

HIGH EARLY STRENGTH CONCRETE OVERLAYS

Evaluation performed by
Office of Materials Management
Cement & Concrete Section
Reported May 7, 2007

This is an evaluation of concrete overlay mixes that are intended to reach a strength that would allow traffic at a very early age (2 to 4 hours). To do this, variations of ODOT standard Superplasticized Dense Concrete (SDC), Latex Modified Concrete (LMC) and Micro-silica Modified Concrete (MSC) mixes from Supplemental Specification 848 were used. The variations included the use of type III cement, Non-chloride accelerators and CTS Rapid Set cement. Two additional systems were used - 4 x 4 mix from BASF and Rapid 1 admixture from Sika.

The targets of the evaluation were to:

- o Determine how quickly each mix gained strength
 - o Compressive
 - o Flexural
 - o Bond
 - o Maturity
- o Determine the affect that different situations have on maturity
 - o 4 x 8 inch cylinders
 - o 1 ¾" overlay on an 18"x 18" class S slab
 - o 5" deep overlay on an 18"x 18" class S slab
 - o 3 x 4 x 15 inch beam mold
- o Measure the shrinkage of the different mixes.
 - o Compare the high early strength variations with the standard overlay mixes to determine if level of cracking will be acceptable.

When possible, the following strengths were obtained. Sometimes, the concrete was not set up or strong enough to test at the scheduled time.

MATURITY / STRENGTH								
TIME	2 HR	3 HR	6 HR	12 HR	1 DAY	2 DAY	28 DAY	
4 x 8 CYL	X	X	X	X	X	X	X	X
FLEX	X		X	X				X
MATURITY	X	X	X	X	X	X	X	X
BOND					X	X	X	X
LENGTH CHANGE	I*	X	X	X	X	X	X	X

* The initial measurement (I) is taken at 2 hours if possible. If it is not able to be measured at 2 hours, the measurement is taken at the earliest possible scheduled test time.

The following materials were used:

- o Type I Cement – Holcim, Dundee
- o Type III Cement – Cemex, Wampum
- o Special Cement Rapid Set CTS
- o Coarse Aggregate - #8 Limestone - Melvin @ Melvin
- o Fine Aggregate – Natural Sand - Olen @ Columbus
- o Latex – Standard Latex Dow
- o Air Entraining Agent- Micro Air BASF
- o Accelerator CNI BASF
- o Rapid Hardener Rapid 1 Sika
- o Superplasticizer Glenium 3030 BASF

The following mix concrete mix designs were used for the evaluation. The three latex mixes had to be re mixed due to high air.

MIX	COARSE AGG (lbs)	FINE AGG (lbs)	TYPE 1 CEMENT (lbs)	TYPE III CEMENT (lbs)	RAPID SET CEMENT (lbs)	MICRO SILICA (lbs)	LATEX EMULSION (GAL)	WATER (lbs)	W / C RATIO	AEA (oz/yd ³)	SUPER (oz/yd ³)	ACCEL (oz/yd ³)	RAPID 1(oz/yd ³)
1 SDC STD	1315	1300	825				222	297	.36	4	70		
2 SDC III	1315	1300		825				297	.36	5	90		
3 SDC ACCEL	1315	1300	825					297	.36	5	70	200	
4 SDC R1	1315	1300	825					297	.36	5	70		200
5 MSC STD	1370	1355	700			50		270	.36	5	60		
6 MSC III	1370	1355		700		50		270	.36	5	100		
7 LMC STD	1315	1645	658				24.5	17.5	.39	0	0		
8 LMC STD REMIX DE-AIR	1315	1645	658				24.5	17.5	.39	0	50		
9 LMC III	1315	1645		658			24.5	17.5	.39	0	50		
10 LMC III REMIX DE-AIR	1315	1645		658			24.5	17.5	.39	-50	50		
11 LMC RS	1300	1420			658		24.5	160	.39	0	50		
12 LMC RS REMIX DE-AIR	1300	1420			658		24.5	160	.39	-50	79		
13 4 x 4 MIX	1186	1376	817					253	.36	26	200	735	

MIX DESCRIPTION

- SDC STD** - the standard Superplasticized Dense Concrete mix from SS848
- SDC III** - the SDC STD mix using Type III cement
- SDC ACCEL** - the SDC STD mix using an accelerating admixture (type C)
- SDC R1** - the SDC STD mix with Sika Rapid 1 admixture
- MSC STD** - the standard Micro-Silica Concrete mix from SS848
- MSC III** - the MSC STD mix with type III cement
- LMC STD** - The standard Latex Modified Concrete mix from SS848. (air too high)
- LMC STD REMIX** - same as above with less air
- LMC III** - the LMC STD with type III cement
- LMC III REMIX** - same as above with less air
- LMC RS** - the LMC STD with CTS Rapid Set cement
- LMC RS REMIX** - same as above with less air
- 4 x 4 MIX** - BASF 4 x 4 (400 psi in 4 hour) mix. Also had high air but was not remixed

RESULTS

The results of the testing can be found in the tables and graphs following the text. The results indicate the following:

- Standard mixes gained enough flexural strength (approximately 400psi) to open to traffic in 6 to 12 hours.
- Mixes using Type III cement or Type C Accelerating Admixture only slightly improved the time to gain the desired strength
- Mixes with the CTS Rapid Set[®] Cement were the only ones that gained strength quickly enough to open to traffic in 2 hours
 - The Rapid Set[®] Cement was only used in the latex mixes, but there is no reason to believe that they would gain strength as quickly in the other overlay types
- Using Type III cement or Type C Accelerating Admixtures increased the shrinkage slightly.
- The BASF 4x4 and Sika Rapid 1 mixes did not perform as anticipated.
 - The strength gain was not as good or much better than the standard mixes
 - The shrinkage was higher than the standard mixes

6. The shrinkage on the CTS Rapid Set[®] Cement was significantly less than the standard mixes

LIMITATION OF THIS EVALUATION:

The above results can be used as an indication of what to expect out of these mixes, but don't consider them to be hard-fast rules. The number of samples and number of mixes from each design was too limited to be statistically valid and to draw reliable conclusions. Inexperience with some of the materials caused high variations in the data. In the interest of time, except for very high air results on the first Latex batches, the mixes were not adjusted and remixed to obtain optimum results.

There are several instances where unexpected results were obtained. Either a mix didn't perform as expected or the maturity results indicate that one mix should be essentially at the same level as another, but wasn't. So consider the results knowing that there is limited data and the reliability is suspect.

Admixture dosage rates were estimated before mixing and adjusted as needed during mixing. The 4 x 4 mix proportions were taken from an article for the system; the Rapid 1 mix was just used with the SDC mix.

CONCLUSIONS:

This evaluation was initiated to determine if it was feasible to overlay bridge decks overnight on the Brent-Spence project, specifically bridges and ramps leading to the B-S Bridge.

- In order to open the bridge to traffic, a mix would have to be able to obtain an acceptable flexural strength in approximately 2 hours.
- According to the results in this evaluation, the only product to meet this criterion was the CTS Rapid Set[®] Cement mixes.
 - The mixes that used this product gained over 400 psi flexural strength in 2 hours.
 - These mixes exhibited lower shrinkage which would result in less cracks.
 - The cost of this product was not determined, but it would be a determining factor to consider should it ever be used.

Instead of overnight construction, the District opted to do weekend work. A plan note was used that uses a micro-silica concrete mix and a 24 hour cure to gain 600 psi before opening to traffic. A copy of the note is included at the end of the report. According to the data:

- It may be close, but the MSC mix specified in the note may have trouble obtaining the desired strength within the 24 hour curing window provided.
 - The strength data shows compliance, but
 - The air on both the standard and type III mixes were 4.0%
 - The slumps were very low in both cases
 - Adjusting the two properties listed above should have a negative affect on the time that it takes to gain strength.
 - A test panel is highly suggested to determine the properties of the mix prior to using the concrete on an actual placement. Adjustments may need to be made.

DATA:

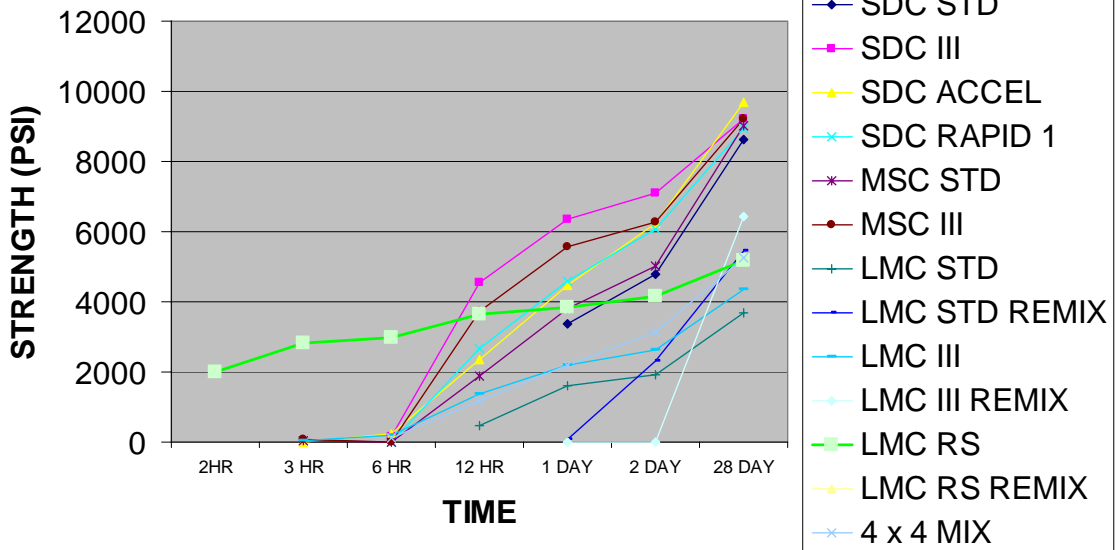
The following tables include the data for the study. Also provided are some graphs for some of the data. For brevity of the report, graphs for the maturity are not included. But, when determination the strength of the in-place concrete is desired, the maturity method is a useful tool. For ODOT guidelines on the use of maturity, see Supplement 1098.

	SDC STD	SDC III	SDC ACCEL	SDC RAPID 1	MSC STD	MSC III	LMC STD	LMC STD REMIX	LMC III	LMC III REMIX	LMC RS	LMC RS REMIX	4 x 4 MIX
DATE MIXED	9/18/06	9/19/06	9/19/06	10/5/06	9/25/06	9/25/06	9/28/06	3/14/07	9/28/06	3/14/07	10/2/06	3/14/07	10/5/06
AIR (%)	5.2	4.1	6.6	5.5	4.0	4.0	14.4	7.0	14.5	4.3	12.4	4.0	13.0
SLUMP (inch)	5 ½	4 ¼	4 ¾	2 ½	¾	1 ¼	6 ½	1 ¼	9 ¼	½	9	1 ¼	11
YIELD	26.7	26	26.3	26.3	25.8	26.0	29.9	26.66	31.2	26.11	29.1	26.4	27.7
TEMP	70	70	72	70	72	70	70		72		70		70
BOND STRENGTH 1 ¾ IN.	4 HR										330		
	1 DAY	505	415	54	210	85	460	160		315		515	260
	2 DAY	775	860	550	475	215	570	330		515		365	485
	28 DAY	930	1075	555	685	680	495	470		595		340	415
BOND STRENGTH 5 IN.	4 HR										405		
	1 DAY	405	160	156	510	325	640	170		325		640	270
	2 DAY	760	685	810	780	590	895	405		410		545	400
	28 DAY	805	1045	840	670	890	890	595		515		495	680
SHRINKAGE % X 10⁻⁴	3 HR										-46		
	6 HR										-85	-112	
	12 HR										-112	-108	
	1 DAY		-85	-135	-188	-123	-77			-54		-169	-162
	2 DAY	-96	-204	-219	-281	-188	-181	-27	-127	-73		-200	-154
	28 DAY	-642	-738	-731	-927	-623	-727	-704	-523	-727		-300	-242

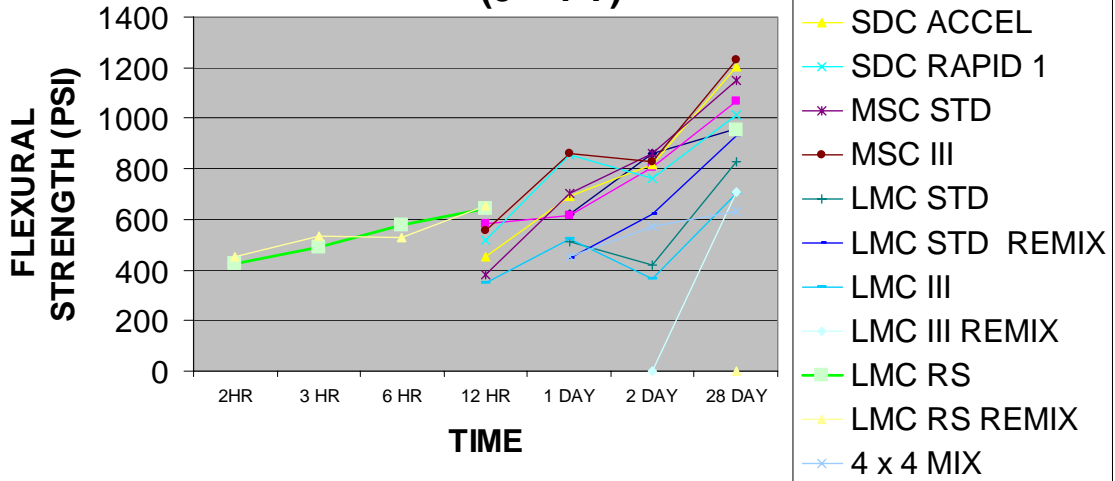
* 5 DAYS

** - LOGGER FAILURE

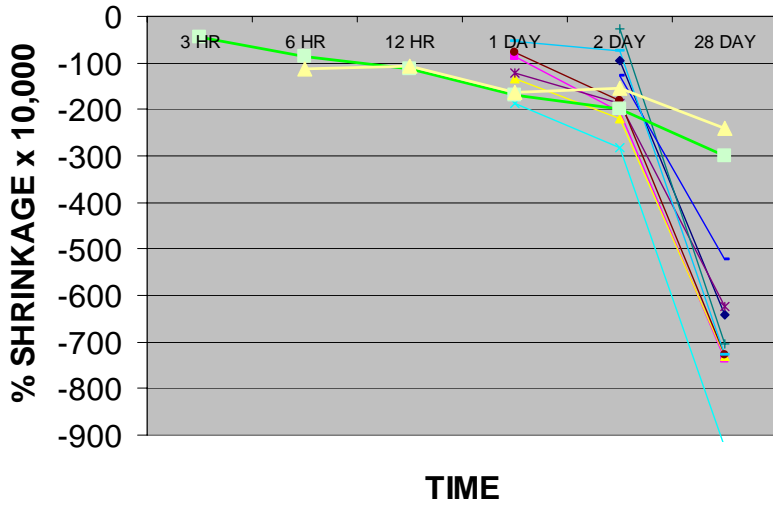
COMPRESSIVE STRENGTH



FLEXURAL STRENGTH (3RD PT)

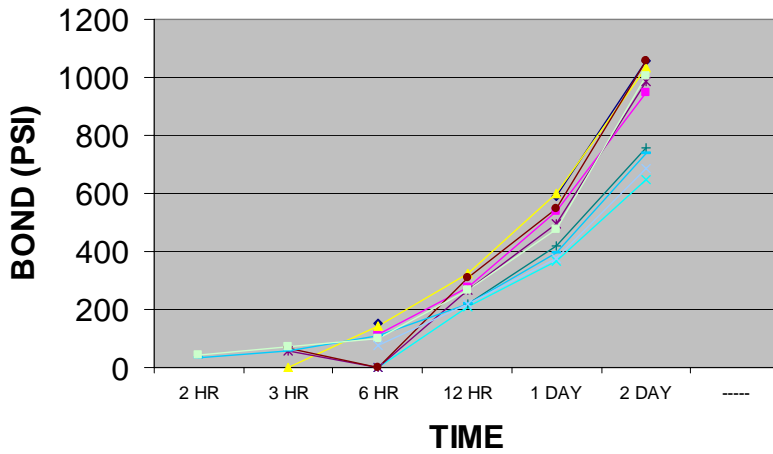


SHRINKAGE



- ◆ SDC STD
- ◆ SDC III
- ◆ SDC ACCEL
- ◆ SDC RAPID 1
- ◆ MSC STD
- ◆ MSC III
- ◆ LMC STD
- ◆ LMC STD REMIX
- ◆ LMC III
- ◆ LMC III REMIX
- ◆ LMC RS
- ◆ LMC RS REMIX
- ◆ 4 x 4 MIX

BOND STRENGTH



- ◆ SDC STD
- ◆ SDC III
- ◆ SDC ACCEL
- ◆ SDC RAPID 1
- ◆ MSC STD
- ◆ MSC III
- ◆ LMC STD
- ◆ LMC STD REMIX
- ◆ LMC III
- ◆ LMC III REMIX
- ◆ LMC RS
- ◆ LMC RS REMIX
- ◆ 4 x 4 MIX

Brent-Spence Plan Note:

**ITEM 848-MICRO SILICA MODIFIED CONCRETE OVERLAY
USING HYDRODEMOLITION, AS PER PLAN (T= 2 ½")**

THIS ITEM SHALL CONFORM TO SUPPLEMENTAL SPECIFICATION 848 WITH THE FOLLOWING CONDITIONS AND REVISIONS:

- A) THE WET CURE TIME IS REDUCED FROM 72 HOURS TO 24 HOURS OR UNTIL BEAM BREAK OF 600 PSI IS ACHIEVED, WHICHEVER IS GREATER. AFTER THE 24 HOUR WET CURE, THE FINISHED OVERLAY SURFACE SHALL BE CURED BY SPRAYING AN UNIFORM APPLICATION OF CURING MATERIAL 705.07, TYPE 1 OR 1D, AS PER CMS 511.17 METHOD B OF MEMBRANE CURING. THE DECK SURFACE MUST BE DRY PRIOR TO PLACEMENT OF THE CURING MATERIAL. IF THE CURING MATERIAL CANNOT BE PLACED WITHIN THE SAME SHORT-TERM CLOSURE PERIOD AS THE OVERLAY, THE CONTRACTOR MAY ALLOW TRAFFIC ONTO THE OVERLAY, AND SHALL HAVE 24 HOURS FROM REMOVAL OF THE WET CURE TO APPLY THE MEMBRANE-CURING COMPOUND.
- B) TRAFFIC WILL NOT BE PERMITTED ON THE FINISHED OVERLAY SURFACE UNTIL AFTER COMPLETION OF THE 24 HOUR WET CURE, AND AFTER TWO TEST BEAMS HAVE ATTAINED AN AVERAGE MODULUS OF RUPTURE OF 600 PSI.
- C) FOR EACH POUR, THE CONTRACTOR SHALL PROVIDE ENOUGH MATERIAL FOR TWO BEAM BREAKS EACH AT 12 HOURS, 24 HOURS, 36 HOURS, AND 48 HOURS. THE DEPARTMENT WILL PERFORM THE BEAM BREAK TESTS AND DOCUMENT THE TIME OF THE POUR, THE TIME OF THE BEAM BREAK TESTS AND THE MODULUS OF RUPTURE OF EACH BEAM UNTIL THE MODULUS OF RUPTURE OF TWO TESTS IS NOT LESS THAN 650 PSI. TRAFFIC WILL BE ALLOWED ON THE OVERLAY AT 600 PSI.
- D) TWO TEST SLABS WILL BE REQUIRED IN ACCORDANCE WITH SS 848 IF A PERIOD OF 30 DAYS OR MORE HAS ELAPSED SINCE THE POURING OF THE TEST SLABS OR ANY OVERLAY OPERATION AS PART OF THIS PROJECT.
- E) THE MAXIMUM AMOUNT OF OVERLAY MATERIAL TO BE CARRIED BY ANY ONE VEHICLE DURING THE OVERLAY OPERATIONS IS 6 CY.
- F) THE REMOVAL OPERATIONS SHALL NOT BEGIN IF SUSTAINED RAINS (5 HOURS OR MORE WITH BREAKS BETWEEN SHOWERS LESS THAN 1 1/2 HOURS) ARE PREDICTED WITHIN 48 HOURS OF COMMENCEMENT.
- G) THE FINAL SOUNDING MAY TAKE PLACE WITHIN 24 HOURS OF A RAIN, AND THE DECK DOES NOT HAVE TO BE COMPLETELY DRY. HAND CHIPPING IS FOR THE PURPOSE OF CHIPPING AREAS WHERE THE HYDRODEMOLITION MACHINE DOES NOT HAVE ACCESS. IF THE DESIRED DEPTH IS ACHIEVED BY HYDRODEMOLITION, NO FURTHER REMOVAL IS NECESSARY.
- H) FULL DEPTH REPAIR WILL NOT BE REQUIRED IF LESS THAN ONE HALF OF THE DECK ORIGINAL CONCRETE THICKNESS IS SOUND.
- I) THE OVERLAY SURFACE EVAPORATION RATE REQUIREMENTS ARE IN EFFECT

FROM 9:30 AM TO 11:00 PM. THEY ARE NOT IN EFFECT FROM 11:00 PM TO 9:30 AM.

J) MECHANICAL MEANS MAY BE USED TO REMOVE THE EXISTING RIGID OVERLAY AND TOP 0.5 INCH OF THE ORIGINAL DECK. THE REMAINING 0.5 INCH OF ORIGINAL DECK SHALL BE REMOVED BY HYDRODEMOLITION.

PAYMENT FOR ALL LABOR, MATERIAL, AND EQUIPMENT NECESSARY TO COMPLETE THE ABOVE WORK SHALL BE INCLUDED IN ITEM 848-MICRO SILICA MODIFIED CONCRETE OVERLAY USING HYDRODEMOLITION, AS PER PLAN.