken - September 12, 1977

This section of the deck showed transverse cracks in areas over the beams. The lengths of the cracks are about 18" long. These cracks do not appear evident between the beams. The spacing of the cracks is about 12" on center, the same spacing as used for the shear connectors. Measurement from the centerline of bearing to the spacing of the cracks appears to agree with the spacing of the shear connectors.

Core Observations

Core No. 3 was taken over a transverse crack, shows the top transverse rebar at a depth of 1 1/4 inches, the crack extended to the top of the rebar. The longitudinal rebar was found at a depth of 2 1/2 inches. The difference in elevation between these rebars may be the result of a broken tie wire.

Core No. 4 - A line connecting transverse cracks over two beams was drawn on the deck. Core No. 4 was then taken over this line in an area between the two cracks to determine the depth of rebar. No cracks were found. This core just cut the corner of a transverse rebar. The depth of cover was 1 5/8 inches.

SOUTHBOUND BRIDGE - POUR SEQUENCE NO. 2 & NO. 3

Checking Out the Finishing Machine

The finishing machine was again checked for alignment, grade, and depth of cover over the top mat of reinforcing steel at six locations over the pour length of 140 feet. Depths of cover over the reinforcing steel at the back of the roll varied from 1 1/2" to 2 5/8". A greater percentage of the readings indicate that 2 inches of cover would not be realized in the final deck after placement of the concrete. The notes indicate that the sixth section checked needed and received adjustment of the finishing machine.

Direction of Pour

This section of the deck, Pour Sequence No. 2 and No. 3 were both poured on the same day in a continuous pour starting at the north end of the deck and proceeding southward or down grade until meeting the north end of Pour Sequence No. 1.

Conditions on the Day of the Pour

Date of Pour: June 27, 1977
Time of Day: 7:30 AM till 3:00 PM
Yardage Poured: 204 c.y.
Weather: Overcast in AM, Sunny in PM
Light breeze, ambient temperature 62° F. to 84° F.
Concrete temperature 75° F. to 79° F.
% of Air in Mix: 5.0 to 7.0 - Average 5.60%
Slump: 2 to 3 1/2 inches - Average: 2.75 inches
Water cement ratio: 0.37
Retarder Schedule: Daratard HC
7 oz/sack 0 to 81 c.y.
6 oz/sack 81 to 204 c.y.
Compressive Strength: 28 day standard cured cylinders
Load #2 - Lab. Report #C7700628 5261 psi
Load #15 - Lab. Report #C7700629 5305 psi

Curing Procedures

Wetting of this portion of the deck did not occur until the morning of June 28, 1977. The deck may have been subjected to areas of drying prior to being covered with Burlene on June 28, 1977. Soaker hoses were used to keep the deck wet. The cure continued for 10 days.

Conditions of the Deck At The Time of The Pour (June 27, 1977) and At The Time Cores Were Taken - September 12, 1977

Before the pour was completed, transverse cracks were observed at the north end of Pour Sequence No. 2 within a few feet of the end of the bridge. Several transverse cracks were also observed over several of the transverse bars in the top mat 30 feet south of the north end of the deck. Contractors personnel worked with the retarded concrete, which by this time, began to loose plasticity. These cracks were smoothed out at this time. The next morning numerous transverse cracks spaced at intervals of 6" were observed over the area of the top mat of transverse bars. Unlike Pour

Sequence No. 1, these transverse cracks extended further across the deck, being visible between the beams as well as over them. Shadows in the deck follow the pattern of the top mat of steel.

Core Observations

Core No. 1 was taken over a transverse crack. Depth of cover is $1 \frac{5}{8}$ inches. The crack extends beneath the bar to a depth of about $3 \frac{3}{4}$ inches. Voids are visible in the concrete on the downgrade side of the bars.

Core No. 2 was taken over a crack and transverse bar splice at the junction of a longitudinal bar. Depth of cover is $2 \frac{1}{4}$ inches. The crack extends beneath the top mat of steel to a depth 5 inches on one side of the core and to a depth of $2 \frac{1}{4}$ inches to the steel on the other side. No noticeable voids were observed around the bar.

Core No. 5 was taken over a crack halfway between beams. Depth of cover is $1 \frac{5}{8}$ inches. No visible crack is found on the east side of core where transverse steel is spliced. The west side of core shows a crack to a depth of $1 \frac{5}{8}$ inches.

Core No. 6 was taken over a transverse crack. Depth of cover is $1 \frac{5}{8}$ inches. The crack extends to a depth of $1 \frac{1}{2}$ inches.

Core No. 7 was taken 8 feet north of Core No. 6; no crack was found but core was taken over a transverse bar. Depth of cover is $2 \frac{3}{8}$ inches. Cracks are visible in the deck about $1 \frac{1}{2}$ and 3 feet north of this core.

NORTHBOUND BRIDGE POUR SEQUENCE NO. 1

Checking Out the Finishing Machine

The finishing machine was checked out for alignment, grade, and depth of cover over the top mat of steel. Field notes indicate the entire deck was checked at one time. Cover varies from $1 \frac{5}{8}$ inches to $2 \frac{3}{4}$ inches. A note indicates low readings of $1 \frac{5}{8}$ inches were adjusted for by raising the inside rail $\frac{1}{2}$ inch. Overall the measured depths average well over 2 inches.

Direction of Pour

The three pours made on this deck were all made in a northerly direction with an increase in the positive grade as the pours continued.

Conditions on The Day of The Pour

Date of Pour: August 20, 1977
Time of Day: 7:30 AM till 11:30 AM
Yardage Poured: 103 c.y.
Weather: Foggy in AM, muggy, partly cloudy with light wind. Ambient temperatures 67^o F. to 90^o F. during pour, temperature reached 100^o F. at 4:40 in the afternoon. Concrete temperatures 80^o F. to 84^o F.
% of Air in Mix: 6.2 to 6.5 - Average 6.33%
Slump: 2 to 4 1/4 inches - Average 2.83 inches
Water Cement Ratio: 0.40
Retarder Schedule: Daratard HC 5 oz/sack 0-36 c.y.
4 1/2 oz/sack 36-72 c.y.
4 oz/sack 72-103 c.y.
Compressive Strengths: 28 day standard cured cylinders
Load No. 4 - Lab. Report #C770753 3683 psi
Load No. 5 - Lab. Report #C770754 3797 psi

Swiss hammer tests performed on August 29, 1977 when this concrete was 40 days old indicated that there was a 10% chance that the compressive strength was below 4933 psi and a 90% chance that the compressive strength was above 4933 psi.

Curing Procedures

Curing started as soon as water could be sprayed onto the deck without harm to finish. This pour was covered with Burlene the same day. Soaker hoses were used to keep the deck wet. The cure continued for 10 days.

Conditions Of The Deck at the Time Cores Were Taken - September 15, 1977

This portion of the deck showed no transverse cracking or shadows. The texture of deck was that of a pan finish.

Core Observations

Core #11 was taken at random and showed the depth of cover to be 2 inches. No signs of any transverse cracks over the steel were observed.

NORTHBOUND BRIDGE POUR SEQUENCE NO. 2

Conditions On The Day of The Pour

Date of Pour: July 26, 1977
Time of Day: 6:55 AM till 10:30 AM
Yardage Poured: 117 c.y.
Weather: Partly cloudy, light wind
Ambient temperature 57° F. to 60° F., concrete
temperature 74° F. to 76° F.
% of Air in Mix: 5.0 to 5.7 - Average 5.28%
Slump: 2 to 4 inches Average 2.84 inches
Water Cement Ratio: 0.38
Retarder Schedule: Daratard HC
5 oz/sack 0-36 c.y.
4 1/2 oz/sack 36-45 c.y.
4 oz/sack 45-54 c.y.
3 1/2 oz/sack 54-81 c.y.
2 1/2 oz/sack 81-117 c.y.
Compressive Strength: 28 day standard cured cylinders
Load No. 3 - Lab. Report #C770773 5040 psi
Load No. 9 - Lab. Report #C770772 4244 psi

Curing Procedures

Curing started as soon as water could be sprayed onto the deck without harm to the finish. This pour was covered with Burlene the same day. Soaker hoses were used to keep the deck wet. The cure continued for 10 days.

Conditions of The Deck At The Time Cores Were Taken - September 15, 1977

This portion of the deck had been bull floated. No noticeable transverse cracks were found. A few small random shrinkage cracks can be found in the laitance. However, shadows could be seen in the deck surface that reflect the pattern of the transverse bars.

Core Observations

Core No. 9 was taken over one of the shadows and a transverse bar was cut and found below the shadows. The depth of cover over the transverse bar was 1 5/8 inches.

NORTHBOUND BRIDGE POUR SEQUENCE NO. 3

Conditions On The Day of The Pour

Date of Pour: July 29, 1977
Time of Day: 6:45 AM till 10:30 AM
Yardage Poured: 79 c.y.
Weather: Cloudy and calm
Ambient temperature 54^oF. to 63^oF.
Concrete temperature 75^oF. to 79^oF.
% of Air in Mix: 5.0 to 6.0 Average 5.32%
Slump: 2 to 3 inches Average 2.60 inches
Water Cement Ratio: 0.38
Retarder Schedule: Daratard HC
3 1/2 oz/sack 0-36 c.y.
2 1/2 oz/sack 35-79 c.y.
Compressive Strength: 28 day standard cured cylinders
Load No. 6 - Lab. Report #C7700799 4836 psi

Curing Procedures

Curing started as soon as water could be sprayed onto the deck without harm to the finish. This pour was covered with Burlene the same day. Soaker hoses were used to keep the deck wet. The cure continued for 10 days.

Conditions of the Deck At The Time Cores Were Taken - September 15, 1977

This portion of the deck had been bull floated. A couple noticeable transverse cracks were found. Shadows were also visable on this section of the deck.

Core Observations

Core No. 10 was taken over a high spot in the deck. Shadows were evident both east and west of the core location but were not evident where core was taken. The depth of cover over the transverse bar measured 2 3/16 inches. No visable cracks were observed in the core.

Core No. 8 was taken over one of the few transverse cracks found in the northbound deck. This core revealed a depth of cover of 2 inches over the top mat of steel. The depth of the crack was 3/4 of an inch on the east side and 1 1/2 inches on the west side. A shear connector was evident in the center of this core. The depth of cover over the shear connector was 2 5/8 inches.

SUMMARY AND REMARKS

The transverse cracks noted primarily in the southbound deck indicate that perhaps more attention has to be given to our methods and procedures presently being used in bridge deck construction.

Two questions come to mind when you observe the condition of the decks on these bridges. Why is the north end of the southbound deck cracked more severely than the south end of the same deck? Why are there more transverse cracks in the southbound deck than there are in the northbound deck? The answers to these questions are not as easily answered as one might envision. However, the following remarks are made in an attempt to create discussion and possibly review some of the procedures we have employed in the past.

Transverse cracking is usually caused by the consolidation of the mix adjacent to the top mat of reinforcing steel. The mat of steel disrupts the subsidence of the concrete causing differential consolidation. More settlement occurs between the bars than occurs over them. As the mix consolidates and flows to one side of the bar or the other, that portion of the mix above the bar tends to be stressed. As the pour proceeds, vibration and consolidation continues. Plastic shrinkage, drying shrinkage and thermal stresses find relief in the area over the bar and causes cracks, particularly if the top mat of steel is close to the surface of the deck.

From the data obtained from this investigation it appears that the southbound deck was subjected to conditions that aided more than hindered the possibility of the creation of transverse cracking. The depth of cover over the rebars in the southbound deck appear to be less than 2 inches. Our requirement of 2 inches of cover may not be enough to insure that 2 inches of cover is realized in the completed deck. I believe that some Engineers may be checking for an average of two inches of cover and not for a minimum of two inches of cover.

The direction of Pour Sequence No. 2 and No. 3 on the southbound deck is one that, if possible, should be avoided in the future. When a pour is made in a downhill direction each transverse bar acts as a dam holding back the flow of the mix. The mix on the downhill side of the transverse bar, through consolidation and its tendency to flow downhill, pulls away from the mix held by the bar, creating a tensile stress in the mix directly over the bar. Had the deck been poured uphill this portion of the mix would have been placed in compression and aided in the prevention of possible transverse cracks. All other sections of both bridges were poured uphill. None of the other sections exhibit the severity or number of cracks that developed in Pour Sequence No. 2 and No. 3 of the southbound deck.

Pour Sequence No. 1 of the southbound deck although poured uphill does exhibit transverse cracking, but only in the areas directly over the beams. These transverse cracks do not, however, follow the spacing of the transverse rebars but do agree with the spacing and location of the shear connectors. Because these cracks are only found over the beams and not in the area of the deck between the beams I feel the shear connectors helped contribute to the creation of these cracks. The northbound deck, which has only a few noticeable transverse cracks, showed the presence of a shear connector directly below the rebar on Core No. 8 where one of the few cracks were found.

The sequence of Pours No. 2 and No. 3 on the northbound deck differed from the sequence of Pours No. 2 and No. 3 on the southbound deck in three ways. First, is the direction of pour. The northbound deck was poured uphill, the southbound deck was poured downhill. Second, is the time interval between Pours No. 2 and No. 3 on the northbound deck. A period of three days elapsed between these pours allowing the concrete in Pour No. 2 time to gain strength before Pour No. 3 was started. Because Pour Sequences No. 2 and No. 3 of the southbound deck were made as one continuous pour the mix at the north end of Pour Sequence No. 2 was

still plastic when concrete was being placed in Pour Sequence No. 3. It was during this period that transverse cracking was noticed in the north end of Pour Sequence No. 2. Even though the mix used at the beginning of Pour Sequence No. 2 was heavily retarded, the loss of surface moisture creates a drying out of the mix. This loss of moisture causes the mix to lose its workability. A crust is then formed on the surface of the concrete which is then subject to cracking at its weakest point. This point is in the area over the rebar which has been placed in tension due to the direction of the pour. The third noticeable difference between Pour Sequence No. 2 and No. 3 of the northbound deck and Pour Sequence No. 2 and No. 3 of the southbound deck is the method of curing. The application of a light wetting of the northbound deck and the covering of the deck the same day helped reduce the amount of moisture loss. The southbound deck received no wetting or covering until the day after the pour.

Another item of concern is the possibility of the rotation of flemming brackets, thereby, allowing a settlement of the finishing machine and resulting in a reduction in the depth of cover over the top mat of steel. If this is occurring, a simple blocking of the brackets between the top of the bracket and the beam could reduce this rotation.

Test results show the mixes used on these decks were all about the same consistency. The average slump on each pour was held below 3 inches. With the methods now being used in the production of this mix it is fairly easy to determine the water cement ratio within the accuracy allowed by meters. The availability of knowledgeable inspectors has increased our control over the mixes being placed. However, the mixes being used require a well planned and well coordinated placement procedure by the contractor in order to place and finish these mixes without a great deal of delay. An increased effort must be given to insure adequate consolidation. Stiff mixes aid in producing a lower water cement ratio which

in turn increases compressive strength, increases the resistance to chloride penetration, and reduces scaling. However, if these mixes do not receive adequate consolidation and transverse cracking continues to be a problem the purpose of using these mixes is defeated.

More attention has to be given to the conditions of the day at the time of placement of these pours. Both the ACI and the Portland Cement Association produce charts indicating conditions under which there is an increased risk in developing cracking on flat surfaces. Each resident engineer should be made aware of these charts and make use of them when contemplating a bridge deck pour. The results of the standard cured cylinders made on August 20, 1977 indicate what high day time temperatures do to a mix. The afternoon of Pour Sequence No. 1 on the northbound deck the ambient temperature reached 100° F. The control of the concrete indicates that the mix used was consistent with the mix used on the other four pour sequences but the compressive strength of the cylinders made on this day obtained a much lower compressive strength.