

Evaluation of Set Accelerating Admixture for Masonry Cement Masonry Mortar

for

**Grace Construction Products
7221 Parkland Court West
Milwaukee, WI 53223**

Conducted by:

**Project No. 09-110-4
Date: November 19, 2010**



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11/19/2010

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Evaluation of Set Accelerating Admixture for Masonry Cement Masonry Mortar

1.0—INTRODUCTION

Admixtures may be used in masonry mortars to alter one or more of the mortar's properties, one of which is to decrease the setting time of masonry mortar through the use of a set accelerating admixture. This project evaluated a set accelerating chemical admixture for use in masonry mortar for compliance with ASTM C1384-06a, *Standard Specification for Admixtures for Masonry Mortars* (Ref. 1).

2.0—MATERIALS

2.1 Cementitious Materials

The mortar prepared in this project was Type S masonry cement mortar. The masonry cement used was a Type S masonry cement produced by CEMEX. While the packaging of the cement stated compliance with ASTM C91-05, *Standard Specification for Masonry Cement* (Ref. 2), compliance was not verified by the Laboratory because compliance with the property specification of ASTM C270-10, *Standard Specification for Mortar for Unit Masonry* (Ref. 3), was performed as part of this project and is required for mortars evaluated in accordance with ASTM C1384-06a.

2.2 Masonry Sand

The sand used for this project was masonry sand from a local quarry that met the gradation requirements of ASTM C144-04, *Standard Specification for Aggregate for Masonry Mortar* (Ref. 4).

2.2 Masonry Mortar Admixtures

The masonry mortar admixture evaluated here was a set accelerating admixture with the trade name "MORSET® Non-Chloride/Non-Corrosive Set Accelerator". This admixture was provided to the Laboratory by the client in a 1 gal (3.8 L) bottle.

3.0—TESTING PROCEDURES

3.1 Air Content, Water Retention, and Compressive Strength Testing

Two batches of mortar were evaluated for compliance with ASTM C270-10, a control batch without admixture and a test batch containing the admixture. Testing was performed for air content as per ASTM C185-08, *Standard Test Method for Air Content of Hydraulic Cement Mortar* (Ref. 5), water retention as per ASTM C1506-09, *Standard Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters* (Ref. 6), and compressive strength as per ASTM C109/C109M-08, *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or [50-mm] Cube Specimens)* (Ref. 7), as modified by ASTM C270-10.

3.2 Consistency Retention Testing

Consistency retention testing was performed in accordance with ASTM C780-09, *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry* (Ref. 8). The procedure used is found in Annex A2, *Consistency Retention of Mortars for Unit Masonry*, specifically the 'disturbed sample' procedures. As with the testing described previously, consistency retention testing was performed on two batches, a control and a test batch. The batches were mixed

according to ASTM C780-09 to an initial cone penetration of 60 ± 5 mm (2.36 ± 0.20 in.). Subsequent cone penetration readings were taken at 15 minute intervals until the penetration was less than 70% of the initial reading. Using this data, a linear interpolation was used to determine the exact time that the penetration was at 70% of the initial penetration. This interpolated time is reported as the board life.

3.3 Time of Set Testing

Time of set was evaluated using the procedures in ASTM C403/C403M-08, *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance* (Ref. 9). For each test, three individual samples were taken from the same test batch. Reported values are the average results from the samples taken from the same batch. This test was performed on two batches; a control batch containing no admixture and a test batch containing the admixture. Accelerating admixtures are typically used in masonry construction during cold weather. Given the typical use of accelerating admixtures ASTM C1384-06a requires that both control and modified mortars be evaluated for time of set at an ambient temperature of $41 \pm 3.6^\circ\text{F}$ ($5 \pm 2^\circ\text{C}$) to determine the admixture's affect on set time.

3.4 Number of Tests Performed

Section 7.1 of ASTM C1384-06a states in part that "Unless more specimens are required by a specific test method, a minimum of three specimens shall be tested and the results averaged". For this project, three specimens were taken from each batch for ASTM C403/C403M-08 testing. A single determination of air content and water retention was taken from each batch for ASTM C270-10 and three cubes were tested at each of 7 days and 28 days of age. For ASTM C780-09 testing, a single determination was made from each batch.

4.0 MORTAR VARIABLES AND BATCHING PROCEDURES

As discussed in Section 2.1, the masonry mortar used to evaluate the mortar admixture was a Type S masonry cement mortar. The proportions of constituent materials used to batch each mortar evaluated in this investigation complied with ASTM C270-10. These proportions are shown in Table 1. For the set accelerating admixture, the manufacturer's recommended dosage rate varied based on the ambient testing temperature. Therefore, the dosage rate for the admixture for ASTM C403/C403M-08 testing was 16 oz per 75 lb cement (473 mL per 34.0 kg cement), while for ASTM C270-10 and ASTM C780-09 testing the dosage rate was 8 oz per 75 lb cement (237 mL per 34.0 kg cement).

Material	Volume Proportions	Weight of Material for C270-10, g (lb)	Weight of Material for C403/C403M-08, lb (kg)	Weight of Material for C780-09, lb (kg)
Type S Masonry Cement	1	450 (0.992)	15.6 (7.08)	8.25 (3.74)
Sand	3	1440 (3.175)	50.0 (22.7)	26.4 (12.0)
MORSET ¹	See above	4.1 (0.009)	0.28 (0.127)	0.07 (0.032)

¹ Admixture not used in control batches.

5.0—RESULTS

5.1 Requirements and Results

Table 2 shows the requirements for mortar modified with a set accelerating admixture as per ASTM C1384-06a as well as the test results. Requirements are based on deviation from the values obtained from the control sets. Additionally, all modified mortars are required to meet the property specification of ASTM C270-10.

The air content and water retention results for the test batches are shown in Table 2. All results meet the property requirements for air content and water retention for a Type S masonry cement mortar in accordance with ASTM C270-10. Detailed results can be found in Appendix A.

Table 2 also shows the compressive strength results. Both sets meet the ASTM C270-10 property requirements for compressive strength for a Type S masonry cement mortar. Additionally, the mortar with admixture complies with the requirements in ASTM C1384-06a at both 7 and 28 days of age that the strength of the modified mortar be 80% or more of the control batch. Detailed results can be found in Appendix A.

ASTM C1384-06a has no specific requirements for the performance of the mortar with a set accelerating admixture for consistency retention (board life), although it is required to report the results for each batch. A summary of the C780-09 results are shown in Table 2, with detailed results in Appendix B.

Results for time of set by penetration resistance are shown in Table 2. The modified mortar complies with the requirements of ASTM C1384-06a at both the initial set, where the mortar with admixture shall reach initial set at least 1 hour, but not more than 3.5 hours earlier than the control, and at final set, where the modified mortar shall reach initial set at least 1 hour earlier than the control. Detailed results can be found in Appendix C.

Table 2: ASTM C1384-06a Requirements and Summary of Test Results						
Physical Property	ASTM C270-10 Property Requirements	Set Accelerator Admixture Requirements	Control Mortar	MORSET® Set Accelerator	% of Control	Pass/Fail /Report
7 day compressive strength, psi (MPa)	---	80% minimum of control	1,810 (12.5)	1,990 (13.7)	110%	Pass
28 day compressive strength, psi (MPa)	1800 (12.4)	80% minimum of control	2,420 (16.7)	2,130 (14.7)	88%	Pass
Water Retention, %	75	Report only*	75	76	-	Report*
Air Content, %	18	Report only*	9.1	9.0	-	Report*
Board Life, %	---	Report only*	106	98	-	Report*
Initial Time of Set						
At least	---	1:00 hr earlier than control	14:28	12:37	Within Permitted Range (10:58 to 13:28)	Pass
Not more than		3:30 hr earlier than control				
Final Time of Set						
At least	---	1:00 hr earlier than control	26:26	24:23	Within Permitted Range (25:26 or earlier)	Pass
Not more than		---				

*ASTM C1384-06a does not require or specify a maximum or minimum value for this mortar property, only that the measured difference relative to the control batch be reported.

6.0—SUMMARY OF OBSERVATIONS

A chemical admixture was evaluated for suitability for use in masonry mortars. Pursuant to the requirements of ASTM C1384-06a, testing was performed on a control mortar and a mortar with MORSET set accelerating admixture for compressive strength, air content, water retention, consistency retention, and time of set. The mortars were both a Type S masonry cement mortar and complied with the property specification of ASTM C270-10. The admixture was provided to the Laboratory by the client.

Based on the results provided above, the set accelerating masonry mortar admixture with the trade name “MORSET® Non-Chloride/Non-Corrosive Set Accelerator” meets all the requirements of ASTM C1384-06a at the dosage rates as reported in this report when used with a Type S masonry cement mortar.

7.0—REFERENCES

1. ASTM Standard C1384, 2006a, “Standard Specification for Admixtures for Masonry Mortars”, ASTM International, West Conshohocken, PA, www.astm.org.
2. ASTM Standard C91, 2005, “Standard Specification for Masonry Cement”, ASTM International, West Conshohocken, PA, www.astm.org.
3. ASTM Standard C270, 2010, “Standard Specification for Mortar for Unit Masonry”, ASTM International, West Conshohocken, PA, www.astm.org.
4. ASTM C144, 2004, “Standard Specification for Aggregate for Masonry Mortar”, ASTM International, West Conshohocken, PA, www.astm.org.
5. ASTM Standard C185, 2008, “Standard Test Method for Air Content of Hydraulic Cement Mortar”, ASTM International, West Conshohocken, PA, www.astm.org.
6. ASTM Standard C1506, 2009, “Standard Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters”, ASTM International, West Conshohocken, PA, www.astm.org.
7. ASTM Standard C109/C109M, 2008, “Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)”, ASTM International, West Conshohocken, PA, www.astm.org.
8. ASTM Standard C780, 2009, “Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry”, ASTM International, West Conshohocken, PA, www.astm.org.
9. ASTM Standard C403/C403M, 2008, “Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance”, ASTM International, West Conshohocken, PA, www.astm.org.

APPENDIX

In the appendix, the values presented are in inch-pound units. The following conversions to SI units can be used:

$$1 \text{ in} = 25.4 \text{ mm}$$

$$1 \text{ lb/ft}^3 = 16.0 \text{ kg/m}^3$$

$$1 \text{ lb (mass)} = 0.4536 \text{ kg}$$

$$1 \text{ lb (force)} = 4.45 \text{ N}$$

$$1 \text{ psi} = 6.895 \text{ kPa}$$

Appendix A – ASTM C270-10 Results

Control Batch

ASTM C270-10 Test Report Mortar for Unit Masonry

Job No.: 09-110-3A
Report Date: 10/21/2010

Client: Grace Construction Products
Address: 7221 Parkland Court West
Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171-4662

Mortar Description:
Masonry Cement Mortar
Type S
Control - No Admixture

Sampling Party: Grace Construction Products

Date Materials Received: 2/24/2009

Summary of Test Results

Tested Property	Specified Values	Tested Values	
Compressive Strength, 7 Day	-----	1810	psi
Compressive Strength, 28 Day	1800 psi min	2420	psi
Air Content	18% max	9.1	%
Water Retention	75% min	75	%

Detailed Results

Batch Information (C270-10)

Material	Type/Brand/Source	Volume Proportions	Material Amount
Masonry Cement	CEMEX Type S	1	450.0 g
Masonry Sand	C144	3	1440.0 g
Water Added to Mix	-----	-----	295.0 mL
Admixture	None	-----	---

Date Mixed: 9/17/2010

Air Calculation (C91-05)

400 mL Brass Cup, full: 1525.5 g
Tare Weight of brass cup: 740.70 g
Weight of 400 mL Mortar: 784.8 g
Density of mortar, D: 2.16 g/mL
Air Content: 9.1 %

Water Retention (C1506-09)

Initial Flow: 110 %
Flow After Suction: 82 %
Water Retention: 75 %

2-inch Cube Compressive Strength (C109/C109M-08)

Cube Age: 7 Days Date Tested: 9/24/2010			
Cube Number	Cube Weight (g)	Load (lb)	Compressive Strength (psi)
1	262.5	7520	1880
2	262.1	7250	1810
3	263.2	7000	1750
Average	262.6	7260	1810

Cube Age: 28 Days Date Tested: 10/15/2010			
Cube Number	Cube Weight (g)	Load (lb)	Compressive Strength (psi)
1	262.3	10170	2540
2	262.4	9680	2420
3	264.0	9250	2310
Average	262.9	9700	2420

NOTE: The tested materials comply with the compressive strength, air content and water retention requirements of ASTM C270-10.

Test Batch with MORSET Set Accelerator

ASTM C270-10 Test Report Mortar for Unit Masonry

Job No.: 09-110-6A
Report Date: 10/21/2010

Client: Grace Construction Products
Address: 7221 Parkland Court West
Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171-4662

Mortar Description:
Masonry Cement Mortar
Type S
Control - No Admixture

Sampling Party: Grace Construction Products

Date Materials Received: 2/24/2009

Summary of Test Results

Tested Property	Specified Values	Tested Values	
Compressive Strength, 7 Day	-----	1990	psi
Compressive Strength, 28 Day	1800 psi min	2130	psi
Air Content	18% max	9.0	%
Water Retention	75% min	76	%

Detailed Results

Batch Information (C270-10)

Material	Type/Brand/Source	Volume Proportions	Material Amount
Masonry Cement	CEMEX Type S	1	450.0 g
Masonry Sand	C144	3	1440.0 g
Water Added to Mix	-----	-----	295.0 mL
Admixture	MORSET	-----	4.1 g

Date Mixed: 9/21/2010

Air Calculation (C91-05)

400 mL Brass Cup, full: 1525.3 g
Tare Weight of brass cup: 740.90 g
Weight of 400 mL Mortar: 784.4 g
Density of mortar, D: 2.16 g/mL
Air Content: 9.0 %

Water Retention (C1506-09)

Initial Flow: 109 %
Flow After Suction: 83 %
Water Retention: 76 %

2-inch Cube Compressive Strength (C109/C109M-08)

Cube Age: 7 Days
Date Tested: 9/28/2010

Cube Number	Cube Weight (g)	Load (lb)	Compressive Strength (psi)
1	264.2	8590	2150
2	265.0	7590	1900
3	265.2	7650	1910
Average	264.8	7940	1990

Cube Age: 28 Days
Date Tested: 10/19/2010

Cube Number	Cube Weight (g)	Load (lb)	Compressive Strength (psi)
1	264.7	9740	2440
2	266.1	8690	2170
3	265.1	7160	1790
Average	265.3	8530	2130

NOTE: The tested materials comply with the compressive strength, air content and water retention requirements of ASTM C270-10.

Appendix B – ASTM C780-09 Results – Consistency Retention

Control Batch

ASTM C780-09 Standard Test Methods Preconstruction and Construction
 Evaluation of Mortars for Plain and Reinforced Unit Masonry
 Annex A2: Consistency Retention of Mortars for Unit Masonry

Job Number: 09-110-3B
 Report Date: 10/21/2010

Client: Grace Construction Products
 Address: 7221 Parkland Court West
 Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
 Research and Development Laboratory
 Address: 13750 Sunrise Valley Drive
 Herndon, VA 20171

Project Identification: Type S Masonry Cement Mortar

Sample Identification: Control - No Admixture

Batch Information: Mortar Type: S

Material	Description	Batch Weight (lb)
Cement	CEMEX Type S	8.3
Masonry Sand:	C144	26.4
Admixture:	None	---
Water:	---	5.4

NOTE: Mixing water added to achieve an initial cone penetration of 60 ± 5 mm as per ASTM C1384-06a.

Test Results:

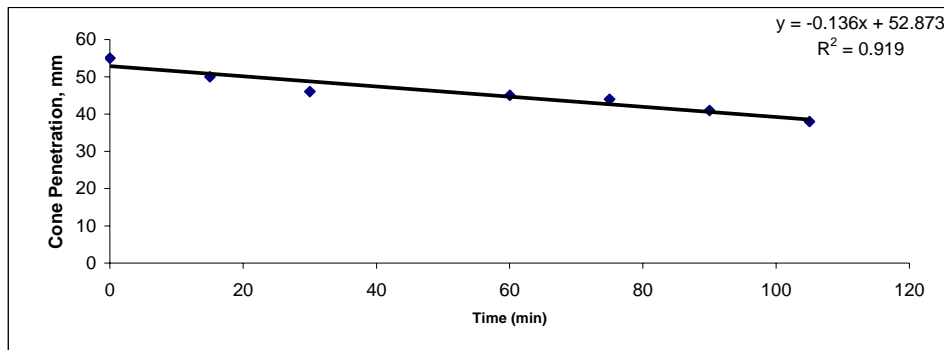
Mixing Time: 5 min

Reading Number	Time (min)	Cone Penetration, mm
T ₀	0	55
2	15	50
3	30	46
4*	45	50
5	60	45
6	75	44
7	90	41
8	105	38

70% of T₀, mm = 38.5
 Board Life, min = 105.7

NOTE: As per ASTM C1384-06a, board life is defined as the interpolated time that the cone penetration is at 70% of the initial penetration, T₀.

* Reading not included in calculation - possible outlier



Trendline: y = -0.136 * x + 52.873

Test Batch with MORSET Set Accelerator

**ASTM C780-09 Standard Test Methods Preconstruction and Construction
Evaluation of Mortars for Plain and Reinforced Unit Masonry
Annex A2: Consistency Retention of Mortars for Unit Masonry**

Job Number: 09-110-6B
Report Date: 10/22/2010

Client: Grace Construction Products
Address: 7221 Parkland Court West
Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171

Project Identification: Type S Masonry Cement Mortar
Sample Identification: Contains Set Accelerating Admixture

Batch Information: Mortar Type: S

Material	Description	Batch Weight	
Cement	CEMEX Type S	8.3	lb
Masonry Sand:	C144	26.4	lb
Admixture:	MORSET	33.8	g
Water:	---	5.4	lb

NOTE: Mixing water added to achieve an initial cone penetration of 60 ± 5 mm as per ASTM C1384-06a.

Test Results:

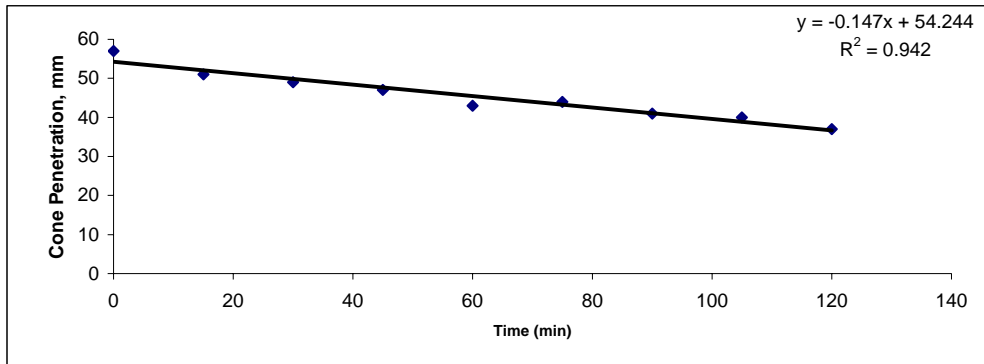
Mixing Time: 5 min

Reading Number	Time (min)	Cone Penetration, mm
T ₀	0	57
2	15	51
3	30	49
4*	45	47
5	60	43
6	75	44
7	90	41
8	105	40
9	120	37

70% of T₀, mm = 39.9
Board Life, min = 97.6

NOTE: As per ASTM C1384-06a, board life is defined as the interpolated time that the cone penetration is at 70% of the initial penetration, T₀.

* Reading not included in calculation - possible outlier



Trendline: y = -0.147 * x + 54.244

Appendix C – ASTM C403/C403M-08 Results – Time of Set

Control Batch

NCMA Research and Development Laboratory
ASTM C403/C403M-08 Standard Test Method for Time of Setting
of Concrete Mixtures by Penetration Resistance

NCMA Job Number: 09-110-3E
 Date Tested: 9/8/2010
 Report Date: 10/21/2010
 Page 1 of 2

Client: Grace Construction Products
 Address: 7221 Parkland Court West
 Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
 Research and Development Laboratory
 Address: 13750 Sunrise Valley Drive
 Herndon, VA 20171

Sample Identification: Type S Masonry Cement Mortar Control - No Admixture at 41 °F

Summary of Test: A masonry mortar mix was batched and prepared using the procedures defined in ASTM C780-09. The amount of water added was such to produce a flow of $110 \pm 5\%$ when tested in accordance with ASTM C1437-07. Three test specimens were molded, each with a diameter of 6 inches and a height of approximately 6 inches. These specimens were cured at ambient laboratory temperatures and sealed in a water-tight container to minimize water evaporation. During the course of testing, the samples were uncovered, any bleed water that had accumulated was removed using a syringe, and the specimens were penetrated with needles of varying surface area. The penetrations were taken periodically until the force required to penetrate one inch into the mortar exceeded 4000 psi. At that point, the testing was stopped. The data is plotted on a graph of time vs. penetration resistance. A power function trendline is fitted to the data and the resulting equation is used to determine the time of setting. Initial setting is defined as the time when the penetration resistance equals 500 psi and final setting is the time when the penetration resistance equals 4000 psi. The data is presented below for each of the three samples, and also as an average for the set.

Batch Information:	Material	Description	Batch Weight (lb)
	Masonry Cement:	CEMEX Type S	15.60
	Aggregate:	C144	50.00
	Admixture:	None	---
	Water:	---	8.86

Water to Cementitious Materials Ratio: 0.57 Curing Temperature of Mortar: 41 °F
 Cementitious Materials to Aggregate Ratio: 0.31

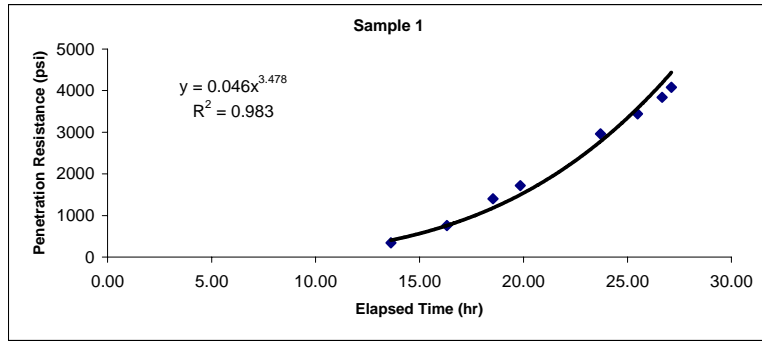
Summary of Time of Set Results:

	Initial Set (hr)	Final Set (hr)
Sample 1	14.47	26.31
Sample 2	14.57	26.43
Sample 3	14.34	26.56
Average	14.46	26.43

Experimental Data and Plots

Sample 1

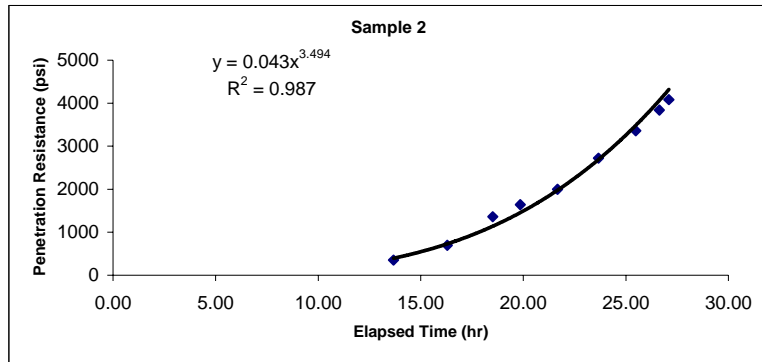
Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.63	172	0.5	344
16.32	76	0.1	760
18.53	70	0.05	1400
19.85	86	0.05	1720
23.70	74	0.025	2960
25.48	86	0.025	3440
26.67	96	0.025	3840
27.12	102	0.025	4080



Penetration Resistance= 0.046 *time^{3.48}

Sample 2

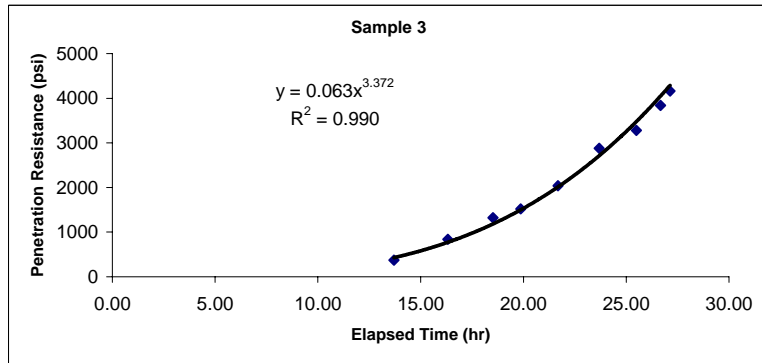
Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.67	176	0.5	352
16.30	174	0.25	696
18.52	68	0.05	1360
19.85	82	0.05	1640
21.67	100	0.05	2000
23.67	68	0.025	2720
25.48	84	0.025	3360
26.63	96	0.025	3840
27.10	102	0.025	4080



Penetration Resistance= 0.043 *time^{3.494}

Sample 3

Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.70	186	0.5	372
16.32	84	0.1	840
18.52	66	0.05	1320
19.87	76	0.05	1520
21.68	102	0.05	2040
23.68	72	0.025	2880
25.50	82	0.025	3280
26.67	96	0.025	3840
27.13	104	0.025	4160



Penetration Resistance= 0.063 *time^{3.372}

Test Batch with MORSET Set Accelerator

NCMA Research and Development Laboratory
ASTM C403/C403M-08 Standard Test Method for Time of Setting
of Concrete Mixtures by Penetration Resistance

NCMA Job Number: 09-110-6C
Date Tested: 9/8/2010
Report Date: 10/21/2010
Page 1 of 2

Client: Grace Construction Products
Address: 7221 Parkland Court West
Milwaukee, WI 53223

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171

Sample Identification: Type S Masonry Cement Mortar with Set Accelerating Admixture

Summary of Test: A masonry mortar mix was batched and prepared using the procedures defined in ASTM C780-09. The amount of water added was such to produce a flow of $110 \pm 5\%$ when tested in accordance with ASTM C1437-07. Three test specimens were molded, each with a diameter of 6 inches and a height of approximately 6 inches. These specimens were cured at ambient laboratory temperatures and sealed in a water-tight container to minimize water evaporation. During the course of testing, the samples were uncovered, any bleed water that had accumulated was removed using a syringe, and the specimens were penetrated with needles of varying surface area. The penetrations were taken periodically until the force required to penetrate one inch into the mortar exceeded 4000 psi. At that point, the testing was stopped. The data is plotted on a graph of time vs. penetration resistance. A power function trendline is fitted to the data and the resulting equation is used to determine the time of setting. Initial setting is defined as the time when the penetration resistance equals 500 psi and final setting is the time when the penetration resistance equals 4000 psi. The data is presented below for each of the three samples, and also as an average for the set.

Batch Information:	Material	Description	Batch Weight	
	Masonry Cement:	CEMEX Type S	15.60	lb
	Aggregate:	C144	50.00	lb
	Admixture:	MORSET	127.90	g
	Water:	---	8.88	lb

Water to Cementitious Materials Ratio: 0.57 Curing Temperature of Mortar: 41 °F
Cementitious Materials to Aggregate Ratio: 0.31

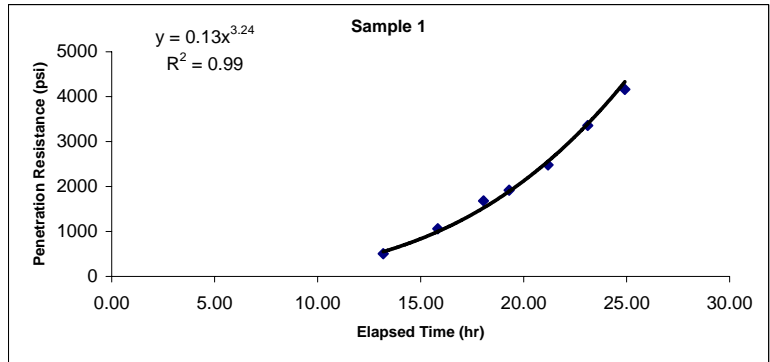
Summary of Time of Set Results:

	Initial Set (hr)	Final Set (hr)
Sample 1	12.78	24.28
Sample 2	12.35	24.48
Sample 3	12.72	24.40
Average	12.62	24.39

Experimental Data and Plots

Sample 1

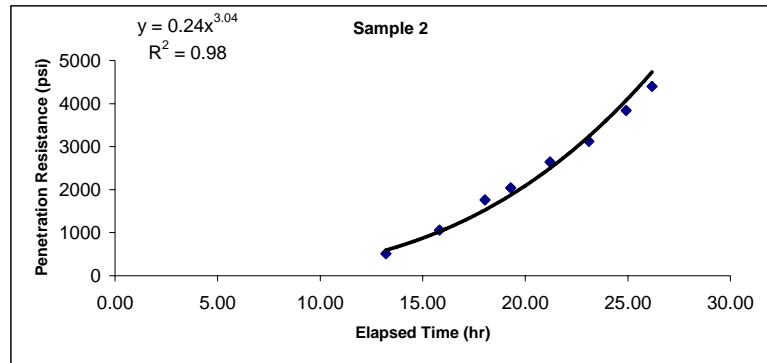
Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.18	126	0.25	504
15.83	106	0.1	1060
18.05	84	0.05	1680
19.30	96	0.05	1920
21.18	124	0.05	2480
23.12	84	0.025	3360
24.92	104	0.025	4160



Penetration Resistance = 0.13 *time^{3.24}

Sample 2

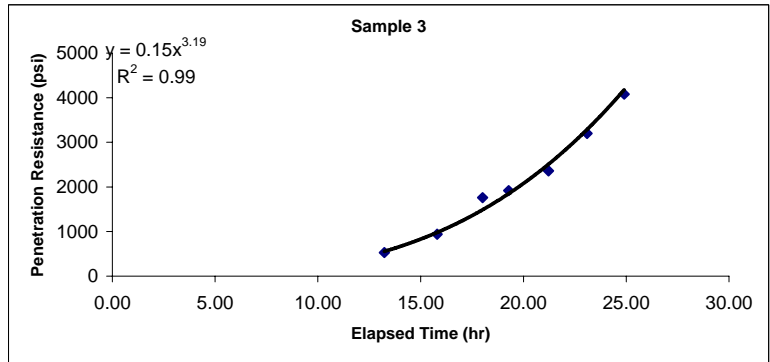
Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.20	128	0.25	512
15.82	106	0.1	1060
18.03	88	0.05	1760
19.28	102	0.05	2040
21.20	132	0.05	2640
23.10	78	0.025	3120
24.92	96	0.025	3840
26.18	110	0.025	4400



Penetration Resistance = 0.24 *time^{3.04}

Sample 3

Elapsed Time (hr)	Penetration Resistance (lb)	Needle Area (in ²)	Penetration Resistance (psi)
13.23	132	0.25	528
15.80	94	0.1	940
18.02	88	0.05	1760
19.28	96	0.05	1920
21.22	118	0.05	2360
23.10	80	0.025	3200
24.90	102	0.025	4080



Penetration Resistance = 0.15 *time^{3.19}