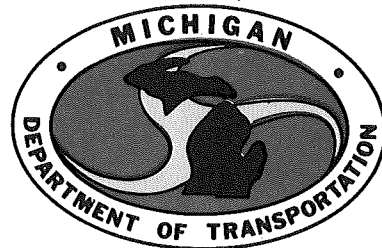


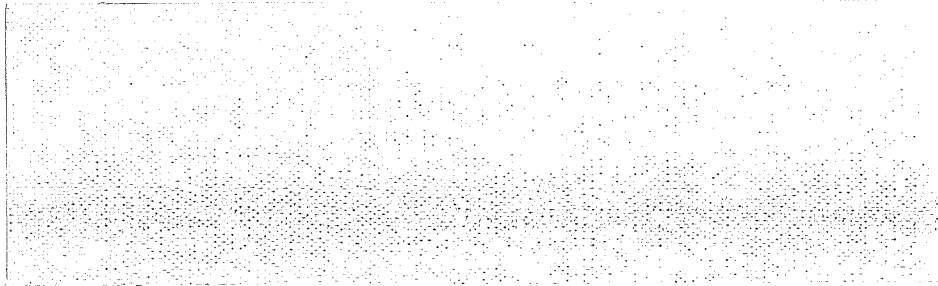
HIGH DENSITY CONCRETE DECK  
OVERLAY WITH SUPERPLASTICIZER



**MATERIALS and TECHNOLOGY DIVISION**



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TG315 .B76 1983 c. 2  
High density concrete deck  
overlay with super  
plasticizer

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**HIGH DENSITY CONCRETE DECK  
OVERLAY WITH SUPERPLASTICIZER**

**M. G. Brown**

**Research Laboratory Section  
Materials and Technology Division  
Research Project 82 TI-801  
Research Report No. R-1227**

**Michigan Transportation Commission  
William C. Marshall, Chairman;  
Rodger D. Young, Vice-Chairman;  
Hannes Meyers, Jr., Carl V. Pellonpaa,  
Shirley E. Zeller, William J. Beckham, Jr.  
James P. Pitz, Director  
Lansing, June 1986**

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## OFFICE MEMORANDUM

DATE: April 4, 1986

TO: C. J. Arnold  
Acting Engineer of Research

FROM: J. E. Simonsen

SUBJECT: High Density Concrete Deck Overlay with Superplasticizer  
Research Project 82 TI-801

Research Report No. R-1227 covering the subject concrete overlay type was written by M. G. Brown and issued in June of 1983. The concrete industry, and in particular the contractor placing the overlay, disagreed with the conclusions in the report. An agreement was made in September of 1983 between the industry and the Department that an independent laboratory should evaluate concrete deck overlay with superplasticizer. Because this independent evaluation was pending, the 1984 assessment of the deck condition mentioned in the report was not made. However, laboratory tests on specimens from the Port Huron deck were continued.

As requested, the deck overlays discussed in Report No. R-1227 and the Port Huron deck were recently inspected. The inspection consisted of visually observing the deck from the sidewalk. This memo is a report of the inspection results. Pertinent laboratory data from the Port Huron deck overlay are also included.

### S25 of 82252 Winchester Ave over I 75

This overlay was placed in the summer of 1981 and an inspection in April of 1983 revealed a fine map cracking pattern in the wetted overlay surface (Fig. 4, Report R-1227). This type of cracking has now advanced to the stage where it is easily visible when the deck is dry. Although the cracks are quite noticeable they are still very tight and apparently do not as yet extend through the overlay.

### S21 of 82252, I 75 over Modern Ave; X08 of 82252, I 75 over DT&I Railroad; S22 of 82252, I 75 over McNichols Ave

These overlays were placed in June and early July of 1982. An inspection in April 1983 revealed a fine crack pattern in the wetted surface which was randomly spaced and mainly longitudinal (Fig. 3, Report R-1227). Now, two years later, the cracks are easily detected without wetting the surface. The longitudinal cracks in some areas extend nearly the full span length and some of them, based on their surface width, are judged to extend through the overlay.

S20 of 77111, Old M 146 SB over I 94

This overlay was placed June 15, 1983. The just-completed inspection was the first one of this overlay, and the fine crack pattern found on the earlier placed overlays is also visible on this two-year old one. The cracks are very tight and not easily detected on a dry surface. As yet it appears the cracks are shallow and do not extend the full depth of the overlay.

Laboratory Testing

Two items, chloride ion penetration into the deck overlay and shrinkage of the overlay mix, are among the most important factors in the performance of an overlay. Laboratory test results on the superplasticized mixes and a latex modified concrete mix show the following:

Chloride Ion Penetration  
(90 day ponding with NaCl)

Structure No.	Mix Type	Avg. Chloride Ion lb/cu yd Depth of Penetration (in.)		
		0 - 1/2	1/2 - 1	1 - 1-1/2
S21 of 82252	Superplasticized	5.30	1.05	0.34
S20 of 77111	Superplasticized	1.70	0.11	0
X11 of 33045	Latex Modified	2.31	0.49	0.30

As can be seen, the chloride ion penetration results from the mix specimens from structure S20 of 77111 are low compared to the results from the mix used on the I 75 overlays. It has not been possible to isolate the factors causing this difference. However, determination of chloride content in cores removed during future evaluations should indicate if this difference in permeability is real or if the laboratory test results were incorrect.

Long Term Shrinkage - The six-month average shrinkage based on laboratory measurements of specimens made from the mixes used on the decks is as follows:

S21 of 82252	Superplasticized concrete	0.97 mil/in.
S20 of 77111	Superplasticized concrete	0.90 mil/in.
X11 of 33045	Latex Modified concrete	0.43 mil/in.

These measurements show that superplasticized concrete shrinks more than twice as much as latex modified concrete. This is reflected in the crack pattern that develops in the overlays shortly after placement which continues to progress in severity with time.

Based on the recent inspection of the deck overlays, it is recommended that the moratorium on using LSHD-HRWR overlays be continued until a better assessment of their performance can be made.

MATERIALS AND TECHNOLOGY DIVISION

*John S. ...*

Acting Supervising Engineer  
Materials Research Unit

With the advent of high range-water reducers (HRWR) that have the capacity of fluidizing low-slump concrete without additional water, a renewed interest was created in the low-slump high density (LSHD) overlays for repairing concrete bridge decks. This concept makes it possible for the concrete to be batched at ready or central mix plants, hauled premixed to the job site in ready mix trucks where the HRWR is introduced, and discharged onto the bridge deck in a temporary high slump condition. Our first field application of this concept was a deck overlay on S24 of 82252 placed in the summer of 1981. At the request of Champagne-Webber, the Department allowed a demonstration of the technique on three bridge decks on northbound I 75 in Detroit. The three designated bridges were northbound I 75 over Modern Ave, the DT&I Railroad, and McNichols Ave (S21, X08, and S22 of 82252, respectively).

The objectives of the demonstration were to compare the performance of this modified LSHD concrete with the conventional latex modified concrete (LMC). A work plan, No. 84, was prepared to cover this field application. The scope of this investigation was to compare the following characteristics of the two materials: properties of the fresh concrete, placement and finishing, unit strength, shrinkage, freeze-thaw durability, and permeability. From this comparison, along with the surveillance of the actual deck overlay, the performance of the application would be assessed for a five-year period.

The application of the modified LSHD concrete to the bridge deck that carries northbound I 75 over Modern Ave began on June 9, 1982. The overlay application started on the south approach in the two median lanes and progressed north. The concrete was delivered in ready mix trucks in 5 cu yd loads from a central mix plant located three miles away at Six Mile and Dequindre. The concrete mix design on a cubic yard basis, described in a special provision dated May 26, 1982, featured 822 lb of Medusa Type I cement, 1,390 lb each of 2NS fine aggregate (50-35) and 26A coarse aggregate (58-1), 7 fl oz of air entraining agent (Daravair), 27 fl oz of the water reducer-retarder "Daratard 17," and sufficient water to produce a 1.5 in. slump (net W/C = 0.37). The 88 fl oz of HRWR/cu yd (WRDA-19) was added at the job site immediately prior to discharge. The concrete trucks backed onto the deck and discharged, immediately in front of the screeding device.

This particular screeding machine, an Allen Razorback screed, features a triangular cross-sectioned truss fabricated from steel angles, with air operated vibrators mounted on the leading edge (Fig. 1). It was drawn along the top surface of pipe rails by light steel cables anchored to the bridge deck surface and winched onto a screed-mounted cable spool at each end of the screed. This type of screed was called for since the Illinois

TABLE 1  
 PROPERTIES OF LSHD OVERLAY CONCRETE WITH HRWR AS APPLIED TO A  
 BRIDGE DECK THAT CARRIES NORTHBOUND I 75 OVER MODERN AVE IN DETROIT (S21 of 82252)\*

Set No.	Fresh Concrete Measurement		Compressive Strength, psi		Flexural Strength, psi		Salt Penetration Slabs Chloride Ion, lb/cu yd, (90 days), depth		Six Month Maximum Shrinkage After Special Cure, mills/in.	Wet Bulk Specific Gravity After 28 Day Cure	Freeze-Thaw Durability After 336 Cycles				
	Temp., F	Slump, in.	Entr. Air, percent	7 Day	28 Day	7 Day	28 Day	0 to 1/2 in.			1/2 to 1 in.	1 to 1-1/2 in.	Weight Increase, percent	Dynamic Modulus, percent of initial	
S	85	2.8	5.5	4780	5400	750	880	810	5.83	0.94	0.10	0.98	2.33	2.96	104
T	83	2.0	5.1	4810	5660	785	900	740	5.01	1.11	0.86	0.95	2.34	2.52	101
U	82	4.8	6.3	4620	5400	785	895	745	5.07	1.11	0.56	0.97	2.30	2.82	100
Avg.	83	3.2	5.6	4740	5490	775	895	765	5.30	1.05	0.34	0.97	2.32	2.77	102
Average of Six Samples Molded in the Field from October 1979 to April 1980**															
Avg.	60	6.3	4.4	4440	5590	1060	1245	1350	2.31	0.49	0.30	0.43	--	0.57	103

\* Samples taken during pour of June 9, 1982.

\*\* Latex modified concrete overlay as applied to X11 of 33045 (Thermoflex 8002 as produced by Reichhold Chemicals of White Plains, New York).



Tollway experienced difficulties using conventional roller screeds and had no trouble with the Allen screed. The weather was clear with a 10 mph southerly breeze, and an air temperature of 85 F. A fluid bonding grout using a 1 to 1 mix of cement and sand was broomed into the dry surface and the concrete was distributed and leveled by hand in front of the vibrating screed. The emerging surface appeared to be smooth, well consolidated, and without blemish. Nuclear gage density measurements on the screeded concrete surface revealed that it exceeded the required density.



Figure 1. Placement of high density mix with superplasticizer using Allen Razorback screed on northbound I 75 (S21 of 82252).

Research Laboratory personnel sampled three different trucks from the center third of their 5 cu yd load, and cast test specimens that would yield the desired test data. The three sets, whose test data are shown in Table 1, were sampled on June 9, covered with sheet plastic, and returned to the laboratory on June 10. Flexural beams and test cylinders were moist cured continuously until their test date. The salt penetration slabs were moist cured seven days during which time their surface was sandblasted and dikes cast around their perimeter; a three-week dryout period followed and at four weeks of age, a 3 percent NaCl solution was ponded within the dikes for a 90-day duration (AASHTO T-259). Both the freeze-thaw (F-T) beams and shrinkage prisms were given a special cure which consisted of seven days moist curing, 14 days laboratory air drying, and seven more days moist curing. Following this simulated field cure, the shrinkage prisms began air drying for six months in laboratory air while the F-T



1000 (7/82)  
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 Secondary Governmental Complex  
 P. O. Box 30049  
 Lansing, Michigan 48909

**REPORT OF TEST**

FILE 300

Job Number	16877A
	(Research Project 82 TI-801)
Control Section Identity	I 82252
	X08 of 82252 (NB I-75/DT&I RR)
Laboratory No.	82 CC-34-39
Date	August 31, 1982

Report on sample of CONCRETE CORES (4 Inch) LSHD - Superplasticized Concrete  
 Date sampled July 7, 1982 Date received July 7, 1982  
 Source of material Champagne-Webber Construction Company  
 Sampled from Deck Overlay Pour of 7-1-82 Quantity represented N/A  
 Submitted by M. G. Brown, Transportation Engineer X  
 Intended use Bridge Deck Overlay Specification Special Provision (5-26-82)

**TEST RESULTS**

Laboratory	Field	Span	Location in NB Deck				Depth of Overlay in.	Shear Strength* at Bond Line psi
			Longitudinal		Transverse			
			Reference Lines	Dist. Ft.	Reference Lines	Dist. Ft.		
82 CC-34	1	2	Exp. Jnt.	4.0	E. Curb Line	26.0	2.3	345
82 CC-35	2	2	Exp. Jnt.	17.4	E. Curb Line	26.3	2.0	490
82 CC-36	3	2	Exp. Jnt.	27.1	E. Curb Line	19.4	2.3	675
82 CC-37	4	3	Exp. Jnt.	5.0	E. Curb Line	32.1	2.3	600
82 CC-38	5	3	Exp. Jnt.	22.7	E. Curb Line	32.0	2.0	435
82 CC-39	6	3	Exp. Jnt.	38.9	E. Curb Line	25.1	2.3	310
Average							2.2	475

\*Cores moisture conditioned in accordance with ASTM C42 prior to testing.

Remarks: Tested for information. Cores were drilled and tested at request of Construction Division and for information for Research Project 82 TI-801. The overlay concrete was fluidized immediately prior to application with WRDA-19, a high range-water reducer, and bonded to the substrate concrete with a cement-sand slurry. The cores were 12 days old at time of test.

cc: File (Also 82 TI-801)  
 D. F. Malott  
 H. B. LaFrance  
 P. Daavettila  
 D. L. Wickham  
 J. J. Nelson

Signed L. T. O'Neil  
 Engineer of Research

Figure 2. Report of Test on 82 C-34-39.

beams went directly into the fast cycling F-T machine (ASTM C-666, Procedure B).

Table 1 also includes corresponding test data from a latex-modified overlay. A comparison of the test results of the two overlay concretes indicates the LSHD concrete with HRWR is roughly equivalent to the LMC in compressive strength and freeze-thaw durability. However, in chloride penetration down to 1 in., flexural strength and shrinkage, the LMC is vastly superior. The difference in shrinkage, as pointed out later, may be very critical. Six cores taken in a later pour on X08 of 82252 indicated adequate shear bond strength (Fig. 2, test result on 82 CC-34-39).

Following the June 9, 1982 pour on S21 of 82252, the two median northbound lanes of X08 and S22 were poured on June 11 and 12, respectively. The balance of these three decks were poured on June 30 and July 1, 2, and 6. Subsequently, the contractor was given approval to do the remaining 13 decks of this contract using the high density concrete with HRWR in place of the LMC mixture originally bid on the project. For this, the contractor agreed to reduce his contract price from \$325/cu yd for the LMC to \$225/cu yd for the LSHD mix with HRWR. A minimum of 2 in. of this latter overlay was also required in lieu of the usual 1.5 in. minimum thickness for LMC. Thus, the resulting costs amounted to \$13.54/sq yd for the LMC mix vs. \$12.50 for the LSHD mix with HRWR.

As mentioned earlier, and indicated in Table 1, we have been concerned about a basic difference in long-term drying shrinkage between the LSHD mix with HRWR and our widely used LMC mixtures. Note the six months drying shrinkage of the former is about double the latter; 0.97 versus 0.43 mils/in. In terms of percent shrinkage, these values would be 0.097 and 0.043 percent, respectively. Similar data from specimens made in 1981 on S25 of 82252 resulted in six months shrinkage of 1.10 mils/in. Data obtained from specimens of our first LSHD overlays in 1975 averaged 0.75 mils/in.

On April 20, 1983, P. Daavettila, D. Wickham, J. Simonsen, H. Patterson and I inspected the inside lane of the first three 1982 decks on northbound I 75 and also the 1981 deck and several older LSHD overlays. Figures 3 through 7 illustrate the cracking problem that has developed.

Briefly, we found numerous fine shrinkage cracks, largely short longitudinal ones, in the inside northbound lane on I 75 of S21, X08, and S22 of 82252 done last year (Fig. 3). The same type of fine cracks were found last July in the 1981 overlay (Fig. 4). The April 20 inspection of this latter deck did not appear to indicate much change from last year in the crack severity.

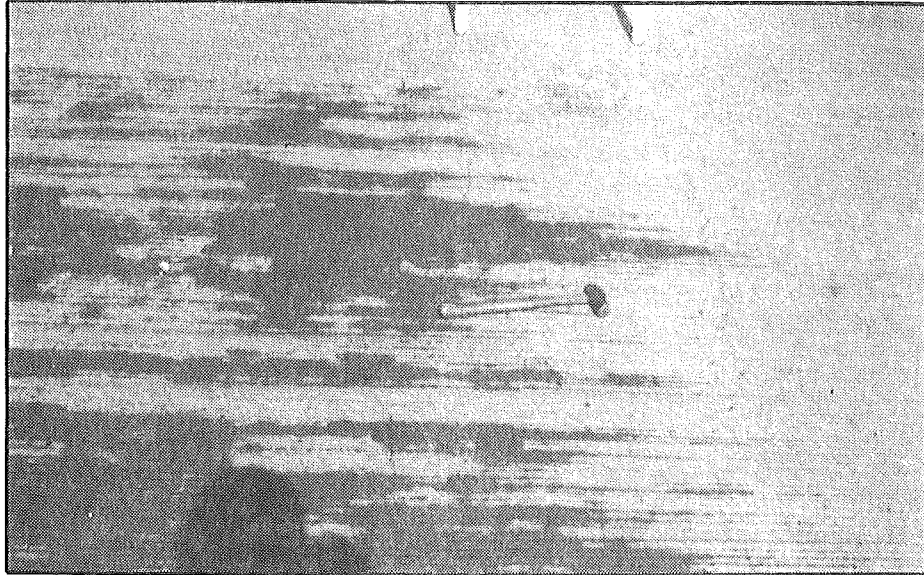


Figure 3. Inspection of northbound median lane on S21 of 82252. Area was wet with water to delineate fine crack pattern which was randomly spaced and mainly longitudinal (April 1983).

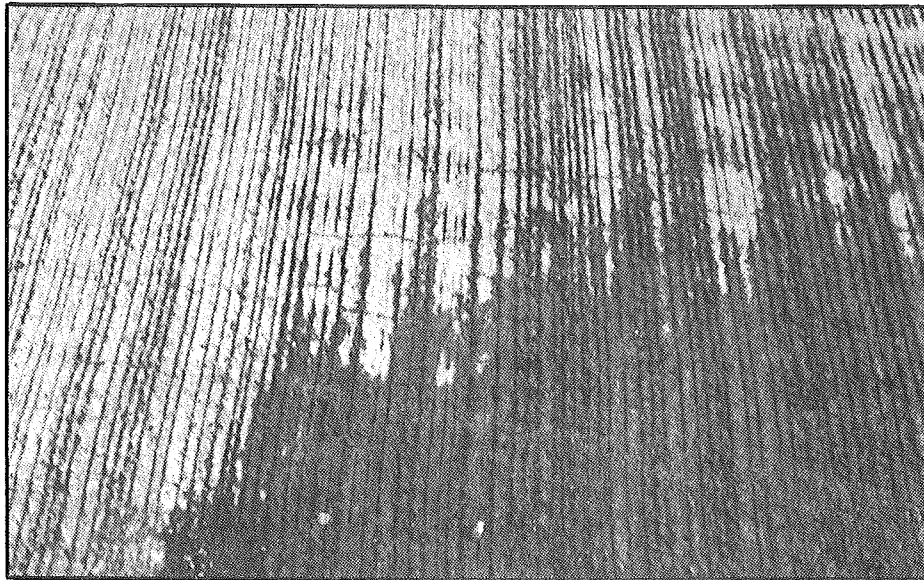


Figure 4. Fine crack pattern in northwest quadrant of Span 3, S25 of 82252, in LSHD and HRWR pour of August 1981 (photo July 1982).

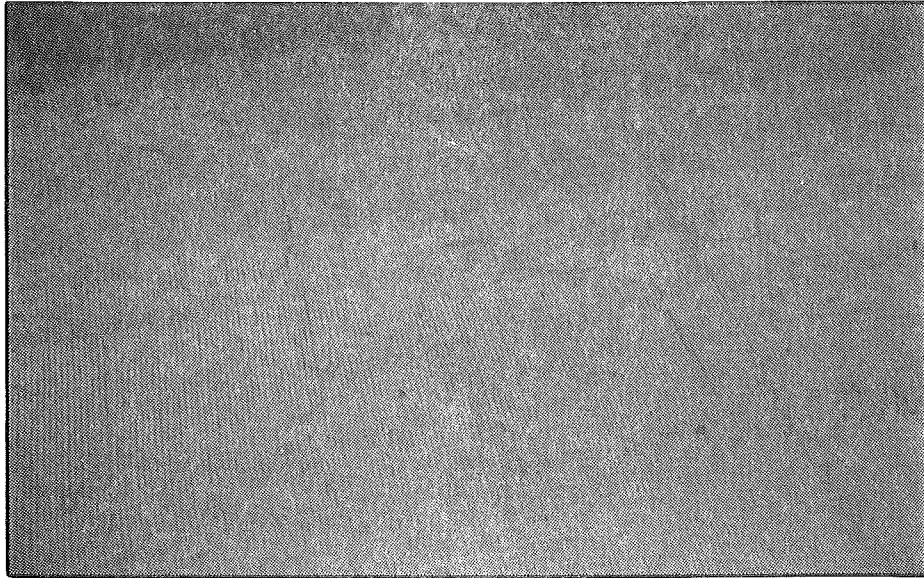


Figure 5. Random cracks in LSHD overlay on S31 of 25132 in eastbound outer lane (July 1982). New two-course construction placed in 1977.

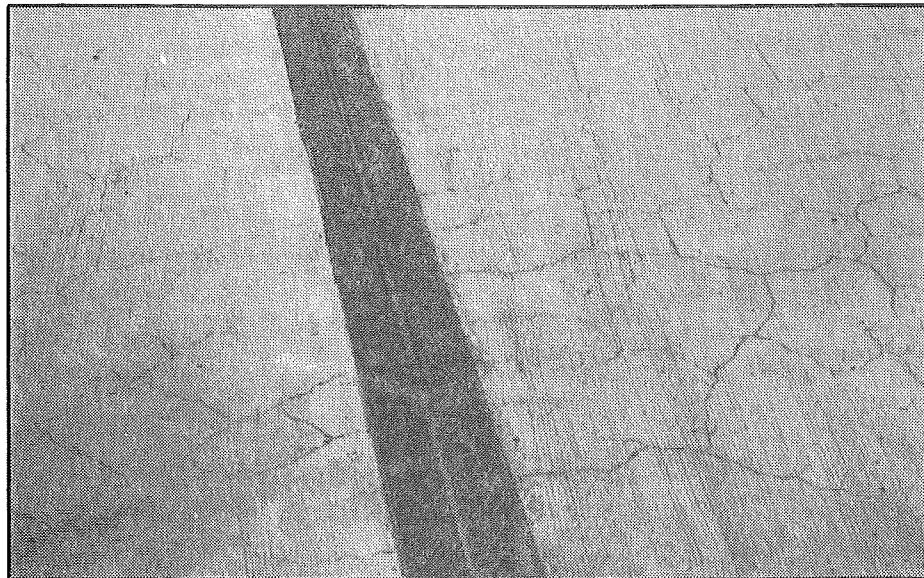


Figure 6. Crack pattern in southbound I 94 near Pier 2 of B03 of 50111. LSHD overlay of 1977 after five years.



Figure 7. Random crack pattern in eastbound I 96 inside lane of LSHD pour of 1975 on S10 of 47065 after seven years.

We have been concerned about this fine cracking because it may develop into the more pronounced and severe type of random cracking we have found, to some degree, on all LSHD overlay jobs done in 1975, '77, and '78. These decks total 27 of which eight of them were new two-course decks on I 475. The LSHD mix design is the same as the superplasticizer type used in 1981 and '82 except for the addition of a high range water reducer just before placement. The long-term shrinkage should be essentially the same. Typical examples of the cracking problem which has been developing on these older LSHD overlays are shown in Figures 5, 6, and 7.

Recently, one more deck overlay has been approved for Champagne-Webber to use the LSHD-HRWR mixture as a substitute for LMC. This structure, S20 of 70111, is a four-span ramp over I 94 in Port Huron and is 363 ft long and 21 ft wide. It is planned to do this pour at the end of the week of June 13 and we plan to sample and monitor this closely as we did S21 and S25 of 82252 in 1982 and 1981, respectively. A different HRWR is to be used, namely Pozzolith 430R, which is an ASTM C-494 Type G or retarder type of superplasticizer. It is also planned to use a roller type of finishing machine in place of the Allen air screed. This will give us a good opportunity to obtain basic data on concrete using a different brand and type of superplasticizer than used in 1981 and '82.

Therefore, we would strongly recommend that no more LSHD-HRWR overlays be placed this year and until an assessment can be made in the spring of 1984 of these type overlays placed in 1981, '82, and '83. We will also have a much better concept of the chloride penetration and long-term drying shrinkage—both of which at this time appear to be a very serious problem. Moreover, other physical properties from laboratory tests well underway as well as specimens made from the Port Huron deck pour can be assessed.