

# Blended Cement Patching Research

Final Report  
for  
MLR-04-01

March 2005

Highway Division



**Iowa Department  
Of Transportation**

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March 2005

## TECHNICAL REPORT TITLE PAGE

<b>1. REPORT NO.</b>	<b>2. REPORT DATE</b>
MLR-05-01	March 2005
<b>3. TITLE AND SUBTITLE</b>	<b>4. TYPE OF REPORT &amp; PERIOD COVERED</b>
Blended Cement Patching Research	Final Report, October 2004 to March 2005
<b>5. AUTHOR(S)</b>	<b>6. PERFORMING ORGANIZATION ADDRESS</b>
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<b>7. ACKNOWLEDGMENT OF COOPERATING ORGANIZATIONS/INDIVIDUALS</b>	
<b>8. ABSTRACT</b>	
<p>With the recent introduction of blended cements, many ready mix producers are using them as their sole source of cement. Iowa DOT specifications currently do not allow blended cements in patching due to their assumed slower strength gain. Patching specifications require opening at 5 hours on 2-lane or 10 hours on 4-lane pavement.</p> <p>This research will investigate early strength of concrete cast with ordinary Type I/II Portland cements and Type I(SM) blended Portland cements.</p> <p>The conclusions of this research are as follows:</p> <ol style="list-style-type: none"><li>1. Obtaining opening strength (5-hour patch) using Type I(SM) cement may be achieved by either 1) allowing one-half hour to one hour longer cure time, depending on ambient temperature or 2) using an increased dosage of mid range water reducer to achieve a lower w/c ratio.</li><li>2. Adequate strength is reached at 10 hours when Type I/II or Type I(SM) cements are used.</li></ol> <p>The following recommendations are based on conclusions from this research:</p> <ol style="list-style-type: none"><li>1. Allow use of Type I(SM) cement for 5 hour patches provided a Type A mid range water reducer is used at a higher rate to achieve a reduction in w/c ratio of at least 0.02 over the same mix with Type I or I/II cement.</li><li>2. Allow use of Type I(SM) for 10 hour patches without fly ash replacement.</li><li>3. Require longer curing time of at least 6 hours when Type I(SM) is used for patching when ambient temperatures are below 55 °F.</li><li>4. Require use of a Type A water reducer for all patching.</li></ol>	
<b>9. KEY WORDS</b>	<b>10. NO. OF PAGES</b>
Blended cement Patching	13

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### DISCLAIMER

The contents of this report reflect the views of the author(s) and do not necessarily reflect the official views or policy of the Iowa Department of Transportation. This report does not constitute a standard, specification or regulation.

## Introduction and Objective

With the recent introduction of blended cements, many ready mix producers are using them as their sole source of cement. Iowa DOT specifications currently do not allow blended cements in patching due to their assumed slower strength gain. Patching specifications require opening at 5 hours on 2-lane or 10 hours on 4-lane pavement.

This research will investigate early strength of concrete cast with ordinary Type I/II Portland cements and Type I(SM) blended Portland cements.

## Materials

The following materials were used in this research:

<u>Cements</u>	<u>Admixtures</u>
Lafarge I/II	WRDA 82
Lafarge I(SM)	MIRA 92
Holcim I	
Holcim I(SM)	

Ft. Dodge limestone and Cordova sand was used with an M-4 mix design with CaCl. The mix design batch weights are included in Figures 1-3 of the Appendix.

CaCl solution, made with 77% flake CaCl, was added at the rate of 2.75 gallons per cubic yard. The CaCl solution produces 1.35 gallons per 1 gallon of water.

## Testing

An M-4 mix design with CaCl solution was batched for each cement type. Initial testing indicated a reduction in slump after CaCl solution was added. A second mix was batched and a normal Type A water reducer was added resulting in an increase in slump and air. A normal Type A water reducer was then used in the first four mixes.

Since slump was reduced after the CaCl solution was added, it was decided to increase slump and minimize the water cement ratio by use of either a Type A mid-range water reducer at a higher dosage rate or a Type F high range water reducer. The mid-range water reducer was used to ensure adequate control of air content during field placement.

Nine cylinders were cast for testing at 5, 7 and 24 hours. Specimens were placed in the Blue M humidity cabinet and cure was accelerated from 85 °F for the first 2 hours, 105 °F for the next 2 hours, 125 °F for 3 hours, and then allowed to return slowly to the 75 °F. Cylinder temperatures for each mix are shown in Figure 4 of the Appendix. This accelerated cure was applied to replicate the temperatures in a patch as shown in previous research<sup>1</sup>. Results of the concrete testing for each mix were as follows:

Cement	Water Reducer	Air, %	Slump, inches	w/c	Compressive Strength, psi		
					5 hr	7 hr	24 hr
Lafarge I/II	WRDA-82	6.0	1.50	0.371	2180	3250	5220
Lafarge I(SM)	WRDA-82	5.8	2.75	0.354	1870	2940	5010
Holcim I	WRDA-82	7.2	2.00	0.377	2230	3840	5950
Holcim I(SM)	WRDA-82	6.2	1.75	0.365	1680	3000	5230
Holcim I(SM)	MIRA-92	5.5	3.75	0.353	2130	3380	5400
Lafarge I(SM)	MIRA-92	5.5	2.75	0.343	2490	3710	5560

## Results and Discussion

The results indicate the Type I(SM) cements achieve slightly lower strengths at 5 hours than the Type I cements. At 10 hours the Type I(SM) cements are still slightly lower in strength, but are more than adequate for opening patches.<sup>1</sup>

Use of the maturity spreadsheet, which performs a linear regression between strength and TTF, tended to over estimate strength at 5 hours. Maturity graphs are shown in Figures 5-10 in the Appendix. Since the specification is based on time only, the compressive strengths were plotted versus the log of time. These plots are shown Figures 11-13 in Appendix. At the curing temperatures in this research, the difference in time to achieve the same strength with Type I(SM) and Type I/II cement is approximately one-half hour.

Use of the Type A mid range water reducer allowed a slightly lower w/c ratio (approximately 0.01) for both Type I(SM) cements and achieved slightly higher slump. This resulted in an increased compressive strength at 5 hours.

## Conclusions and Recommendations

The conclusions of this research are as follows:

1. Obtaining opening strength (5-hour patch) using Type I(SM) cement may be achieved by either 1) allowing one-half hour to one hour longer cure time, depending on ambient temperature or 2) using an increased dosage of mid range water reducer to achieve a lower w/c ratio.
2. Adequate strength is reached at 10 hours when Type I/II or Type I(SM) cements are used.

The following recommendations are based on conclusions from this research:

1. Allow use of Type I(SM) cement for 5 hour patches provided a Type A mid range water reducer is used at a higher rate to achieve a reduction in w/c ratio of at least 0.02 over the same mix with Type I or I/II cement.
2. Allow use of Type I(SM) for 10 hour patches without fly ash replacement.
3. Require longer curing time of at least 6 hours when Type I(SM) is used for patching when ambient temperatures are below 55 °F.
4. Require use of a Type A water reducer for all patching.

## Acknowledgement

The authors would like to thank Mike Coles, Leroy Lutjen, and Ken Kennedy from the Cement and Concrete Section for their help in this research.

## **References**

1. Narotam, Champ and Vu, John, MLR-93-7, Evaluation of Concrete Patching Mixes and Opening Time using the Maturity Concept, November 1993

## Appendix

**Figure 1 - Type I/II Mix Design with WR**

**GENERAL INFORMATION**

PROJECT:		0
PROJECT TITLE:	Patch Research	
MIX TYPE:		0
MIX NUMBER:	M-4 CACL	
DATE:	1/0/1900	

MATERIALS	Source	Type/Class	SPG	Percent	Percent
CEMENT:	Holcim & Lafarge	I & II/II	3.14		
FLY ASH:				0.00	
MINERAL ADMIXTURE:				0.00	
SILICA FUME SLURRY:				0.00	
FINE AGGREGATE:	Cordova		2.67	50.00	
COARSE AGGREGATE:	Ft. Dodge		2.66	50.00	100.00
INTERMEDIATE AGGREGATE:				0.00	0.00
AIR ENTRAINING AGENT:	Daravair 1400				
RETARDER:					
WATER REDUCER:	WRDA82				
SUPER WATER REDUCER:					
ACCELERATOR:					
DESIGN W/C(+FLY ASH):	0.33				
DESIGN SLUMP:	4.0				
DESIGN AIR CONTENT:	6.0				

**QUANTITIES (absolute volume method in SSD condition)**

	Volume ft3 Batch Size 1.0 yd3	Volume ft3 Batch Size 1.0 ft3						Weight lbs Batch Size 1.0 ft3	Weight lbs Batch Size 1.0 yd3	Weight lbs Lab Batch Size 0.75
CEMENT:	4.2120	0.1560	X	3.14	X	62.4	=	30.6	825	22.9
FLY ASH:	0.0000	0.0000						0.0	0	0.0
MINERAL ADMIXTURE:	0.0000	0.0000						0.0	0	0
SILICA FUME SLURRY:	0.0000	0.0000						0.0	0	0
WATER:	4.3645	0.1616	X	1.00	X	62.4	=	10.1	272	7.6
FINE AGGREGATE:	8.4018	0.3112	X	2.67	X	62.4	=	51.8	1400	38.9
COARSE AGGREGATE:	8.4018	0.3112	X	2.66	X	62.4	=	51.7	1395	38.7
INTERMEDIATE AGGREGATE:	0.0000	0.0000						0.0	0	0.0
AIR:	1.6200	0.0600	X	0.00	X	62.4	=	0.0	0	0.0
<b>Summation</b>	<b>27.0000</b>	<b>1.0000</b>						<b>144.1</b>	<b>3892</b>	<b>108.1</b>
<b>Paste Content</b>	<b>31.8</b>									
<b>Mortar Content (abs vol)</b>	<b>68.9</b>									
<b>Mortar Content (% pass)</b>	<b>37.8</b>									

**CHEMICAL ADMIXTURES**

	Rate oz/100 lbs cementitious							Rate ml Batch Size 1.0 ft3	Rate ml Batch Size 1.0 yd3	Rate ml Lab Batch Size 0.8
AIR ENTRAINING AGENT:	0.6	30.57	X	0.006	X	29.57	=	5.4	146.4	4.1
RETARDER:										
WATER REDUCER:	3.5	30.57	X	0.035	X	29.57	=	31.6	854.1	23.7
SUPER WATER REDUCER:										
ACCELERATOR:										

## Figure 2 - Type I(SM) Mix Design with WR

### GENERAL INFORMATION

PROJECT:		0
PROJECT TITLE:	Patch Research	
MIX TYPE:		0
MIX NUMBER:	M-4 CACL	
DATE:	1/0/1900	

MATERIALS	Source	Type/Class	SPG	Percent	Percent
CEMENT:	Holcim & Lafarge	I(SM)	3.1		
FLY ASH:				0.00	
MINERAL ADMIXTURE:				0.00	
SILICA FUME SLURRY:				0.00	
FINE AGGREGATE:	Cordova		2.67	50.00	
COARSE AGGREGATE:	Ft. Dodge		2.66	50.00	100.00
INTERMEDIATE AGGREGATE:				0.00	0.00
AIR ENTRAINING AGENT:	Daravair 1400				
RETARDER:					
WATER REDUCER:	WRDA82				
SUPER WATER REDUCER:					
ACCELERATOR:					
DESIGN W/C(+FLY ASH):	0.33				
DESIGN SLUMP:	4.0				
DESIGN AIR CONTENT:	6.0				

### QUANTITIES (absolute volume method in SSD condition)

	Volume	Volume					Weight	Weight	Weight	
	ft3	ft3					lbs	lbs	lbs	
	Batch Size	Batch Size					Batch Size	Batch Size	Lab Batch Size	
	1.0 yd3	1.0 ft3					1.0 ft3	1.0 yd3	0.75	
CEMENT:	4.2120	0.1560	X	3.10	X	62.4	=	30.2	815	22.6
FLY ASH:	0.0000	0.0000						0.0	0	0.0
MINERAL ADMIXTURE:	0.0000	0.0000						0.0	0	0
SILICA FUME SLURRY:	0.0000	0.0000						0.0	0	0
WATER:	4.3089	0.1596	X	1.00	X	62.4	=	10.0	269	7.5
FINE AGGREGATE:	8.4296	0.3122	X	2.67	X	62.4	=	52.0	1404	39.0
COARSE AGGREGATE:	8.4296	0.3122	X	2.66	X	62.4	=	51.8	1399	38.9
INTERMEDIATE AGGREGATE:	0.0000	0.0000						0.0	0	0.0
AIR:	1.6200	0.0600	X	0.00	X	62.4	=	0.0	0	0.0
<b>Summation</b>	<b>27.0000</b>	<b>1.0000</b>						<b>144.0</b>	<b>3887</b>	<b>108.0</b>
<b>Paste Content</b>	<b>31.6</b>									
<b>Mortar Content (abs vol)</b>	<b>68.8</b>									
<b>Mortar Content (% pass)</b>	<b>37.6</b>									

### CHEMICAL ADMIXTURES

	Rate					Rate	Rate	Rate		
	oz/100 lbs cementitious					ml	ml	ml		
	Batch Size					Batch Size	Batch Size	Lab Batch Size		
	1.0 ft3					1.0 ft3	1.0 yd3	0.8		
AIR ENTRAINING AGENT:	0.6	30.18	X	0.006	X	29.57	=	5.4	144.6	4.0
RETARDER:										
WATER REDUCER:	3.5	30.18	X	0.035	X	29.57	=	31.2	843.2	23.4
SUPER WATER REDUCER:										
ACCELERATOR:										

**Figure 3 – Type I(SM) Mix Design with Mid Range WR**

**GENERAL INFORMATION**

PROJECT:		0
PROJECT TITLE:	Patch Research	
MIX TYPE:		0
MIX NUMBER:	M-4 CACL	
DATE:	1/0/1900	

MATERIALS	Source	Type/Class	SPG	Percent	Percent
CEMENT:	Lafarge/Holcim	I(SM)	3.1		
FLY ASH:				0.00	
MINERAL ADMIXTURE:				0.00	
SILICA FUME SLURRY:				0.00	
FINE AGGREGATE:	Cordova		2.67	50.00	
COARSE AGGREGATE:	Ft. Dodge		2.66	50.00	100.00
INTERMEDIATE AGGREGATE:				0.00	0.00
AIR ENTRAINING AGENT:	Daravair 1400				
RETARDER:					
WATER REDUCER:	MIRA 92				
SUPER WATER REDUCER:					
ACCELERATOR:					
DESIGN W/C(+FLY ASH):	0.33				
DESIGN SLUMP:	4.0				
DESIGN AIR CONTENT:	6.0				

**QUANTITIES (absolute volume method in SSD condition)**

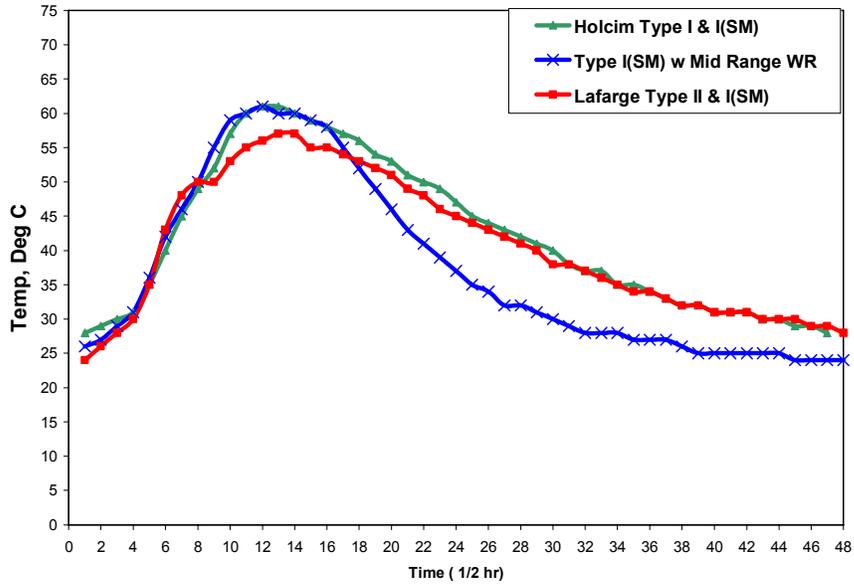
	Volume ft3 Batch Size 1.0 yd3	Volume ft3 Batch Size 1.0 ft3						Weight lbs Batch Size 1.0 ft3	Weight lbs Batch Size 1.0 yd3	Weight lbs Lab Batch Size 0.75
CEMENT:	4.2120	0.1560	X	3.10	X	62.4	=	30.2	815	22.6
FLY ASH:	0.0000	0.0000						0.0	0	0.0
MINERAL ADMIXTURE:	0.0000	0.0000						0.0	0	0
SILICA FUME SLURRY:	0.0000	0.0000						0.0	0	0
WATER:	4.3089	0.1596	X	1.00	X	62.4	=	10.0	269	7.5
FINE AGGREGATE:	8.4296	0.3122	X	2.67	X	62.4	=	52.0	1404	39.0
COARSE AGGREGATE:	8.4296	0.3122	X	2.66	X	62.4	=	51.8	1399	38.9
INTERMEDIATE AGGREGATE:	0.0000	0.0000						0.0	0	0.0
AIR:	1.6200	0.0600	X	0.00	X	62.4	=	0.0	0	0.0
<b>Summation</b>	<b>27.0000</b>	<b>1.0000</b>						<b>144.0</b>	<b>3887</b>	<b>108.0</b>
<b>Paste Content</b>	<b>31.6</b>									
<b>Mortar Content (abs vol)</b>	<b>68.8</b>									
<b>Mortar Content (% pass)</b>	<b>37.6</b>									

**CHEMICAL ADMIXTURES**

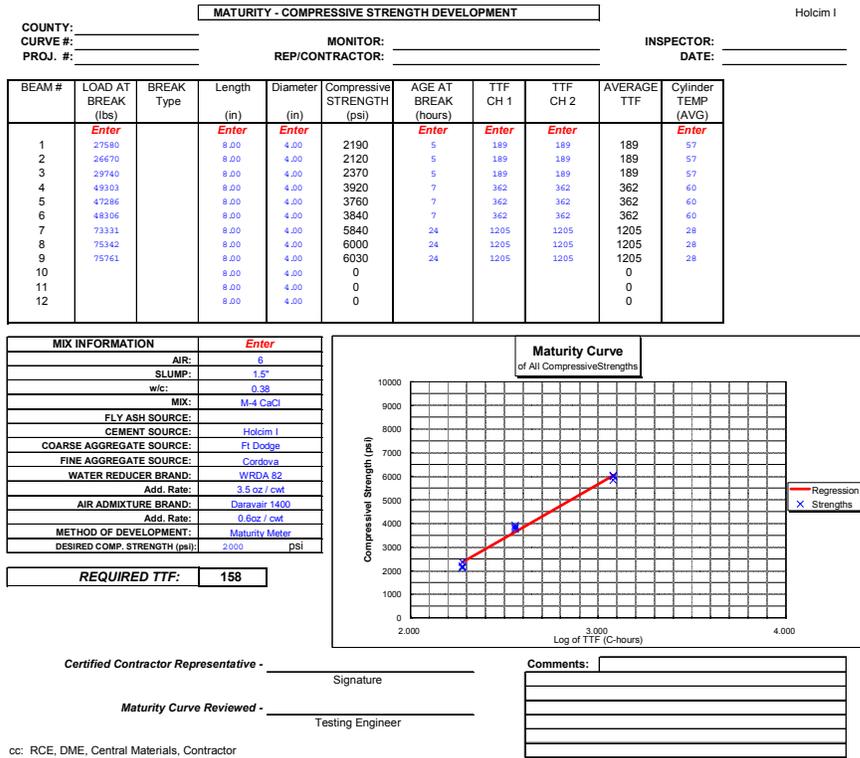
	Rate oz/100 lbs cementitious							Rate ml Batch Size 1.0 ft3	Rate ml Batch Size 1.0 yd3	Rate ml Lab Batch Size 0.8
AIR ENTRAINING AGENT:	0.6	30.18	X	0.006	X	29.57	=	5.4	144.6	4.0
RETARDER:										
WATER REDUCER:	6.0	30.18	X	0.06	X	29.57	=	53.5	1445.6	40.2
SUPER WATER REDUCER:										
ACCELERATOR:										

Figure 4 – Temperature Profile in Cylinders

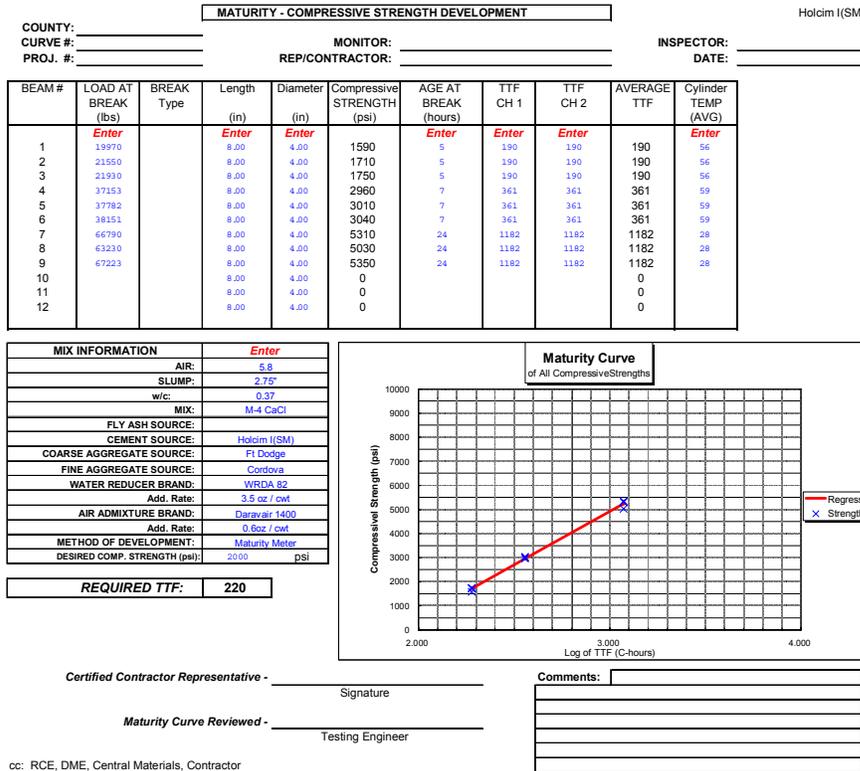
Cylinder Temperatures by Mix



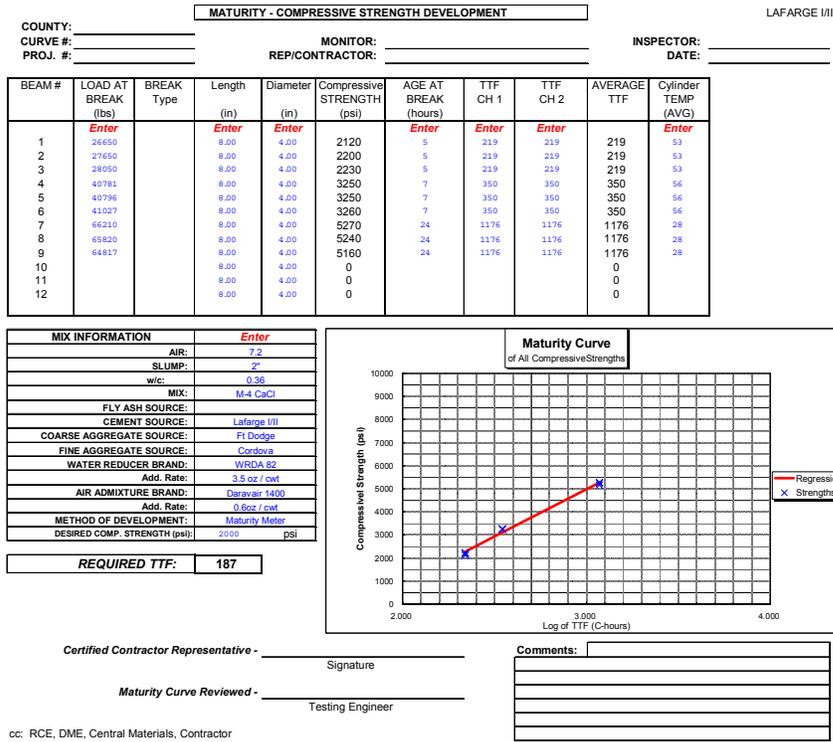
### Figure 5 – Maturity Curve Holcim Type I



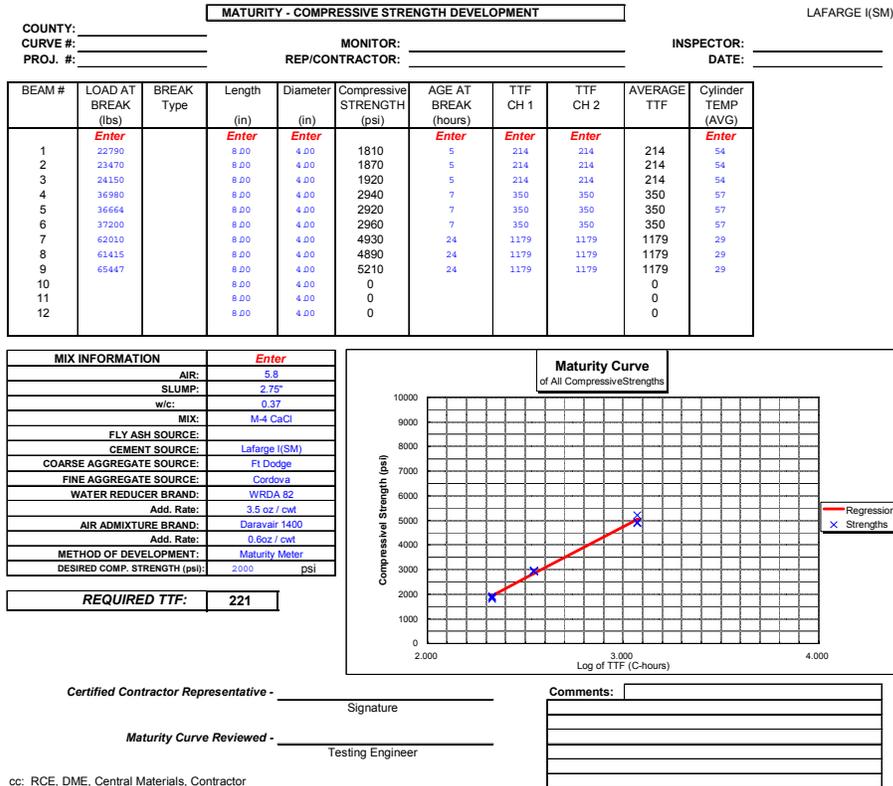
### Figure 6 – Maturity Curve Holcim Type I(SM)



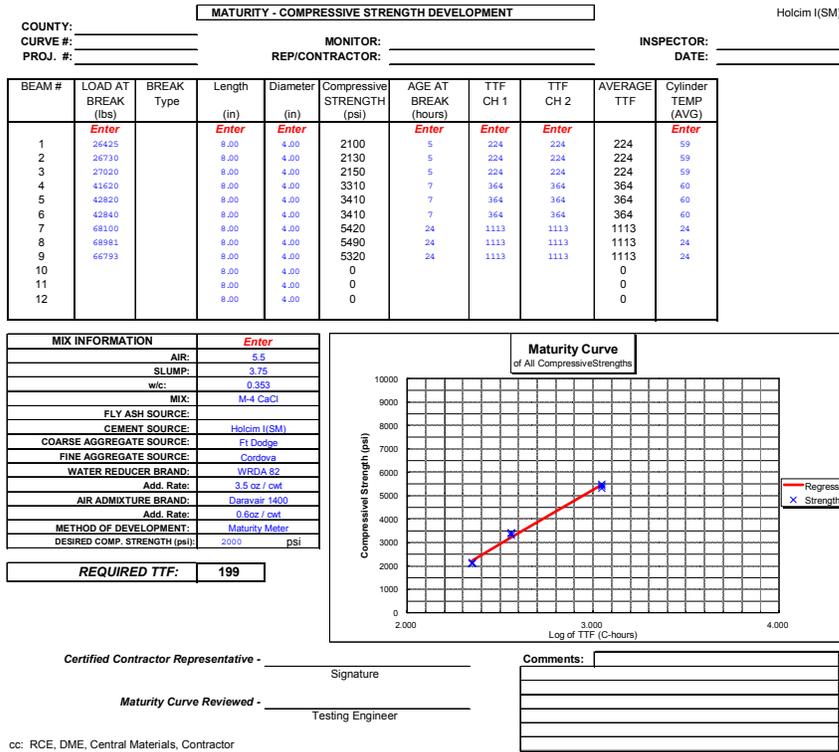
**Figure 7 – Maturity Curve Lafarge Type I/II**



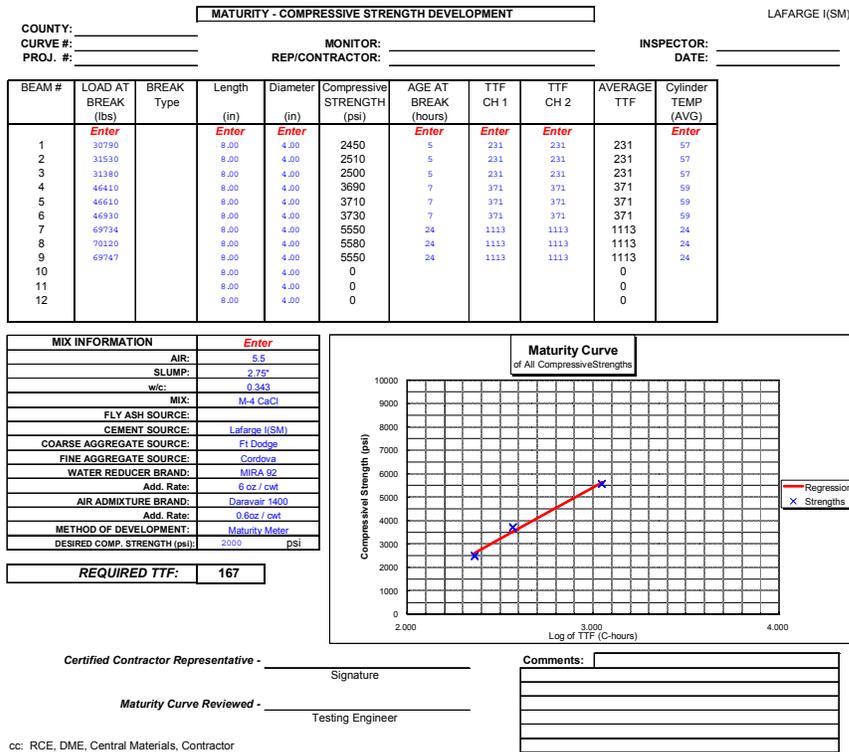
**Figure 8 – Maturity Curve Lafarge Type I(SM)**



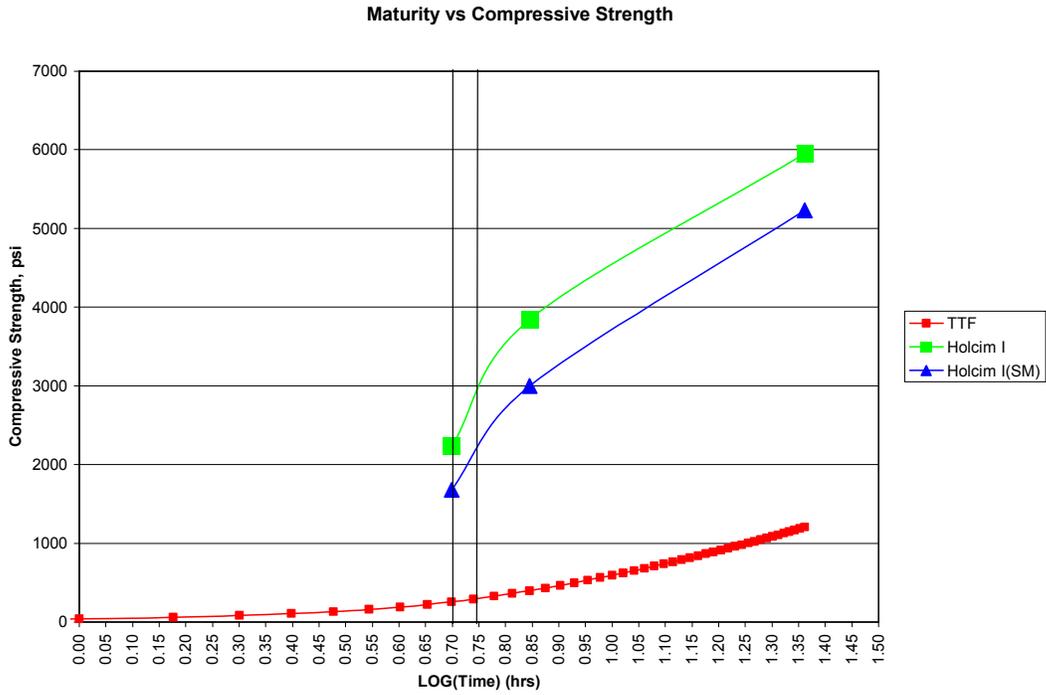
**Figure 9 – Maturity Curve Holcim Type I(SM) with Mid Range Water Reducer**



**Figure 10 – Maturity Curve Lafarge Type I(SM) with Mid Range Water Reducer**



**Figure 11 – Time versus Compressive Strength Holcim Cements**



**Figure 12 – Time versus Compressive Strength Lafarge Cements**

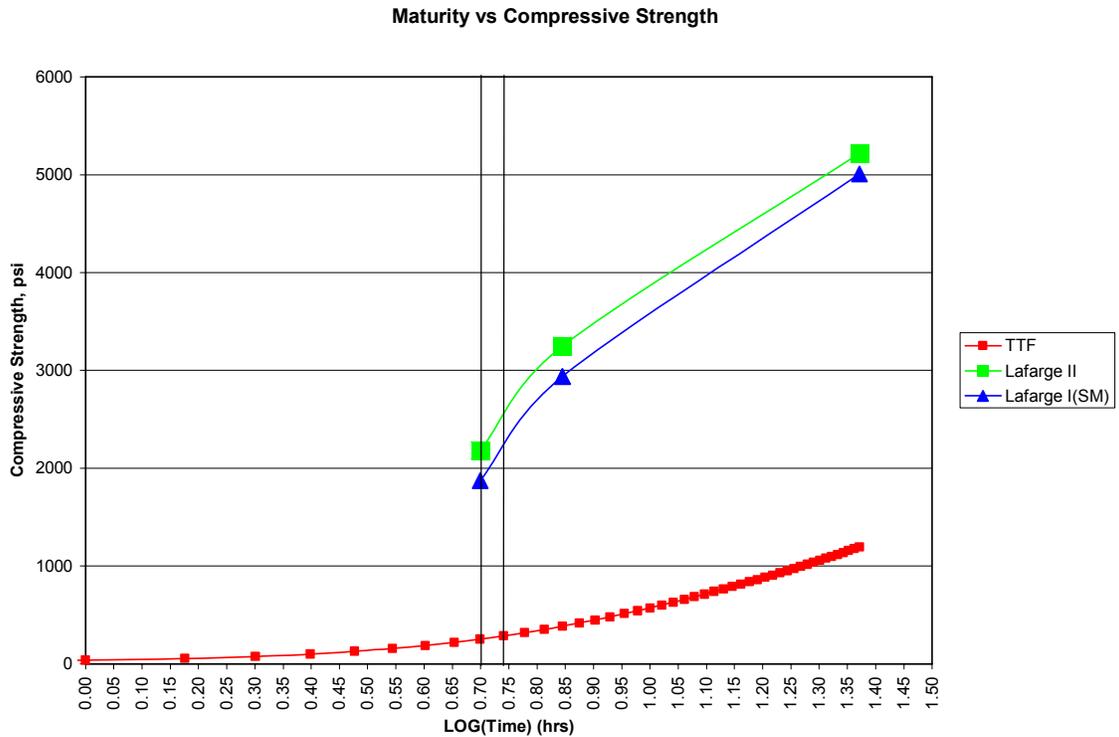


Figure 13 – Time versus Compressive Strength Type I(SM) Cements w Mid Range WR

