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Effects of Boric Acid and Water Content on Fundamental Properties of Proprietary Magnesium Phosphate Cement (MPC) Products

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Abstract

Magnesium phosphate cements (MPCs) have been used for decades in proprietary products for pavement repairs. However, products with high exothermic temperatures have short working times, and research is needed to overcome these unfavorable characteristics. The effects of different boric acid and water contents on the fundamental properties of concrete was investigated through 34 trial batch modifications on the following commercially available MPC products: (1) Premier Magnesia's PREMag PGDM, (2) BASF Master Builder's MasterEmaco T545, and (3) CeraTech Inc.'s Pavemend TR. Overall results indicated that the increase of boric acid and water content produced favorable decreased temperatures and increased set times but retardation in the early age development of compressive strength.

Modifications in the PREMag PGDM product resulted in poor workability, inaccurate time of setting due to a thixotropic nature, and unacceptable compressive strength loss. The Pavemend TR product was significantly affected by the addition of boric acid resulting in non-recoverable compressive and bond strength loss, excessive expansions, failure at low freezing and thawing cycles, and unacceptable times of setting for rapid-repair applications. The T545 product showed promising performance with 28-day recovery in compressive, flexural, and bond strengths and minimal differences in other properties when compared to the control mixture.

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Preface

This study was conducted under MIPR F4ATA48226JW01 for the Air Force Civil Engineer Center (AFCEC) located at Tyndall Air Force Base in Panama City, FL. The AFCEC technical manager of this project was Dr. Craig Rutland. The findings and recommendations presented in this report are based on laboratory evaluations conducted during the period 2014 through 2018.

The work was performed by the Airfields and Pavements Branch (GMA) and the Concrete and Materials Branch (GMC) of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Dr. Timothy W. Rushing was Chief, GMA; Mr. Christopher M. Moore was Chief, GMC; Mr. Justin S. Strickler was Chief, GM; and Mr. R. Nicholas Boone, GZT, was the Technical Director for Force Projection and Maneuver Support. The Deputy Director of the GSL was Mr. Charles W. Ertle, and the Director was Mr. Bartley P. Durst.

COL Teresa A. Schlosser was the Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

Magnesium phosphate cements (MPCs) are increasingly being used in proprietary rapid-repair products for pavement projects due to the many advantages MPCs have over ordinary portland cement (OPC). Some of these advantages include better heat resistance, faster setting time, higher early strength, quicker setting at low temperatures with additional heat, bonding well to existing concretes, acid resistance, chemical and mold resistance, good durability with respect to cycles of freezing and thawing, low drying shrinkage, low coefficient of thermal expansion, and use of the material helps reduce CO_2 emissions compared to OPC. However, there are some disadvantages of MPCs including short working times due to the rapid setting nature, the materials evolve substantial amounts of heat, and water can potentially dissolve unreacted phosphates, thus increasing the porosity and making the hardened MPC substantially weaker. Another disadvantage of rapid-repair proprietary products is they are often intended for small patch repair sections using volumes less than 0.5 ft^3.

Proprietary products are primarily pre-bagged mixes to which a manufacturer-prescribed amount of water is added. The materials are formulated by the manufacturer with a prescribed water-content-to-binder ratio with a targeted strength and, as such, are rarely adjustable for other applications. Material properties are often very dependent on the prescribed water content, yet the sensitivity of the product is often unknown; i.e., if there are any deviations in the amount of water added or how the product might react to a retarding admixture. Before investigating the raw materials for development of a potentially unique MPC design, the nature of modifying existing proprietary products was investigated.

1.1 Objective

The primary objective of this research was to investigate the effects of adding boric acid as a retarder to existing commercially available MPC products on fundamental concrete properties. Variations in the water content were also investigated to determine the sensitivity of the products. The goal was to determine the use of boric acid as a retarder that would delay the time of setting and decrease the heat generation without compromising the fundamental fresh and hardened properties of the proprietary product. Target requirements included (1) minimum 5,000 psi compressive strength at 28 days' age, (2) minimum 500 psi flexural strength at 28 days' age, (3) approximately 60-min. setting time, (4) good bond strength, (5) adequate workability, and (6) good durability.

1.2 Research approach

Three commercially available MPC products were selected based on previous laboratory testing experience. Each product was tested to determine the sensitivity of the product to the manufacturer's water content and the effects of using boric acid on multiple properties. Initial trial batching only included early age compressive strength properties, time of setting, and temperature of the material after mixing due to the economics and logistics of testing a large range of fresh and hardened properties simultaneously. Once optimal mix designs were identified, full-scale testing was executed to determine if modifications to the proprietary products could meet applicable requirements.

2 Materials

The three single-component, water-activated proprietary MPC-based products selected for investigation were (1) PREMag MPC PGDM Cement manufactured by Premier Magnesia, (2) MasterEmaco T545 manufactured by BASF Master Builders, and (3) Pavemend TR manufactured by CeraTech Inc. The retarder admixture commercially known as Three Elephants Boric Acid manufactured by Searles Valley Minerals was used for the MasterEmaco T545 and Pavemend TR trial batches. The PreMag MPC RET product was used as the retarder for the PreMag MPC PGDM cement for potentially better compatibility with the Premier Magnesia products. All product data sheets are in Appendix A. A summary of the materials with the Concrete Material Branch (CMB) identifying serial number is shown in Table 1.

Table 1. Summary of proprietary products investigated.

Material Name	Manufacturer	CMB Serial No.
Pavemend TR	CeraTech Inc.	150121
Master Emaco T545	BASF Master Builders	150123
PreMag MPC PGDM Cement	Premier Magnesia, LLC	150125
PreMag MPC RET	Premier Magnesia, LLC	150126
Three Elephants Boric Acid	Searles Valley Minerals	150134

2.1 PreMag MPC PGDM

Premier Magnesia's PREMag MPC PGDM cement is a fully formulated, high-performance, quick-setting cement based on MPC binder chemistries. The material is activated upon the addition of water to the material. This product is formulated to be used in a wide variety of applications, including patching mixes and repair mortars.

Premier Magnesia's PREMag® MPG RET is a boric acid-based set retarder specially designed for use with MPCs. This product was used in conjunction with the PREMag MPC PGDM cement to achieve the best material compatibility.

2.2 T545

MasterEmaco T 545 is a one-component, magnesium phosphate-based mortar formulated for ambient temperatures below 85°F. This product was formerly known as the “Set 45” product manufactured by the same company. This concrete repair and anchoring material uses a chemical action for quick curing. Only water is required for mixing, but up to 60% rounded, sound aggregate can be used if extension is required. The material cures in air only, and no wet curing compounds are required. Applications for this product include roadway repair, airport runways, heavy industrial repairs, dowel bar replacement, concrete pavement joint repairs, bridge deck and highway overlays, horizontal and formed vertical or overhead repairs.

2.3 Pavemend TR

At the time of testing, Pavement TR was part of CeraTech’s family of products comprised of MgO natural-mineral-based non-traditional cementitious materials activated by water. According to the manufacturer, Pavemend TR is a rapid setting slope grade (up to 60%) structural repair mortar with a gel-like consistency suitable for troweling on horizontal and/or slopped grades and for aggregate extension. Only 3/8- or ½-in. clean-washed fractured stone up to 50% maximum by weight is recommended for aggregate extension. The product is an ideal repair material for roads and bridges, airport runways, warehouse or manufacturing facility floors, loading dock ramps, parking garages, post-tension cable repairs, form and pour projects, overlay of concrete surfaces, joint repair, pavements, etc.

2.4 Boric acid

Due to the short working times, the addition of a retarder was tested with the commercially available products to determine its effects on selected properties. Boric acid (H_3BO_3) was selected as the set retarder for this study due to its wide availability. Other retarders such as sodium tri-poly phosphate (STP) were considered but, due to the significant higher cost of this material, it was eliminated from the testing plan. The granular boric acid used in this research was manufactured by Searles Valley Minerals in Trona, CA, with a purity of 99.76%.

3 Trial Batching

3.1 PreMag MPC PGDM

Table 2 details the test matrix of trial batch proportions for the Premier Magnesia's PREMag MPC PGDM product. The influence of the variations in water content and retarding effects of boric acid indicated by compressive strength were investigated. Test parameter variations included water contents of 22% 24%, 26%, 28%, and 30% by weight of cement and boric acid addition of 0, 1%, 2%, and 3% by weight of cement. The selection of the water content range was based on the manufacturer's recommendation of 22-28 lb of water used for every 100 lb of cement. A batch size of 1,150 g of cement was selected based on the ASTM C109 batch size for a 6-cube mix (500 g) and the ASTM C191 batch size for a Vicat time of set (650 g). Only up to 3% of the retarder addition was used in efforts to prevent a significant loss of strength. The boric acid was added by a mass percentage of the 1,150 g of PGDM cement (e.g., 1% = 11.5 g boric acid).

Table 2. Test matrix for Premier Magnesia PREMag PGDM product.

Mix #	PGDM Cement (g)	Retarder (g)	Water Content (%)
1	1,150	0	22
2	1,150	0	24
3	1,150	0	26
4	1,150	0	28
5	1,150	0	30
6	1,150	11.5	22
7	1,150	11.5	24
8	1,150	11.5	26
9	1,150	11.5	28
10	1,150	11.5	30
11	1,150	23.0	22
12	1,150	23.0	24
13	1,150	23.0	26
14	1,150	23.0	28
15	1,150	23.0	30
16	1,150	34.5	22
17	1,150	34.5	24
18	1,150	34.5	26
19	1,150	34.5	28
20	1,150	34.5	30

3.1.1 Mixture proportions

Mixes of the premier magnesia PGDM product were prepared at different water and retarder contents in order to determine the effect on the compressive strength of 2-in. cubes after 24 hr. Overall, 20 mixes were attempted, but the lowest water content (22%) gave insufficient workability with all variations in the retarder amount, so specimens could not be fabricated. The details of the 16 mixture proportions and results of the compressive strengths tested in accordance with ASTM C109 are given in Table 3.

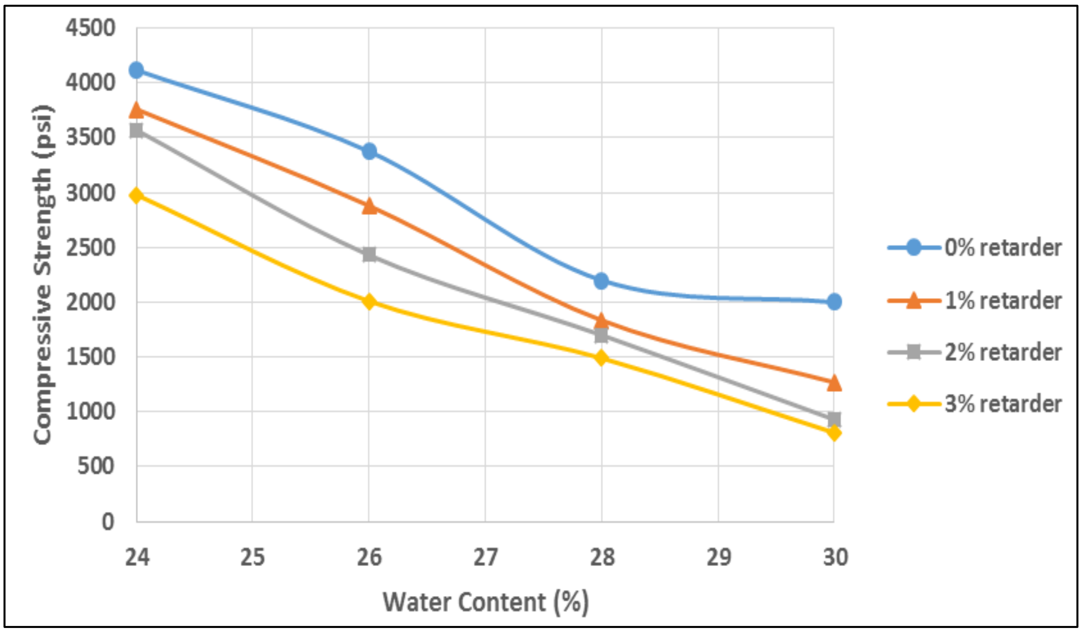
Table 3. Table of mixture proportions and properties of PGDM trial batches.

Mix ID	PGDM cement (g)	Water (mL)	Retarder (g)	Water content (%)	Retarder (%)	24-hr compressive strength (psi)
1	1,150	253	0	22	0	-
2	1,150	276	0	24	0	4,117
3	1,150	299	0	26	0	3,375
4	1,150	322	0	28	0	2,200
5	1,150	345	0	30	0	2,000
6	1,150	253	11.5	22	1	-
7	1,150	276	11.5	24	1	3,760
8	1,150	299	11.5	26	1	2,880
9	1,150	322	11.5	28	1	1,835
10	1,150	345	11.5	30	1	1,270
11	1,150	253	23	22	2	-
12	1,150	276	23	24	2	3,570
13	1,150	299	23	26	2	2,430
14	1,150	322	23	28	2	1,700
15	1,150	345	23	30	2	930
16	1,150	253	34.5	22	3	-
17	1,150	276	34.5	24	3	2,980
18	1,150	299	34.5	26	3	2,010
19	1,150	322	34.5	28	3	1,490
20	1,150	345	34.5	30	3	810

3.1.2 Compressive strength

The 24-hr compressive strengths as a function of water content and boric acid are shown in Figure 1. As the boric acid and water content increases in the mixtures, there is a concomitant drop in strength. The individual curves show the influence of the boric acid on the strength of the material. Strengths were generally reduced by approximately 1,000 psi for each 1% of boric acid. At a 24% water content, a 3% addition of boric acid reduced the compressive strength by a factor of 1.4 compared to no retarder. At the 30% maximum water content, the compressive strength with the 3%t boric acid was reduced by a factor of 2.5 compared to no retarder.

Figure 1. 24-hr compressive strength of 2-in.-cubes in the PGDM trial batches.



3.1.3 Discussion

Set times on all mixtures were attempted, but unsuccessful due to the thixatropic nature of the material. The freshly mixed cement pastes were fluid during mixing, then became very thick and viscous under static conditions prior to setting. The mixtures appeared to set. but once agitated, they became workable again. This made the attempts to determine the time of set unsuccessful. The temperature was also periodically monitored by an infrared temperature gun, and extreme exothermic heat generations (>160°F) were observed. No further testing was conducted on the PGDM products due to the uncertainty experienced in the microstructure change of this proprietary product.

3.2 T545

The test matrix shown in Table 4 details the nine mixture proportions with water content and boric acid retarder variations used during testing of the proprietary product MasterEmaco T545. The manufacturer's maximum water recommendation of 40 pints of water per 50-lb bag of T545 was used as the standard dosing of water. Deviations of 20% more and less of the recommended water were tested. In addition, 1% and 2% of the boric acid retarder was tested by dry blending the powder material into the proprietary product before adding to the water content. For each mixture, the setting time was determined using the penetrometer method in accordance to ASTM C403. Concrete cylinders for determining compressive strength were cast in 4-in. x 8-in. plastic molds and consolidated by rodding. Testing followed the procedures of ASTM C39 and were performed at 1, 7, and 28 days. The temperature of the fresh concrete was also measured in accordance to ASTM C1064.

Table 4. Test matrix for T545 product testing.

Mix #	Description	Cement	Water	Retarder
1	High water testing (+20% over standard) with no retarder	(1) 50-lb bag	5.0 lb	0% ret
2	Standard water testing (4 quarts or 4.165 lb) with no retarder *Control Mix	(1) 50-lb bag	4.2 lb	0% ret
3	Low water testing (-20% under standard) with no retarder	(1) 50-lb bag	3.3 lb	0% ret
4	High water testing (+20% over standard) with 1% retarder by weight of cement	(1) 50-lb bag	5 .0 lb	1% ret (0.5 lb)
5	Standard water testing with 1% retarder by weight of cement	(1) 50-lb bag	4.2 lb	1% ret (0.5 lb)
6	Low water testing (-20% under standard) with 1% retarder by weight of cement	(1) 50-lb bag	3.3 lb	1% ret (0.5 lb)
7	High water testing (+20% over standard) with 2% retarder by weight of cement	(1) 50-lb bag	5 .0 lb	2% ret (1.0 lb)
8	Standard water testing with no retarder with 2% retarder by weight of cement	(1) 50-lb bag	4.2 lb	2% ret (1.0 lb)
9	Low water testing (-20% under standard) with 2% retarder by weight of cement	(1) 50-lb bag	3.3 lb	2% ret (1.0 lb)

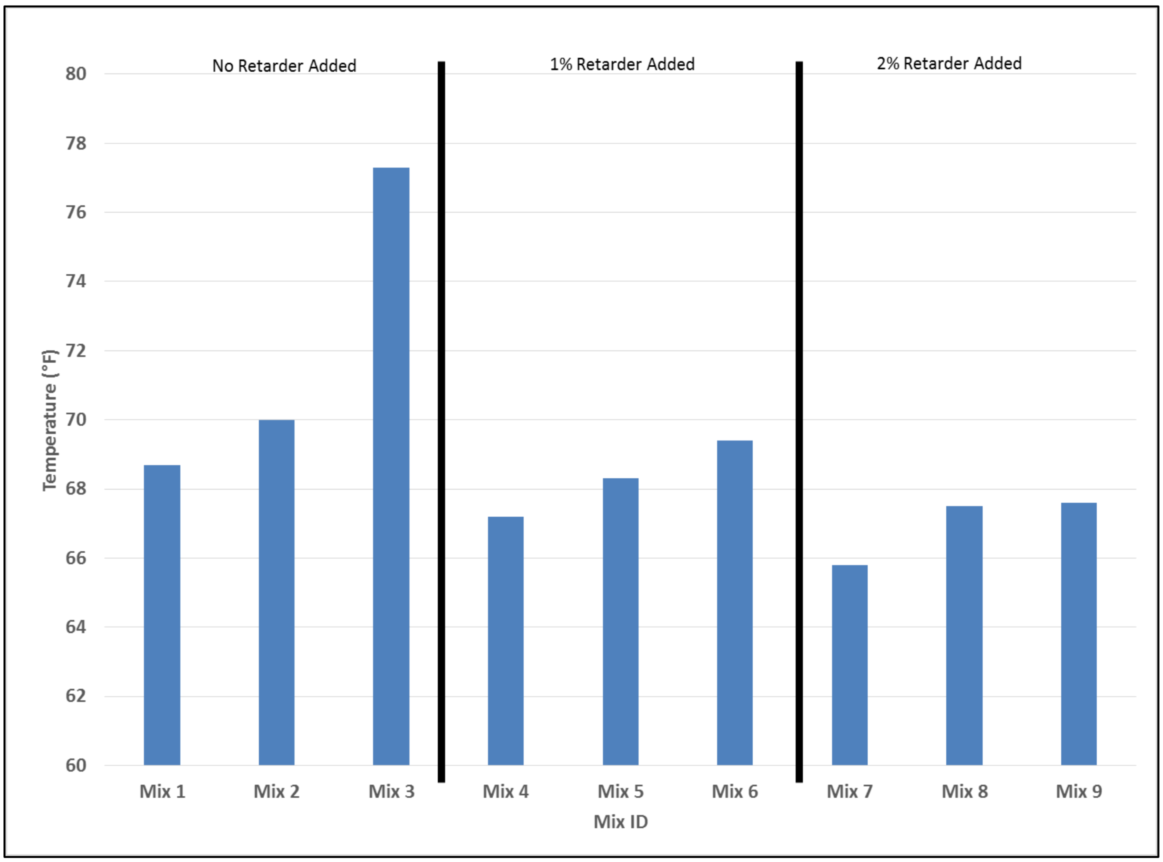
Notes:

Standard water testing is equal to 4 pints of water per 50-lb bag as recommended by the manufacturer.

3.2.1 Temperature

Temperature results based on variations in boric acid and water content of the T545 product are illustrated in Figure 2. As expected, Mix 3 with the lowest water content and 0% boric acid produced the highest temperature of 77.3°F. However, the range of temperatures (excluding Mix 3) is only 3.6°F. For any of the boric acid percentages (0%, 1%, or 2%), the mixtures with the highest dosage of water resulted in the lowest temperature when compared to mixtures at the same water content, i.e., Mix 1, 4, and 7. As the boric acid increased, the temperature decreased, but only approximately 1°F lower for each 1% increase in boric acid. This indicates that the temperature was not significantly affected by modifications to the T545 product.

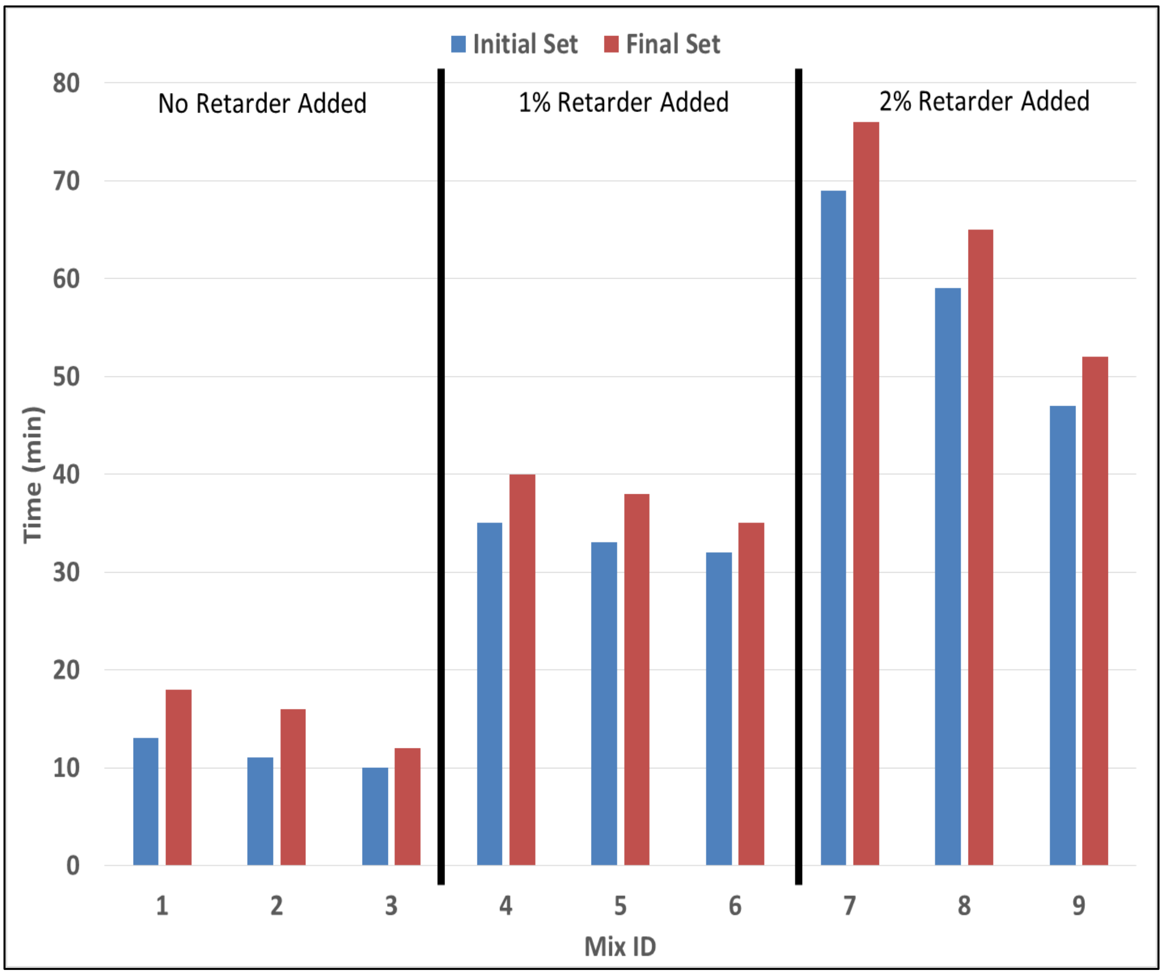
Figure 2. Initial temperatures after mixing of T545 trial batches Mix 1-9.



3.2.2 Time of setting

Time of setting is important because it strongly influences the workability, finishing, and load-carrying capacity of fresh concrete. Time of setting results based on modifications in the T545 product are illustrated in Figure 3. The dosing of the boric acid significantly affects both the initial and set time. As expected, the longest set time resulted from Mix 7, which was proportioned with the highest water content and boric acid percentage. This mix resulted in an initial set of 69 min. and final set of 76 min. The shortest set time was produced from Mix 3, which was proportioned with the lowest amount of water and no retarder. Mix 3 resulted in an initial set of 10 min. and a final set of 12 min.

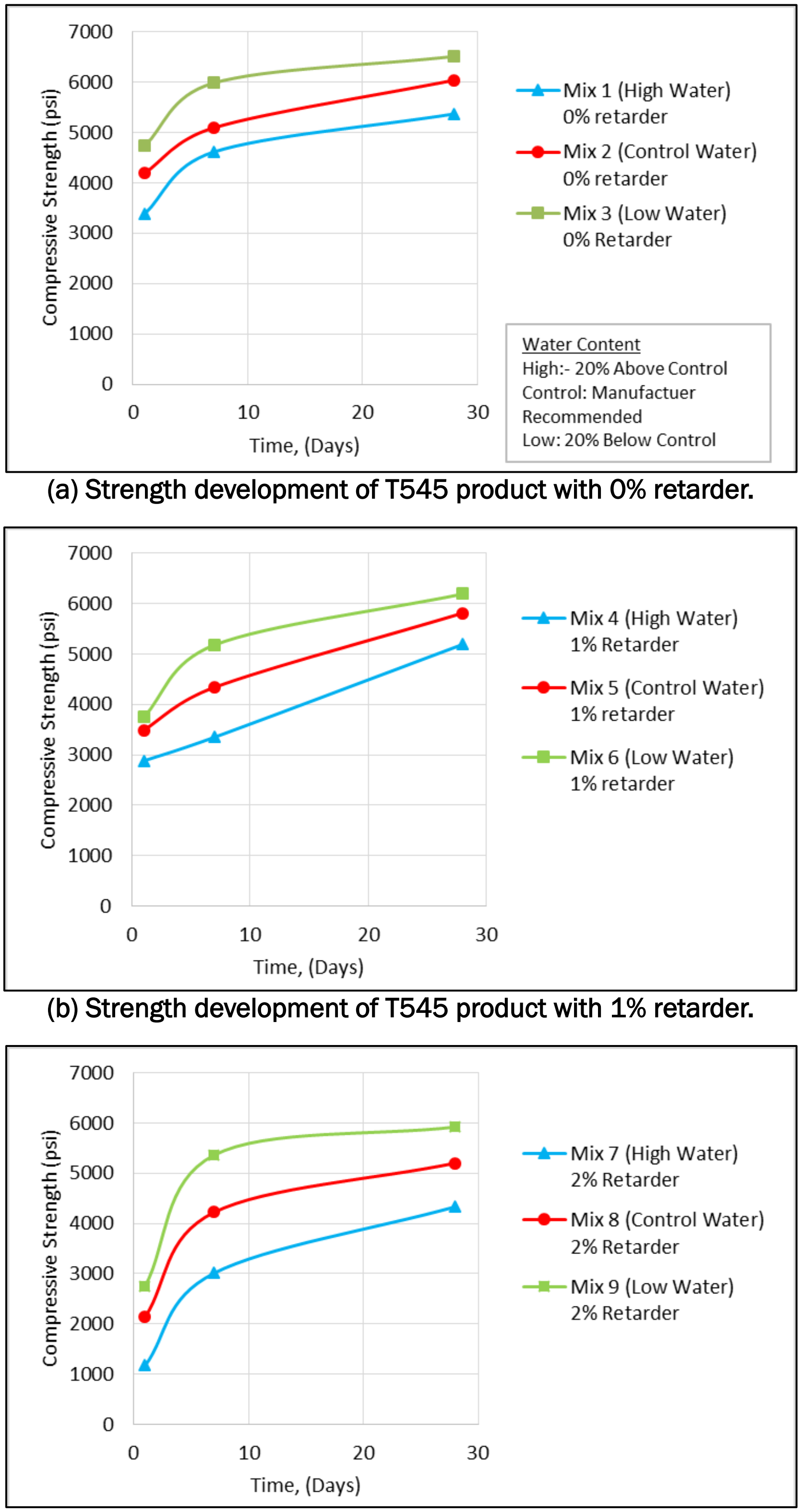
Figure 3. Results of time of setting on trial batches 1-9 of T545.



3.2.3 Compressive strength

The strength development of the T545 trial batches with variations of water content and retarder at ages of 1, 7, and 28 days are in Figure 4. As expected, the compressive strength of the T545 series had an inverse relationship with the water and boric acid content at all ages. At higher water and boric acid contents, the compressive strength decreased. Furthermore, there appeared to be a greater reduction in strength at 24 hr compared to the 28-day samples. This may be simply explained that the retarder changes the hydration properties such that a similar strength occurs later due to the retarder, and then at later ages, i.e., 28 days, the resultant strength is attained. For example, the 24-hr compressive strength of the control mixture with no boric acid and lowest water content was 4,730 psi; the strength of the T545 mixtures with the addition of boric acid at 1% and 2% were 3,750 and 2,750 psi, respectively. This is an approximate 1,000 psi strength reduction for each 1% increase of boric acid. The 28-day compressive strength of the control mixture with lowest water content was 6,510 psi; the strength of the T545 mixtures with the addition of boric acid at 1% and 2% were 6,190 and 5,920 psi, respectively. This is only a reduction of 320 psi for the 1% addition of boric acid and 590 psi for the 2% addition of boric acid. This suggests most of the compressive strength values are regained with time but are reduced at early ages with the increased boric acid. Similar patterns of strength development were comparable for each water content tested.

Figure 4. Effect of water content and boric acid on the compressive strength of T545 trial batches.



(a) Strength development of T545 product with 0% retarder.

(b) Strength development of T545 product with 1% retarder.

(c) Strength development of T545 product with 2% retarder.

3.2.4 Summary

Table 5 summarizes trial batch T1-9 results for the T545 product.

Table 5. Results of T545 Mix 1-9 trial batch variations.

Mix ID	Mixture Description	Temp. (°F)	Compressive Strength (psi)			Time of Setting (min)	
			1 day	7 day	28 day	Initial	Final
Mix 1	High water testing (+20% over standard) with no retarder	68.7	3,380	4,610	5,370	10	15
Mix 2	Control Mix Standard water testing with no retarder	70	4,190	5,090	6,040	11	16
Mix 3	Low water testing (-20% under standard) with no retarder	77.3	4,730	5,980	6,510	7	12
Mix 4	High water testing (+20% over standard) with 1% retarder	65.8	2,880	3,350	5,190	33	39
Mix 5	Standard control water testing with 1% retarder	67.5	3,490	4,340	5,810	32	38
Mix 6	Low water testing (-20% under standard) with 1% retarder	67.6	3,750	5,180	6,190	35	41
Mix 7	High water testing (+20% over standard) with 2% retarder	67.2	1,170	3,010	4,330	69	76
Mix 8	Standard water testing with 2% retarder	68.3	2,140	4,220	5,200	59	65
Mix 9	Low water testing (-20% under standard) with 2% retarder	69.4	2,750	5,360	5,920	44	52

Notes:

[1]Compressive strength performed in accordance to ASTM C39 using 4-in. x 8-in. cylinders. The results provided are an average of a minimum of three specimen.

[2] Time of setting performed using the penetrometer method in accordance to ASTM C430.

[3]Standard (control) water testing was defined by the manufacturer recommended water content of 4 pints of water per 50-lb bag.

3.3 Pavemend TR

Mixture proportions for the Pavemend TR product are detailed in Table 6. These mixes were numbered mix 10-18 continuing from the sequence of mix 1-9 of the MasterEmaco T545 product. The manufacturer's maximum water recommendation of 1 gal of water per 47-lb bag of Pavemend TR was used as the standard dosing of water. Similar to the T545 trial batch variations, deviations of 20% more and less of the recommended water were tested. In addition, 1%-2% of the boric acid retarder was tested by dry blending the powder material into the proprietary product before adding to the water content. For each mixture, the setting time was determined using the penetrometer method in accordance to ASTM C403. Concrete cylinders for determining compressive strength were cast in 4-in. x 8-in. plastic molds and consolidated by rodding. Tests followed the procedures of ASTM C39 and were performed at 1, 7, and 28 days. The fresh concrete temperature was also measured in accordance with ASTM C1064.

Table 6. Test matrix for Pavemend TR product.

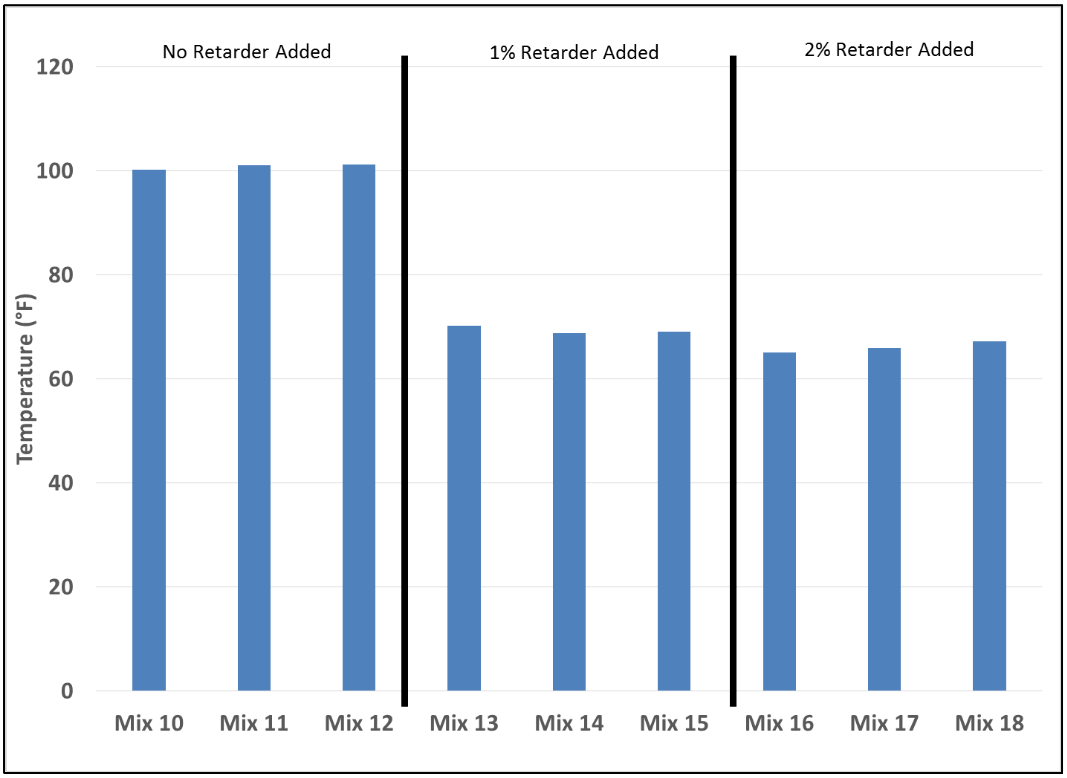
Mix #	Description	Cement	Water	Retarder
10	High water testing (+20% over standard) with no retarder	(1) 47-lb bag	10.0 lb	0% ret
11	Standard water testing (1 gal or 8.3 lb) with no retarder *Control Mix	(1) 47-lb bag	8.3 lb	0% ret
12	Low water testing (-20% under standard) with no retarder	(1) 47-lb bag	6.7 lb	0% ret
13	High water testing (+20% over standard) with 1% retarder by weight of cement	(1) 47-lb bag	10.0 lb	1% ret (0.47 lb)
14	Standard water testing with 1% retarder by weight of cement	(1) 47-lb bag	8.3 lb	1% ret (0.47 lb)
15	Low water testing (-20% under standard) with 1% retarder by weight of cement	(1) 47-lb bag	6.7 lb	1% ret (0.47 lb)
16	High water testing (+20% over standard) with 2% retarder by weight of cement	(1) 47-lb bag	10.0 lb	2% ret (0.94 lb)
17	Standard water testing with no retarder with 2% retarder by weight of cement	(1) 47-lb bag	8.3 lb	2% ret (0.94 lb)
18	Low water testing (-20% under standard) with 2% retarder by weight of cement	(1) 47-lb bag	6.7 lb	2% ret (0.94 lb)

Notes:
Standard water testing is equal to 1 gal of water per 47-lb bag as recommended by the manufacturer.

3.3.1 Temperature

Temperature results based on variations in boric acid and water content of the Pavemend TR product are illustrated in Figure 5. Note that highly exothermic temperatures (100.4°F average) were observed in the mixtures with no boric acid (Mix 10, 11, and 12). Minimal temperature differences are observed as the water content is varied within each boric acid variable group. With the addition of 1% boric acid, about 30°F decrease in temperature is observed. The addition of an additional 1% of boric acid dropped the temperature by approximate 3°F.

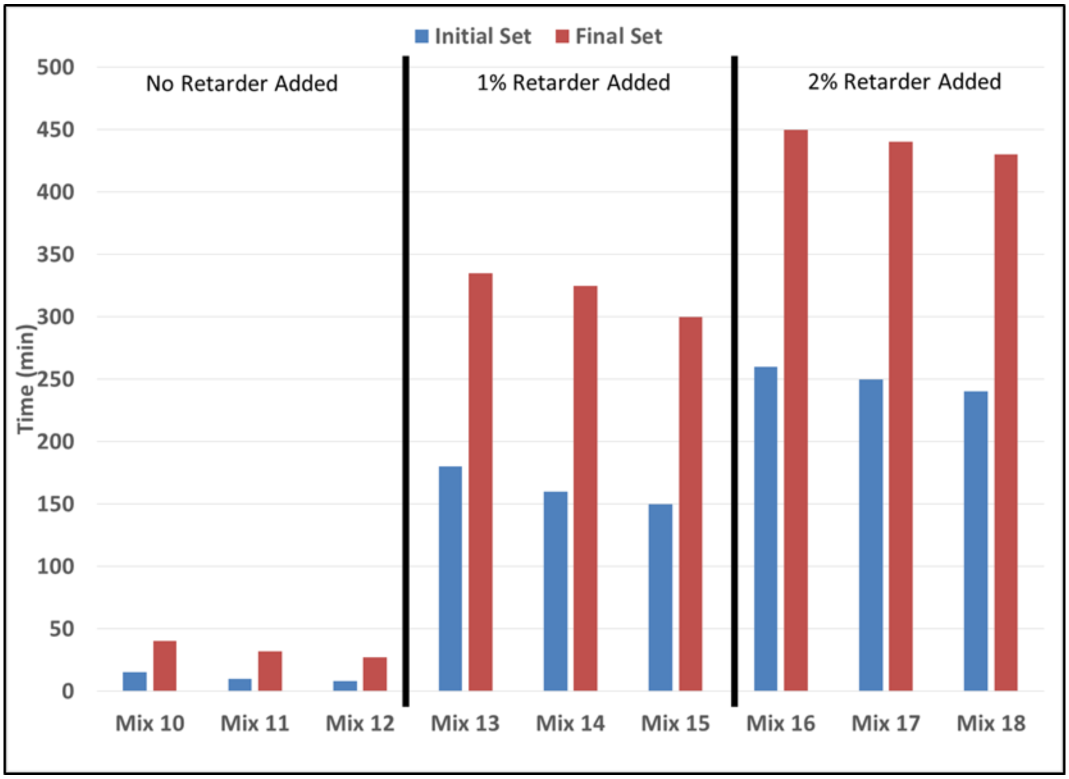
Figure 5. Initial temperature after mixing of T545 trial batches Mix 1-9.



3.3.2 Time of setting

Time of setting results based on modifications in the Pavemend TR product are illustrated in Figure 6. The boric acid increased the setting time significantly, particularly when compared to the T545 results. As expected, the shortest set time was produced from Mix 12, which was proportioned with the lowest amount of water and no retarder. Mix 12 resulted in an initial set of 8 min. and a final setting time of 27 min. The longest set time resulted from Mix 16, which was proportioned with the highest water content and boric acid percentages. Mix 16 resulted in an initial set of 260 min. and final setting time of 450 min.

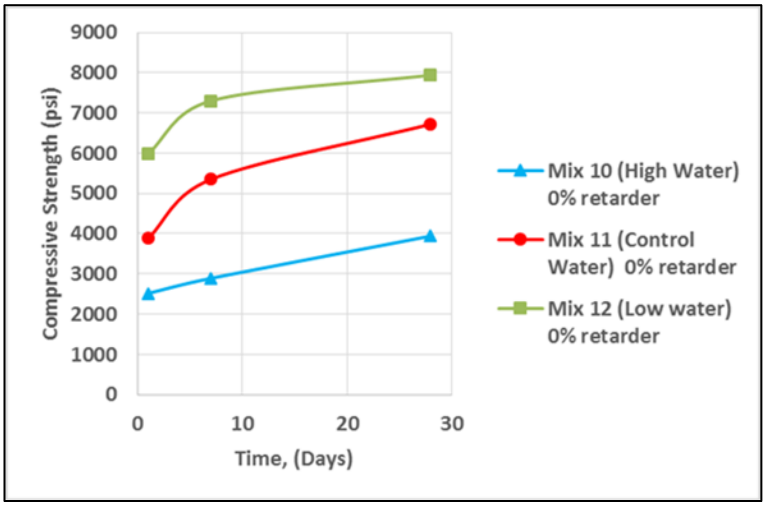
Figure 6. Time of setting results from trial batches 10-18 for Pavemend TR.



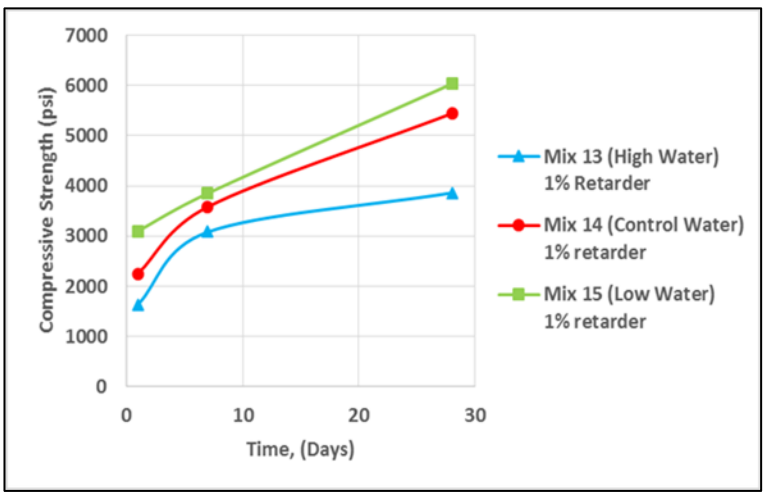
3.3.3 Compressive strength

The strength development of the Pavemend trial batches with variations of water content and retarder at the age of 1, 7, and 28 days are shown in Figure 7. As expected, higher water content in the mixtures resulted in lower strength development. The boric acid retarder did greatly influence the compressive strength of Pavement TR. The strength reduction was most noticeable at early ages (1 day). For example, strengths decreased almost 50% with 1% boric acid and almost 90% with 2% boric acid with mixtures at the lowest water content (Mix 12, Mix 15, and Mix 18). For the same mixtures, results also show the strengths were not recovered by 28 days when compared to the control mixture. At 28 days, the strength with 1% boric acid was approximately 2,000 psi less with 1% boric acid and approximately 3,500 psi less with 2% boric acid.

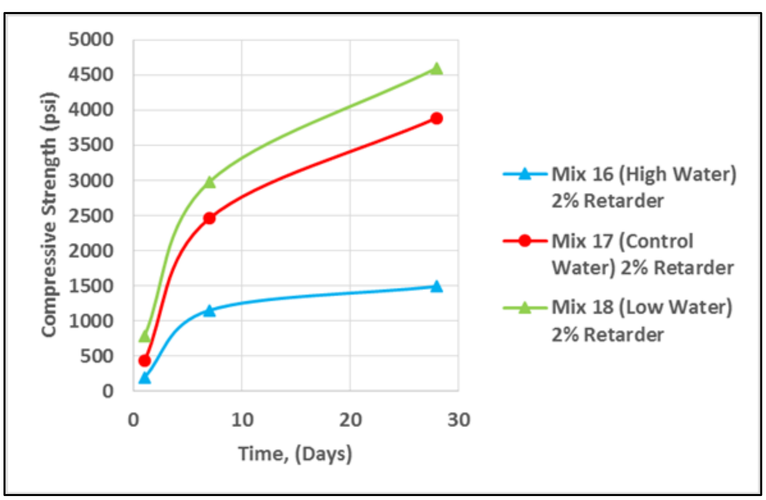
Figure 7. Effect of water content and boric acid on the compressive strength of Pavemend TR trial batches.



(a) Strength development of Pavemend TR product with 0% retarder.



(b) Strength development of Pavemend TR product with 1% retarder.



(c) Strength development of Pavemend TR product with 2% retarder.

3.3.4 Summary

Results of the effect of the addition of water and boric acid retarder on the temperature, compressive strength, and time of setting for the Pavemend TR product are shown in Table 7.

Table 7. Results of Pavemend TR Mix 10-18 trial batch variations.

Mix ID	Mixture Description	Temp. (°F)	[1]Compressive Strength (psi)			[2]Time of Setting (min)	
		Initial	1 day	7 day	28 day	Initial	Final
Mix 10	High water testing (+20% over standard) with no retarder	100.1	2,517	2,890	3,940	15	40
Mix 11	Control Mix [3]Standard water testing with no retarder	101.1	3,890	5,350	6,720	10	32
Mix 12	Low water testing (-20% under standard) with no retarder	100.1	5,990	7,300	7,940	8	27
Mix 13	High water testing (+20% over standard) with 1% retarder	69.1	1,637	3,080	3,860	180	335
Mix 14	Standard water testing with 1% retarder	68.8	2,250	3,580	5,440	160	325
Mix 15	Low water testing (-20% under standard) with 1% retarder	70.3	3,100	4,850	6,030	150	300
Mix 16	High water testing (+20% over standard) with 2% retarder	65.1	197	1,150	1,490	260	450
Mix 17	Standard water testing with no retarder with 2% retarder	65.9	430	2,460	3,890	250	440
Mix 18	Low water testing (-20% under standard) with 2% retarder	67.3	780	2,980	4,600	240	430

Notes:

[1] Compressive strength performed in accordance to ASTM C39 using 4-in. x 8-in. cylinders. The results provided are an average of a minimum of three specimen.

[2] Time of setting performed using the penetrometer method in accordance to ASTM C430.

[3]Standard water testing defined by manufacturer recommended water content of 1 gal of water per 47-lb bag of Pavemend TR material.

4 Full-Scale Laboratory Testing

4.1 Methodology

Based on the results of the trial batch mixtures of T545 and Pavemend TR, the following three mixture proportions were selected for full-scale testing, i.e., (1) control mix with no modifications from manufacturer's recommendation, (2) addition of 1% boric acid and standard water content, and (3) addition of 1% boric acid and 20% reduction of standard water content. The mixture identifications selected for the T545 and Pavemend TR trial batches are in Table 8. All mixtures were extended 50% with a 3/8-in. pea gravel from a local source.

Table 8. Summary of modifications to products T545 and Pavement TR by Mixture ID.

T545	Pavemend TR	Description of Mix
Mix 2	Mix 11	Control mix with no modifications from the manufacturer's recommendations
Mix 5	Mix 14	Addition of 1% boric acid by mass of cement with standard manufacturer's water content
Mix 6	Mix 15	Addition of 1% boric acid and 20% less water than standard manufacturer's water content

The performance measures for comparing the T545 and Pavemend TR mixtures included compressive strength, flexural strength, bond strength, splitting tensile, modulus of elasticity, coefficient of thermal expansion, length change, time of setting, and freeze-thaw durability. Table 9 summarizes the experimental test methods for the mixtures selected for full-scale testing.

Table 9. Test matrix for full-scale laboratory testing.

Test Property	Testing Specification	Testing Details
Compressive Strength	ASTM C39	1 day
		7 day
		28 day
Flexural Strength	ASTM C78	28 day
Splitting Tensile	ASTM C496	28 day
Bond Strength (RS/RS)	ASTM C882	1 day
		7 day
Bond Strength (RS/PCC)	ASTM C882	1 day
		7 day
Modulus of Elasticity	ASTM C469	28 day
Time of Setting	ASTM C403	Initial Set
		Final Set
Slump	ASTM C143	-
Length Change	ASTM C157	Air and Water Cure
Coefficient of Thermal Expansion	ASTM C531	-
Freeze-Thaw	ASTM C666	Procedure A

4.2 Results and discussion

Complete results of all laboratory testing is provided in Table 10 followed by additional discussion for each test method.

Table 10. Results of full scale testing for T545 and Pavemend TR.

Property	Testing Specification	Testing Details	T545			Pavemend TR		
			Mix 2	Mix 5	Mix 6	Mix 11	Mix 14	Mix 15
Compressive Strength (psi)	ASTM C39	1 day	4,190	3,490	4,750	3,890	2,250	3,100
		7 day	5,090	4,340	5,360	4,350	3,580	3,640
		28 day	6,040	5,810	6,190	5,220	4,630	4,710
Flexural Strength (psi)	ASTM C78	28 day	610	555	655	560	480	585
Splitting Tensile (psi)	ASTM C496	28 day	550	540	560	440	430	490
Bond Strength (psi) (RS/RS)	ASTM C882	1 day	1,600	1,150	1,450	1,560	950	1,120
		7 day	1,780	1,390	1,660	1,770	1,330	1,610
Bond Strength (psi) (RS/PCC)		1 day	1,240	1,010	1,050	1,790	600	1,030
		7 day	1,530	1,290	1,340	1,920	1,060	1,310
Modulus of Elasticity (ksi)	ASTM C469	28 day	5350	4650	5200	4650	3650	3700
Time of Setting (min)	ASTM C403	Initial	11	38	32	10	160	150
		Final	16	41	35	32	325	300
Slump (inch)	ASTM C143	-	7	7	4	11	11	6
Length Change (%) Water Cure	ASTM C157	28 day	0.025	0.042	0.036	0.0315	0.0483	0.0355
		64 weeks	0.040	0.055	0.053	0.055	0.076	0.063
Length Change (%) Air Cure		28 day	0.013	0.026	0.015	0.019	0.027	0.022
		64 weeks	-0.003	0.012	0.005	0.008	0.019	0.013
Coefficient of Thermal Expansion	ASTM C531	-	7.2	6.5	8.1	7.2	6.3	8.5
Freeze-Thaw	ASTM C666	Method A	DF 18 @ 78 cycles	DF 9 @ 44 cycles	DF 16 @ 55 cycles	DF 10 @ 69 cycles	DF 5 @ 32 cycles	DF 11 @ 43 cycles

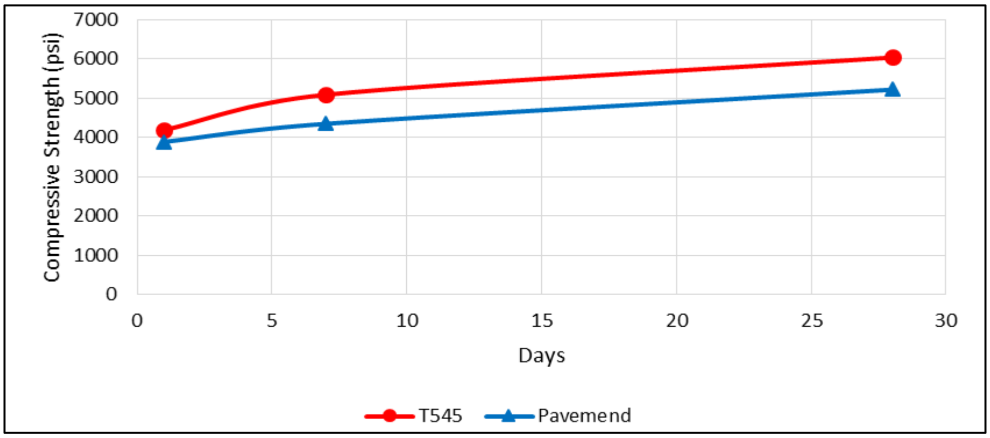
4.2.1 Compressive strength

Compressive strength testing was performed on all mixes in accordance with ASTM C39 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." For each mix, nine 4-in. x 8-in. concrete cylinder specimens were prepared by the rodding method. The strength tests were obtained for samples at 1, 7, and 28 days (3 cylinders at each age). The average compressive strength data are shown in Figure 8.

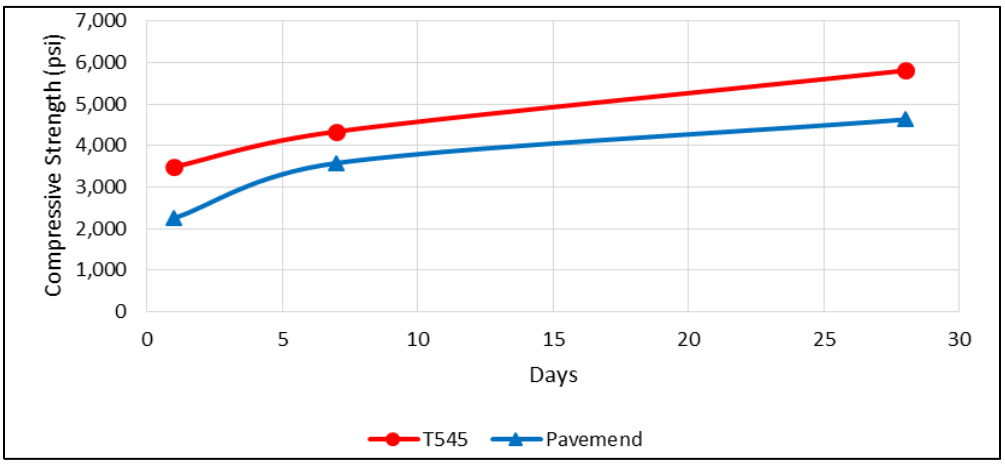
Overall, the T545 product resulted in slightly higher compressive strengths compared to the Pavemend TR product on all mixture variations. For the T545 product, the 1% addition of boric acid was shown to significantly affect the early 1- and 7-day strengths but gained similar strengths by 28 days. Somewhat surprisingly, when the water was reduced 20% with the 1% boric acid in Mix 6, all strengths increased when compared to the control Mix 2. This indicated that the water content was the controlling factor for T545. This effect was not observed in the Pavemend TR product. Strengths were much lower with the 1% boric acid retarder at all ages and not recovered with the 20% water reduction.

The target compressive strength requirement was a minimum of 5,000 psi at 28 days. All T545 mixes exceeded this requirement, while only the control mixture reached the target compressive strength requirement for the Pavemend TR product.

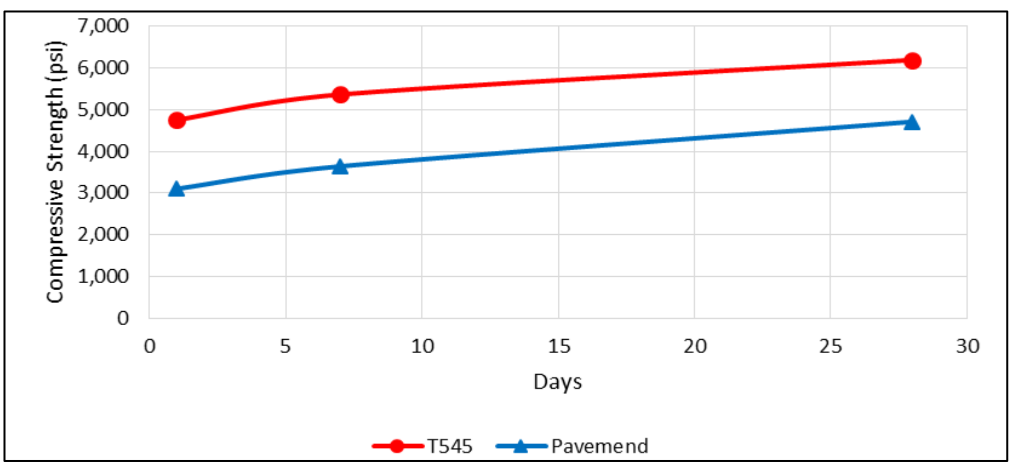
Figure 8. Effect of boric acid and water content on the compressive strength of T545 and Pavemend TR.



(a) Control.



(b) 1% boric acid.

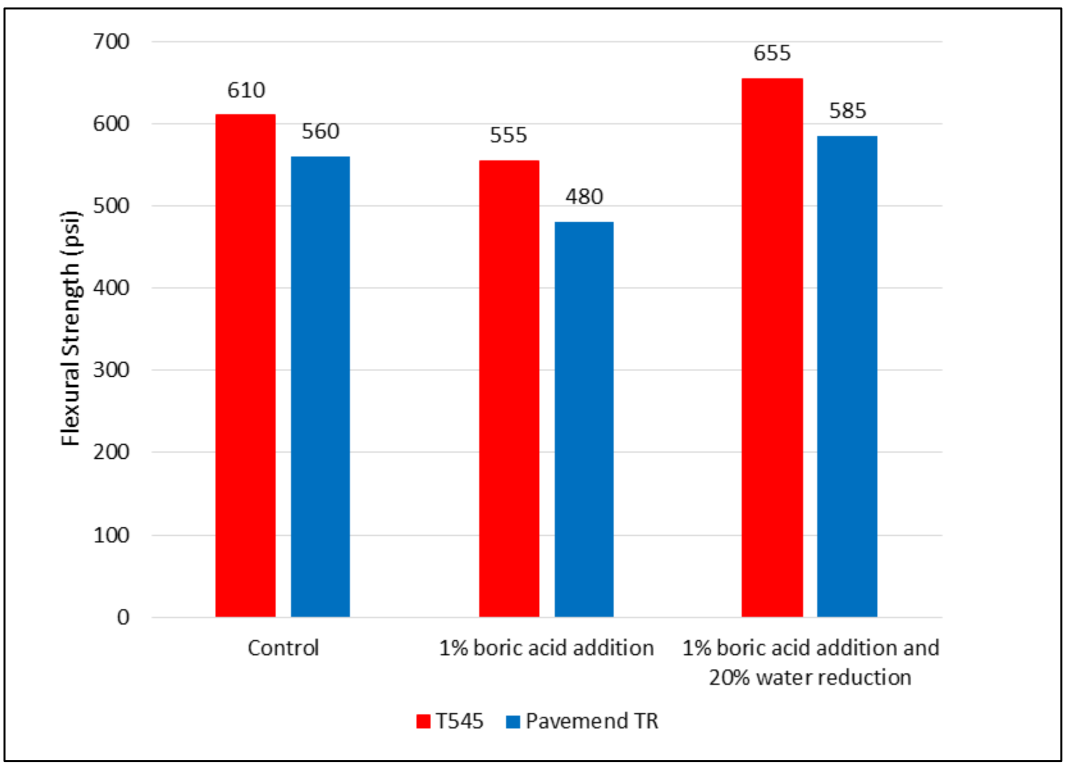


(c) 1% boric acid addition and 20% water reduction.

4.2.2 Flexural strength

Flexural strength tests were performed in accordance to ASTM C78 “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).” The triplicate test specimens were rectangular beams with dimensions of 3 in. × 3 in. × 12 in. with loading applied at third-points of the span. Figure 9 compares the 28-day flexural strength for mixture modifications to the T545 and Pavemend TR products. The 1% addition of boric acid reduced the flexural strength by 9% and 14% for the T545 and Pavemend TR products, respectively. However, when the water is reduced by 20%, the flexural strength increases over the control by 7% and 4% for the T545 and Pavement TR products, respectively. This suggests there is some reduction in flexural strength using boric acid, but it can be compensated for by decreasing the water in both products. The target flexural strength requirement was a minimum of 500 psi at 28 days. All T545 mixes exceeded this requirement, and only the mixture with 1% boric acid failed for the Pavemend TR product.

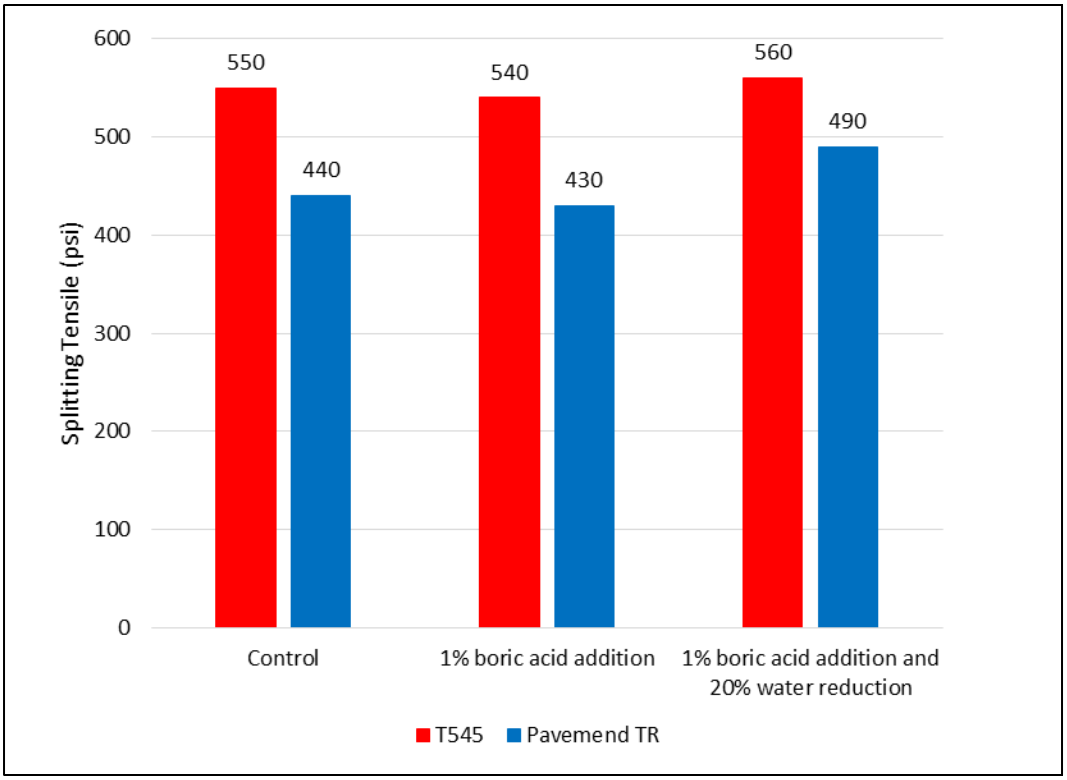
Figure 9. Comparison of 28 day flexural strengths for T545 and Pavemend TR.



4.2.3 Splitting tensile strength

The splitting tensile testing was accomplished in accordance with ASTM C496 “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.” Results of the average of triplicate 4-in. × 8-in. cylinders at 28 days are shown in Figure 10. The addition of 1% boric acid reduced the splitting tensile strength by 10 psi in both products. When the water was reduced 20% in addition to the 1% boric acid, the splitting tensile strength exceeded the control mixture in both products. This indicates that, while the 1% addition of boric acid slightly reduces the 28-day splitting tensile strength, it can be compensated for by reducing the water by 20%. Overall, the splitting tensile was not significantly affected by the boric acid or deviations in the water content. In all mixtures, the T545 outperformed the Pavemend TR product.

Figure 10. Comparison of 28-day splitting tensile strength in T545 and Pavemend TR.

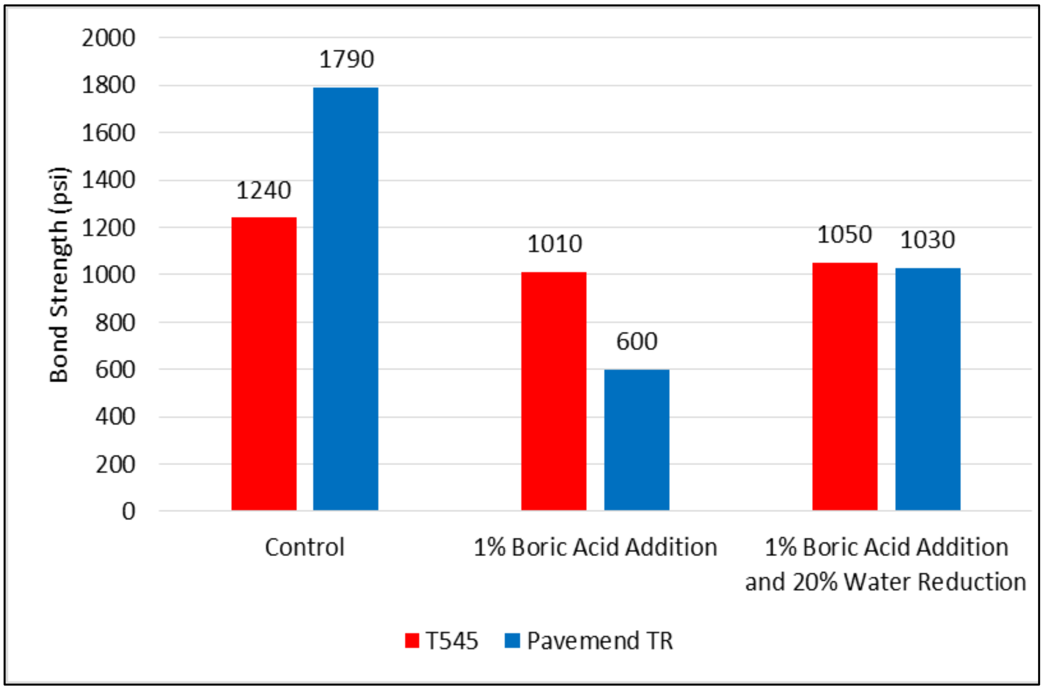


4.2.4 Bond strength

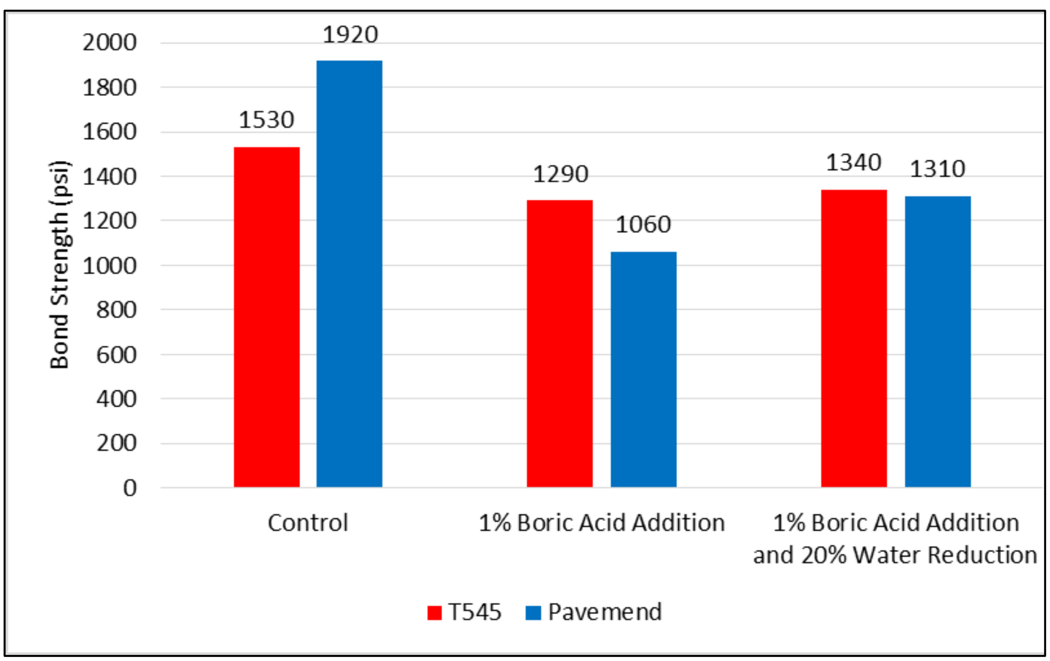
Bond strength tests were performed in accordance to ASTM C882 “Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear.” Triplicate slant shear 3-in x 6-in specimens were cast for each test age. Both repair slant to repair slant (RS/RS) and repair slant to portland cement concrete (RS/PCC) were tested at 1 and 7 days as illustrated in Figure 11 and Figure 12. Pavemend TR resulted in higher strengths compared to T545 for the PCC/RS control mixes. Results were comparable between the two products for the RS/RS bond strengths. For the PCC/RS bond strengths, both products were significantly affected by the 1% boric acid addition. For example, the 1-day PCC/RS bond strength of the Pavemend TR product was almost 3 times lower compared to the control. At 7 days, the PCC/RS bond strength was still almost half the control. Decreasing the water 20% compensated for some of the strength reduction, but it was not fully recovered at 7 days. Interestingly, the T545 product outperformed the Pavemend TR in all the modified mixes. This indicates that bond strength of the Pavemend TR product is more sensitive to the boric acid and changes in the water content. It is also of interest to note that the PCC/RS bond strengths were more affected by the modifications than the RS/RS bond strengths. This suggests the modified materials will not bond well to the parent substrate.

ASTM C928 provides minimum performance requirements for this test of 1,000 psi at 1 day and 1,500 psi at 7 days for cementitious, rapid-setting materials. Based on this criteria, all 1 day PCC/RS and RS/RS bond strengths met the target requirement with the exception of the Pavemend TR with 1% boric acid. Both the T545 and Pavemend TR with 1% boric acid RS/RS and PCC/RS failed the 7 day requirement. In addition, the PCC/RS Pavemend TR and T545 with 1% boric acid and 20% reduced water failed the 7-day requirement.

Figure 11. Comparison of bond strengths for portland cement concrete (PCC) material to repair slant (RS) material at 1 and 7 days.

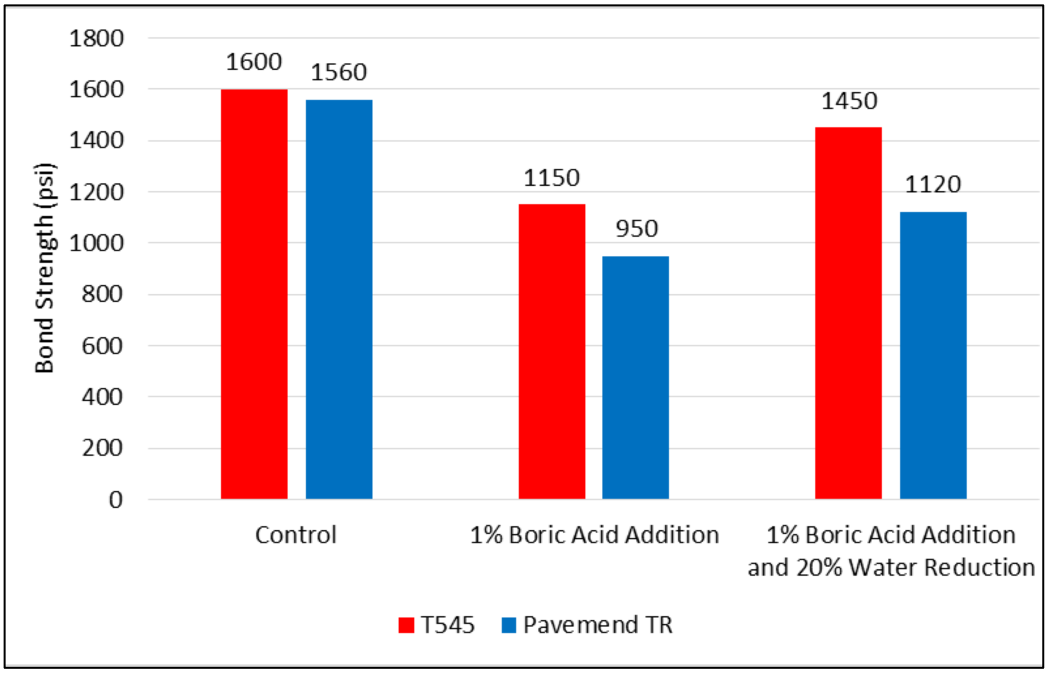


(a) PCC/RS at 1 day.

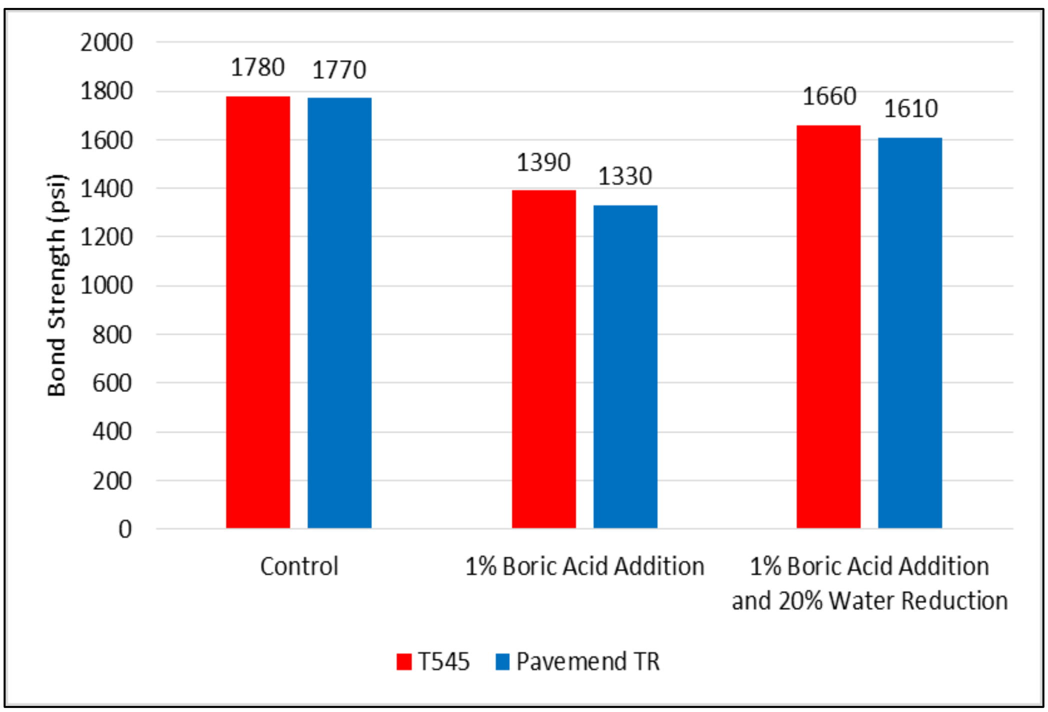


(b) PCC/RS at 7 days.

Figure 12. Comparison of bond strengths for repair slant (RS) material to repair slant (RS) material at 1 and 7 days.



(a) RS/RS 1 day.

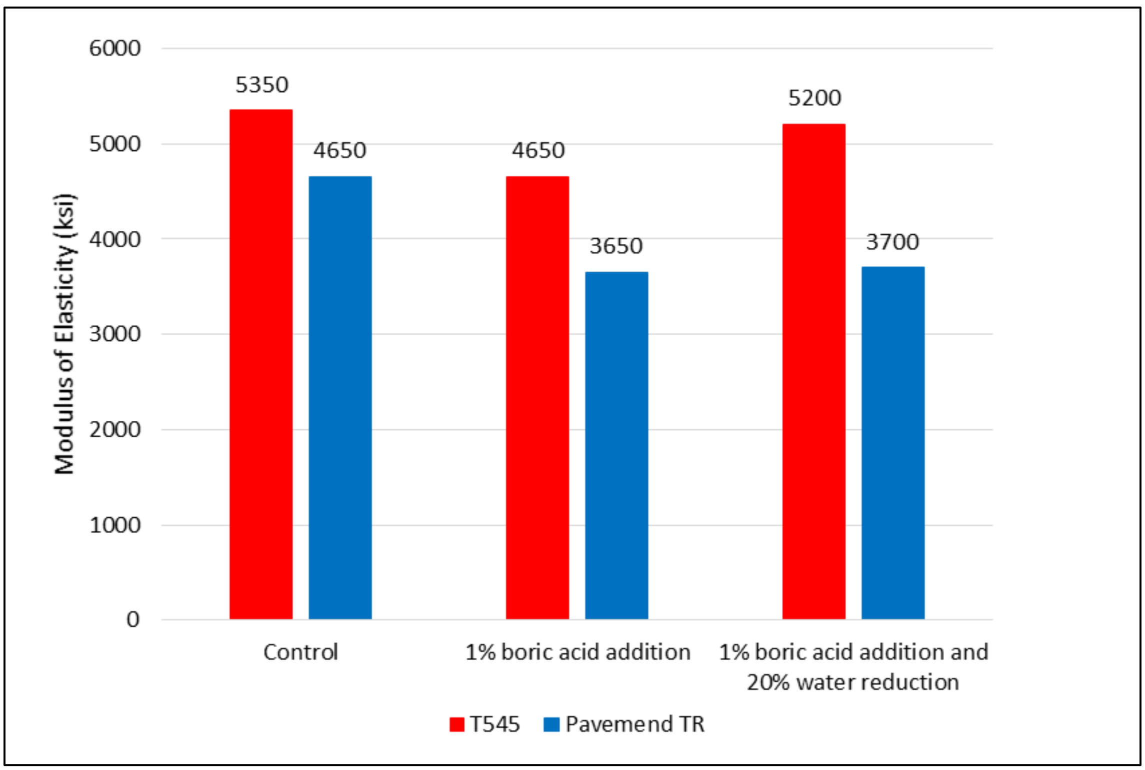


(b) RS/RS at 7 days.

4.2.5 Modulus of elasticity

Modulus of elasticity (MOE) testing was accomplished in accordance with ASTM C469 "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression." Triplicate 4-in. x 8-in. cylinders instrumented with an unbounded sensing device were attached to the cylinders at mid-height for the purpose of measuring vertical deformation. The modulus of elasticity was calculated as change in stress divided by change in strain, where strain is calculated as vertical deformation divided by gauge length. A comparison of the T545 and Pavemend TR product's MOE at 28 days is illustrated in Figure 13. Overall, the T545 product performed better than the Pavemend TR product. Adding 1% boric acid to the Pavemend TR product reduced the 28-day results by 1,000 psi with minimal improvement when the water content was reduced 20%. The T545 product also showed a reduction in the 28-day MOE with the 1% boric acid addition but recovered significantly when the water was reduced 20%. Once again, this indicates the Pavemend TR is more sensitive to any modification to the manufacturer's recommendations.

Figure 13. Comparison of 28-day modulus of elasticity for T545 and Pavemend TR.

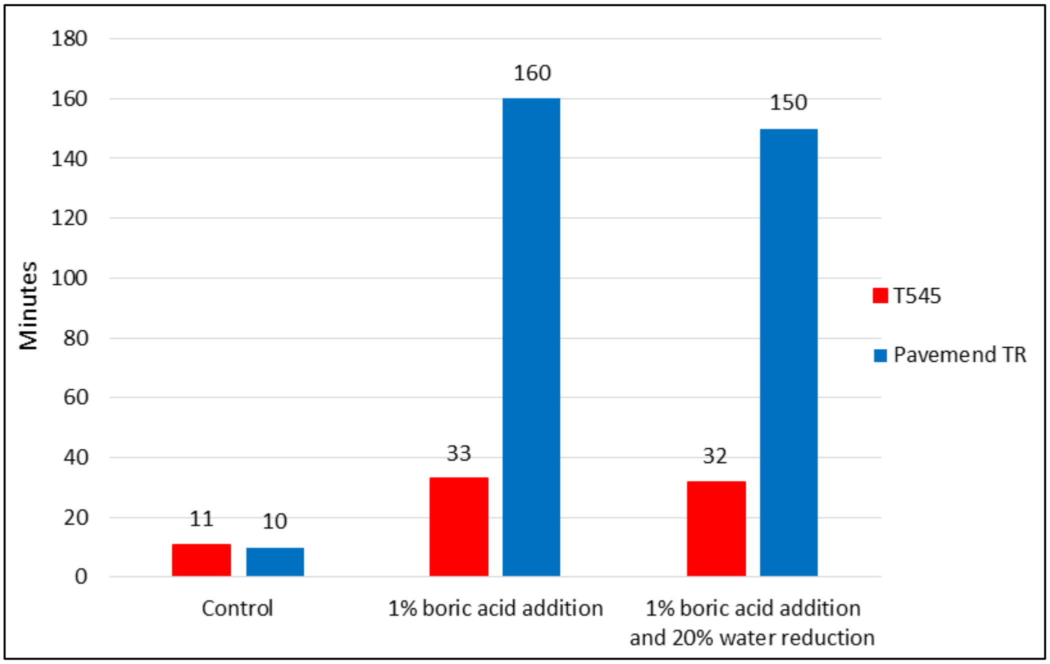


4.2.6 Time of setting

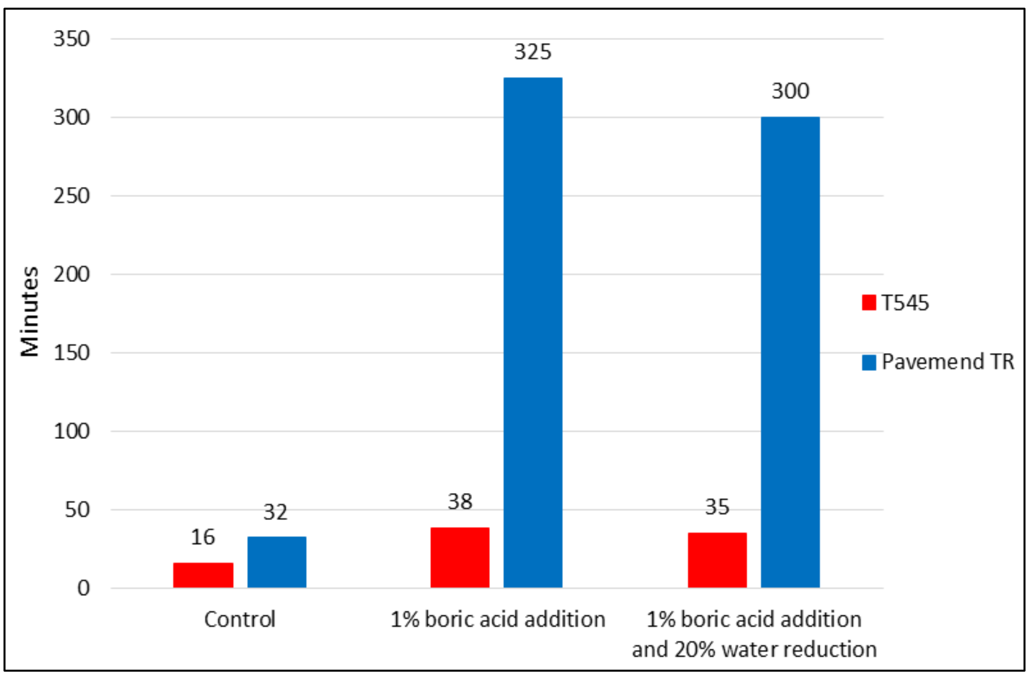
The time of setting was accomplished in accordance to ASTM C403 "Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance." Periodic penetration tests were performed using a penetrometer with an analog gauge by inserting a standardized needle of known surface area into the fresh concrete material and recording the resistance force. The penetration resistance (in psi) was calculated by dividing the recorded force (in pounds) by the bearing area of the needle (in square inches). The initial time of setting was the time elapsed between the initial contact of cement and water and the time when the penetration resistance equaled 500 psi. The final time of setting was reached when the penetration resistance equaled 4,000 psi.

The time of setting for the T545 and Pavemend TR mixtures are shown in Figure 14. The addition of boric acid is interpreted to more significantly affect the Pavemend TR as compared to the T545 product. For the Pavemend TR product, the initial time of setting increased from 10 min. in the control mix to 160 min. when 1% boric acid was added. In addition, even greater affect was shown for the final setting times, which increased from 32 min. in the control mix to 325 min. with the 1% boric acid addition. This setting time is outside of the target setting time of 60 min. and is unacceptable for rapid repair applications. For the T545 product, the initial setting time was tripled and final setting time doubled when the 1% boric acid was added. However, the maximum final setting time was 41 min., which also failed to reach the target requirement of 60 min. For both products, the 20% decrease in water reduced the setting times but only by a few minutes. It is notable to mention that only approximately 5 min. typically elapsed between the initial and final setting times for any of the T545 mixtures. This indicates a very short working time might be available during full-scale placement.

Figure 14. Time of setting for T545 and Pavemend TR products.



(a) Initial set.

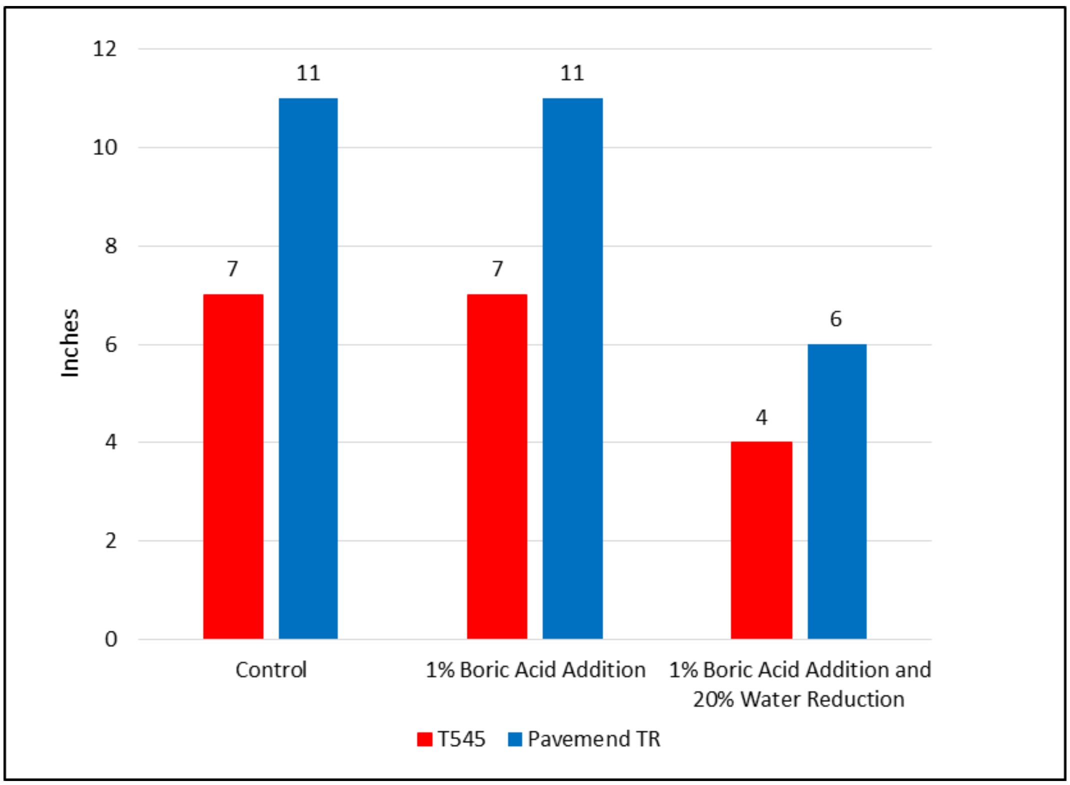


(b) Final set.

4.2.7 Slump

Adequate workability was a project requirement for the products tested. The workability was accomplished using the slump test in accordance to ASTM C143 "Standard Test Method for Slump of Hydraulic-Cement Concrete." Slump test results are illustrated in Figure 15. The control mixture slump of the T545 product was 7 in., and the Pavement TR product was 11 in. The slump was unaffected in both products by the addition of 1% boric acid. As expected, reducing the water 20% resulted in a loss of workability in both products. Pavemend TR displayed a higher slump loss of 5 in. compared to 3 in. in the T545 material. Results indicate the products still maintain adequate workability with the test modification, and water content is the controlling factor.

Figure 15. Slump comparisons for modifications to T545 and Pavemend TR products.



4.2.8 Length change

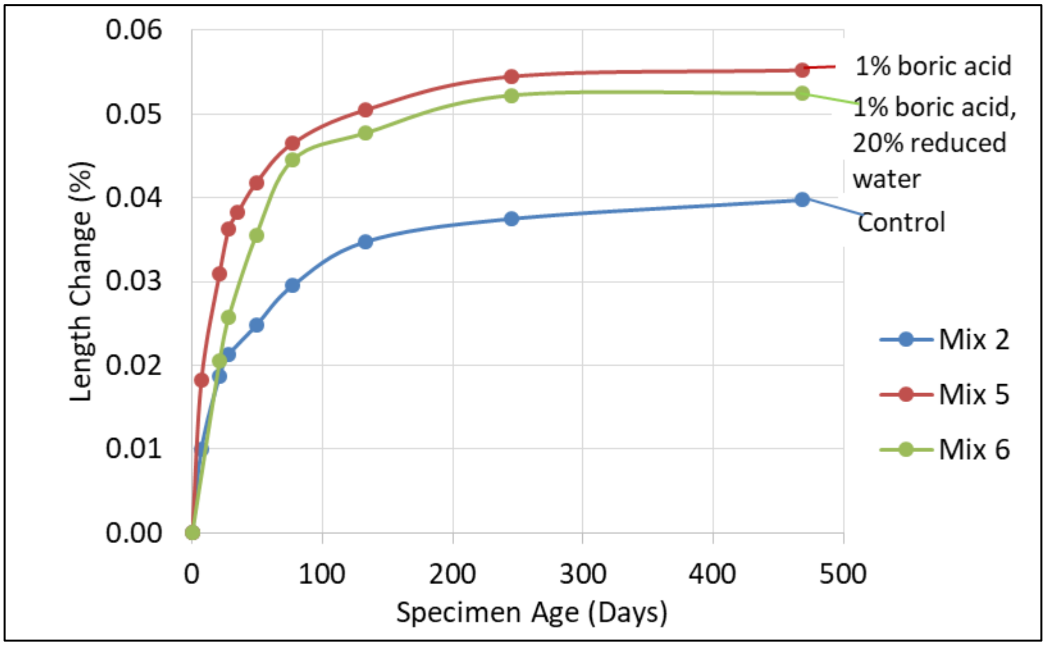
Length-change testing was accomplished in accordance with ASTM C157 procedures with both air and water storage curing. Six 3-in. x 3-in. x 11.25-in. beam specimens with embedded gauge studs were prepared from each concrete mix. Specimens were demolded at the age of 24 hr, and an initial reading was taken with a length comparator. Visible expansion was observed in the mixtures with 1% boric acid upon demolding at 24 hr as shown in the photos provided in Figure 16. The beams were then wet-cured in a 73°F lime-water bath until the age of 28 days. At this time, a zero comparator reading was taken, then the specimens were moved to their appropriate test environment. Three of the prisms specimens were re-submerged in the water bath environment until subsequent readings. The remaining three specimens were openly stored in a room maintained at 73°F and a relative humidity of 50%. Readings were taken during the air and water curing periods after 4, 7, 14, and 28 days and then at 8, 16, 32, and 64 weeks. Similar length-change trends between the T545 and Pavemend TR results are presented in Figure 17 and Figure 18. Clearly, mixtures with 1% boric acid resulted in the highest expansions and subsequently the lowest shrinkage. Mixtures with 1% boric acid and 20% less water produced results in between the control and 1% boric acid mixtures. Pavemend TR Mix 15 resulted in the largest 64-week expansion when cured in water of 0.076% and lowest shrinkage when cured in an ambient air environment of 0.019%. Overall, length-change results indicate expansions are potential concern for both products.

Figure 16. Visible expansion in prisms with 1-% boric acid at 24 hr.

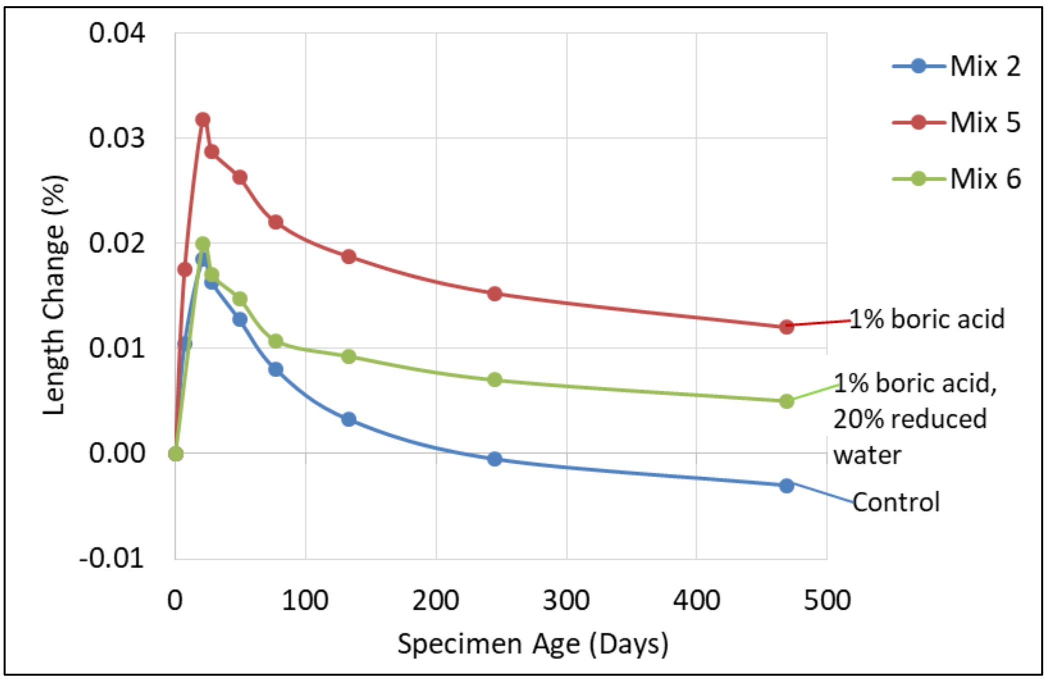
(a) T545 Mix 5.

(b) Pavemend TR Mix 15.

Figure 17. Summary of ASTM C157 average percent length change of T545.

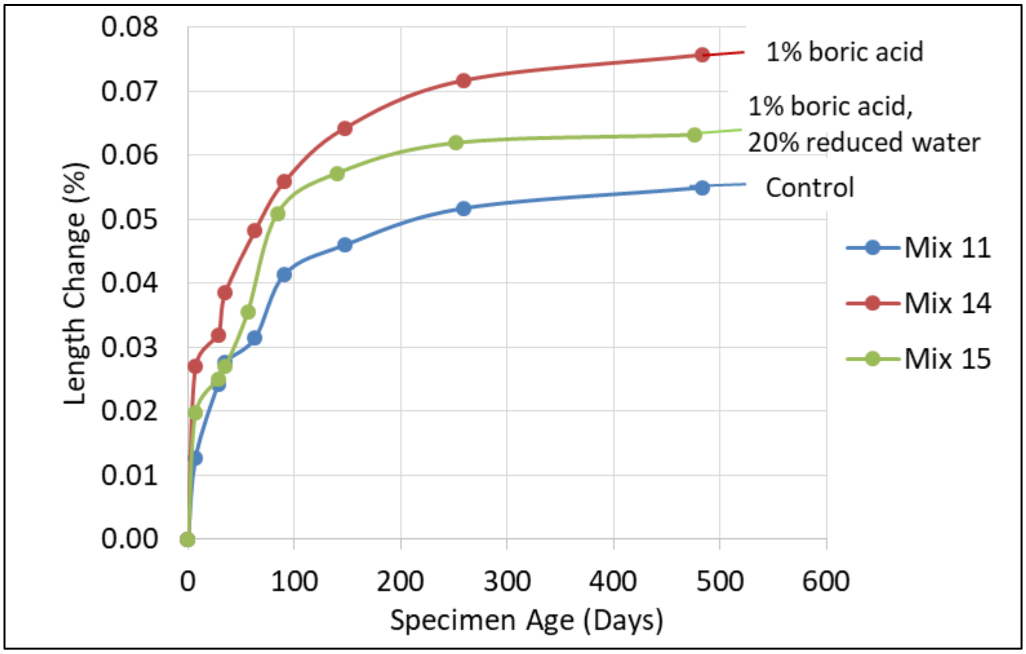


(a) Expansions of T545 specimens cured in water.

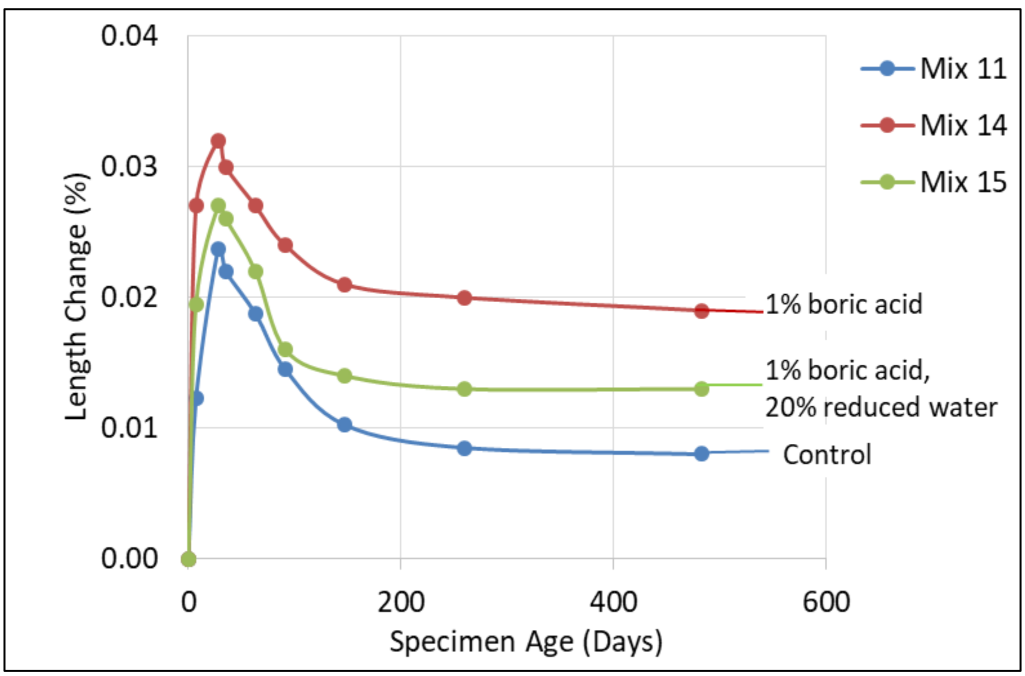


(b) Shrinkage of T545 specimens cured in air.

Figure 18. Summary of ASTM C157 length change specimens for Pavemend TR.



(a) Expansions of Pavemend TR specimens cured in water.



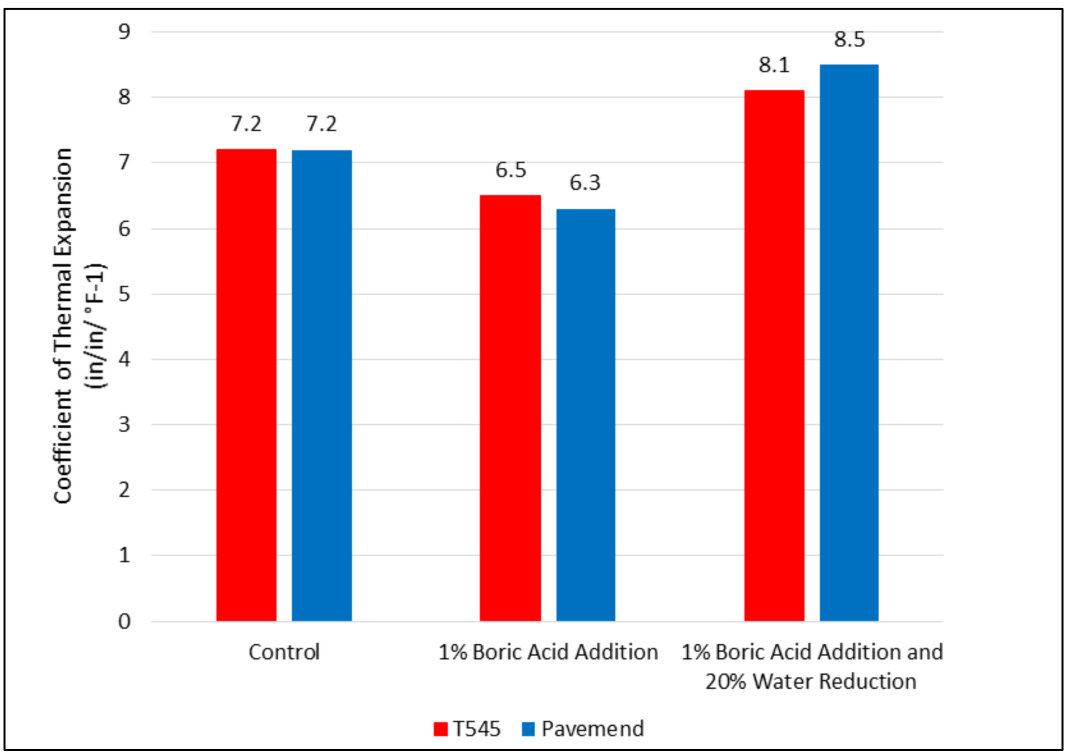
(b) Shrinkage of Pavemend TR specimens cured in air.

4.2.9 Coefficient of thermal expansion

The coefficient of thermal expansion was accomplished in accordance to ASTM C531 "Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes." Test bar specimens with dimensions of 1 in. x 1 in. x 11.25 in. with embedded gauge studs were measured daily for two weeks at 73°F to determine the length change. Test specimens then cycled between environmental conditions of 210 and 73°F until a constant CTE expansion was determined.

Figure 19 illustrates the similar CTE values for the modifications to the T545 and Pavemend TR products. Both control product mixtures showed an identical 7.2 in./in./°F value. The 1% addition of boric acid reduced the CTE value to 6.5 in./in./°F in the T545 product and to 6.3 in./in./°F in the Pavemend TR product. When the water was reduced by 20%, the CTE values increased to 8.1 in./in./°F for the T545 product and to 8.5 in./in./°F for the Pavemend TR product. These results suggest that boric acid reduces the heat generation. However, a lower water content will still increase the heat generation and control the mixture's CTE value even in the presence of the boric acid.

Figure 19. Comparison of final CTE values T545 and Pavemend TR products.



4.2.10 Freezing and thawing

The freeze-thaw resistance testing was accomplished in accordance with ASTM C666 Procedure A. Test specimens with dimensions of 3 in. × 4 in. × 16 in. were moist-cured for 14 days before testing, then subjected to freeze-thaw cycles until failure (60% loss in dynamic modulus) or at a maximum of 300 cycles. During testing, specimens were weighed, and their fundamental transverse frequency was measured approximately every 36 cycles. Results are reported as the durability factor, which is a function of the number of cycles survived by the specimens, and the relative dynamic modulus of elasticity at the time the test is terminated.

The relative dynamic modulus of elasticity,P_c, is defined by equation 1:

$$P_c = \frac{(n_1)^2}{(n)^2} \text{ x } 100 \tag{1}$$

where:

P_c = relative dynamic modulus of elasticity after c cycles
n = fundamental transverse frequency at 0 cycles
n_1 = fundamental transverse frequency after c cycles

The durability factor, DF, is defined by equation 2:

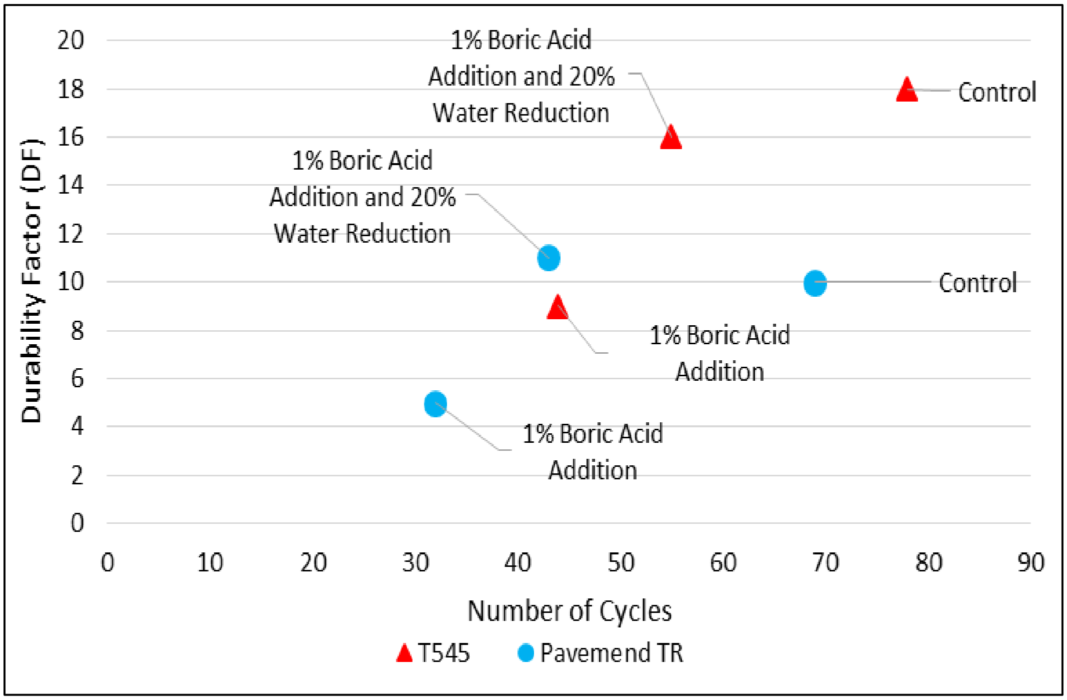
$$\text{DF} = \frac{\text{P x N}}{\text{M}} \tag{2}$$

where:

DF = durability factor of the test specimen
P = relative dynamic modulus of elasticity at N cycles, percent
N = number of cycles at which P reaches the specified minimum value for discontinuing the test or the specified number of cycles at which the exposure is to be terminated, whichever is less
M = specified number of cycles at which the exposure is to be terminated (300 cycles in accordance to procedure A)

The graph illustrated in Figure 20 presents the durability factor with respect to the cumulative number of freezing and thawing cycles for the Pavemend TR and T545 mixtures. The freeze-thaw and length-change properties were significantly affected by the variations of water and 1% addition of the boric acid. Both the durability factor and number of cycles decrease by approximately half with the addition of 1% boric acid. However, when the water was reduced 20%, the number of cycles and durability factor increased closer to the control results.

Figure 20. Durability factor and number of cycles completing freezing and thawing for Pavemend TR and T545 specimens.



5 Summary and Conclusions

The objective of this research was to determine the effects of boric acid and variations in the water content on fundamental concrete properties of the following three proprietary MPC products: (1) PREMag MPC PGDM manufactured by Premier Magnesia, (2) MasterEmaco T545 manufactured by BASF Master Builders, and (3) Pavemend TR manufactured by CeraTech Inc.

The following summary and conclusions can be drawn from the research.

- Sixteen variations of the premier magnesia PGDM product were prepared at varying water contents and boric acid dosages. As expected, the lower the water content and boric acid dosage, the higher the compressive strengths. Strengths at 24 hr were reduced by approximately 1,000 psi when 3% boric acid was used. The time of setting was attempted but unsuccessful due the rapid setting and thixatropic nature of the PGDM cement. This proprietary product is not recommended due to poor workability, extreme reactivity, and low compressive strengths.
- Eighteen trial batches (9 for each product) were prepared at varying water contents and boric acid dosages for the T545 and Pavemend TR products. For each batch, the measured concrete properties included temperature, time of setting, and compressive strength. Overall, additions of boric acid favorably decreased exothermic temperatures and increased the time of setting but led to an increasingly pronounced retardation in the early age development of compressive strength. The addition of 2% boric acid caused the most significant decrease in the early age strengths; thus, no further investigation was conducted on other concrete properties.
- Based on analysis from the T545 and Pavemend TR preliminary trial batching, three similar mixture proportions from each product were down-selected for additional concrete property investigation. The mixture proportions consisted of (1) control mix with no modifications from manufacturer’s recommendation, (2) addition of 1% boric acid using standard manufacturer’s water recommendation, and (3) addition of 1% boric acid and 20% reduction in manufacturer’s water recommendation. Concrete properties investigated included compressive strength, flexural strength, bond strength, splitting

tensile, modulus of elasticity, coefficient of thermal expansion, length change, time of setting, and freezing and thawing durability.

- Results showed the properties most effected by the addition of boric acid and variations of water content included early age compressive strength, bond strength, time of setting, length change, and freezing and thawing durability.
- Properties least affected by the mixture modifications included 28- day compressive, flexural, and splitting tensile strengths, modulus of elasticity, slump, and coefficient of thermal expansion.
- The 28-day minimum compressive and flexural strength requirements were 5,000 psi and 500 psi, respectively. The T545 met these target strengths for all modified mixtures presented in this study. The Pavemend TR product failed the compressive strength with modified mixtures and flexural strength with the addition of boric acid. However, flexural strength was recovered with 20% water reduction.
- Both products failed to meet the time of setting requirement of approximately 60 min. The addition of 1% boric acid resulted in an excessive 5-hr final set time that is unacceptable for rapid-repair applications. The outcome of the T545 product with the same modification was 41 min., which fell short of the target time.
- Although a quantitative value was not specified for required durability, results showed freeze-thaw specimens with 1% boric acid failed at approximately half the cycles as the control for both materials. This indicates poor durability with modifications to the proprietary products.
- A quantitative value was also not specified for bond strength. Both products revealed decreased bond strengths with product modifications that were not fully recovered at 7 days. Larger variations were expressed in the PCC/RS bond strengths compared to the RS/RS. The Pavemend TR product indicated high sensitivity to the addition of boric acid and deviations in the water content.
- Slump tests revealed no change in the workability when only boric acid was added and all other variables held constant. A reduction in the water content resulted in lower workability, which is expected for any typical concrete mixture.
- Overall, the T545 product outperformed the Pavemend TR product and showed less negative variability. The Pavemend TR product was significantly affected by the addition of boric acid resulting in non-recoverable compressive and bond strength losses, excessive length-change expansions, failure at low freezing and thawing cycles, and unacceptable times of setting for rapid-repair applications. No

modifications researched in this study are recommended for the Pavemend TR product. The T545 product showed promising performance with 28-day recovery in compressive, flexural, and bond strengths and minimal differences in modulus of elasticity and coefficient of thermal expansion tests.

- Field testing is recommended for the T545 product with 1% boric acid dosage.

Appendix A: Manufacturer Data Sheets

A.1 PREMagMPC PGDM Cement

PREMIERCPG
CONSTRUCTION PRODUCTS GROUP

'roduct Information

PRE MagMPC®

PREMagMPC® PGDM Cement

Description: Fully formulated, high-performance, quick-setting Magnesium Phosphate cement mix. Material is formulated to be used in a wide variety of applications where moderate strength, quick-setting cement is used, such as shotcrete, patching mixes and repair mortars.

Product Properties: PREMagMPC PGDM Cement

PHYSICAL PROPERTIES			
	Low Temp	Mod Temp	High Temp
Set Time – min - init	15-30	10-15	< 10
Set Time – min - final	40-50	20-30	< 15
Compressive Strength – psi 3 hrs	80-1000	1000-1500	>1500
BULK DENSITY (lbs/ft³):	40-50		

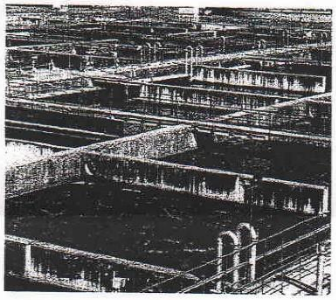
Product Description: PREMagMPC PGDM cement is a high-performance, quick-setting cement based on magnesium phosphate (MPC) binder chemistries. Material is ready to use and will harden when water is added in the right proportions. MPC cement provide a strong and durable binder system for a wide variety of construction products applications for both external and internal use. This binder system bonds tenaciously to a wide variety of substrates such as concrete, asphalt, wood, certain plastics and extruded polystyrene foam thus providing a wide spectrum of potential applications

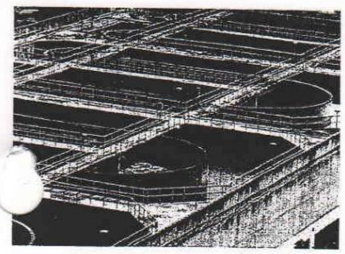
The main applications for this cement are for use as a dry shotcrete mix or rapid hardening patching mortar. Due to its properties, PREMagMPC PGDM is ideally suited for a number of applications where rapid setting and quick strength gain are desirable such as repair of roads, bridges, joint repairs, garage structures, anchoring, airport repairs, truck ramps, etc. In addition, when used as shotcrete, due to its resistance to acid attack, it provides an ideal solution for repair to concrete damaged by hydrogen sulfide (sulfuric acid attack), such as water and waste-water handling and treatment facilities. It can also be applied as a coating for standard portland cement concrete to prevent acid attack.

When used neat, the cement hardens in 15 minutes and expected compressive strength gain is 1,500 psi in three hours and > 3,000 psi in three days. Set time and strength gain are dependent on method of application, temperature, and amount of water used (see below for proper proportions).

MagMPC® **PREMagMPC® PGDM Cement**

http://www.premiercpg.com
1-800-227-4287





Uses: There is a wide range of applications for PREMagMPC PGDM:

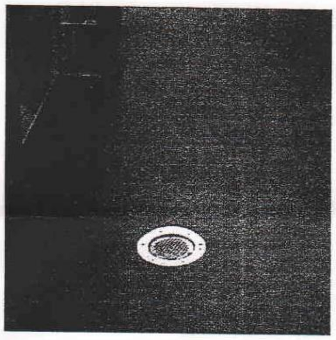
- Shotcrete
- Cementitious protective coating over concrete
- Acid-resistant overlayment
- Quick-setting patching mixes for highways, airports, bridges and dams
- Repair mortars
- Concrete overlayments and underlayments
- Marine decking and underlayments
- Fire-protection walls and partitions
- Fiber wrapping repairs (carbon fiber or glass scrim)
- Anchoring mortar
- Impact resistant panels (hurricane resistant, ballistic panels)

MPC cement exhibits excellent binding properties to a wide variety of substrates and is thus forgiving as far as surface preparation. Due to its resistance to acid attack, as shotcrete it can easily be applied to either new or damaged concrete in municipalities, water and waste-water treatment plants, and chemical plants. Because the resulting pH is significantly lower than portland cement, glass scrim can be used in contact with the cement as for fiber reinforcements/repair without concern for alkali-silica-reactivity (ASR). Hardened PREMagMPC PGDM exhibits high early strength, abrasion resistance, conductivity, insect and mold resistance, fire resistance and high resistance to oil, grease, chemicals and paints. These unique properties make PREMagMPC PGDM an ideal candidate for sustainability and for life cycle extension of damaged concrete structures.

Benefits of PREMagMPC Cement:

- Greener / sustainable technology
- Quick setting, early strength development
- Non-shrinking
- Water resistant
- Fire-resistant and non-combustible
- Mold, bacteria and insect resistant
- Abrasion and wear resistant
- Impact, indentation and scratch resistant
- Low electrical conductiviy
- Acid resistant
- Oil, grease and solvent resistant
- Good thermal conductivity
- Lightweight
- Resilient
- Excellent bonding
- Cost-effective

PREMIERCPG
CONSTRUCTION PRODUCTS GROUP



Performance: PREMagMPC PGDM has many superior qualities when compared to portland cement concrete. The material can be handled and mixed like standard portland cement concrete, but does not need wet curing, has high fire resistance, very low thermal conductivity, low shrinkage and very good abrasion resistance. Set times can be very quick, particularly when used as shotcrete, and develop high temperatures, thus care should be taken in handling material during the quick curing period. Compressive strength develops quickly, reaching approximately 1,500 psi in 3 hours. When set, cement is also resistant to freeze/thaw damage and is deicer scale resistant.

Note that due to its strong binding characteristics and quick set times, care must be taken not to let material set in or on equipment once it has been mixed with water. It is highly recommended that for shotcreting applications only dry shotcrete equipment be used so that water is not mixed with the cement until it reaches the nozzle. Cement can be easily washed off with plenty of water while it is still wet or within 10-15 minutes of application.

Using PREMagMPC PGDM Cement: PREMagMPC PGDM cement is ready to use like any dry mix material, just add water to initiate the reaction. Amount of water to be used should be 24-28 lbs of water added to each 100 lbs of cement. Higher amounts of water will result in loss in strength, lower amounts will result in material that does not flow and sets up before being able to finish. The material is thixotropic, vibration is necessary to get material to flow. Material should be finished immediately after pouring. It is recommended that the users familiarize themselves with the unique properties of this material by doing a small test section.

PREMagMPC PGDM cement will set in a wide range of temperatures including in freezing conditions. Set time and strength development are dependent on temperature with the higher the temperature the quicker the set. If slower set time is desired it is recommended that water be chilled prior to use. Do not use if temperatures are above 85 degrees F without chilling water.

For orders or technical questions, contact Premier CPG Customer Service at 1-800-227-4287, or your local distributor.

A.2 PREMagMPC Set Retarder

PREMIERCPG
CONSTRUCTION PRODUCTS GROUP
www.premiercpg.com • 1-800-227-4287

Product Information

PREMag® RET
Magnesium Phosphate Cement Set Retarder

PREMagMPC RET
Magnesium Phosphate Cement Set Retarder

Description: PREMag® MPC RET is a boric acid based set retarder specially designed for magnesium phosphate cements. The material was specifically designed to be used with PREMag MPC OFS cement when retardation of set time is desirable for a specific application. Additions of up to 5 % by weight to PREMag MPC OFS can retard set time to a few hours working time. Additions greater than 5% should not be used to prevent significant loss in strength and potentially stop the crosslinking reaction of the cement and permanently prevent hardening. See PREMag MPC OFS Product Information Sheet for further details.

Product Properties: PREMag® MPC RET

		Minimum	Maximum
CHEMICAL ANALYSIS			
Boric Acid Content, %		96	
Additives and inert materials , %			4
Solubility in water, %	25 C		4.7
	100 C		27.5
pH of solution @ 20 C	0.1 % solution	6.0	6.2
	1.0 % solution	5.0	5.2
	4.7 % solution (sat)	3.5	3.7
PHYSICAL PROPERTIES			
Color		off white	
Odor		odorless	
BULK DENSITY		lbs/ft3	94
		g/cc	1.5

Packaging and Storage: Available in 50 lb bags and 5 gallon polyethylene buckets.

Store in a dry area protected from moisture. Once bags are opened they must be resealed until all material is used. Material is hygroscopic and will tend to cake if subjected to moisture. Material should be consumed within one year. Special packaging is available upon request.

PRODUCT WARRANTY: Premier warrants that its Products shall be free from defects in material and workmanship and shall substantially conform to Premier's Product specifications upon shipment. If Buyer believes this warranty has been breached, it will provide written notice to Premier as soon as the defect becomes apparent, but no later than six (6) months from the date of shipment. If during the warranty period the Products are found to be defective in material or workmanship or fail to substantially conform to Premier's Product specifications, Premier will furnish replacement Products, ex-works jobsite, or at Premier's option, refund the purchase price, provided the Buyer has stored and installed the Products in accordance with Premier's instructions and provided further that Premier is given the opportunity to inspect and test the Products within fifteen (15) days from when the defect becomes apparent and is given access to all necessary operating records with respect to the use of the Products. THE EXPRESS WARRANTY SET FORTH IN THIS ARTICLE IS EXCLUSIVE, AND NO OTHER WARRANTIES OF ANY KIND, WHETHER STATUTORY, ORAL, WRITTEN, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, SHALL APPLY. THE BUYER'S EXCLUSIVE REMEDIES AND PREMIER'S ONLY OBLIGATIONS ARISING OUT OF OR IN CONNECTION WITH DEFECTIVE MATERIAL OR WORKMANSHIP, WHETHER BASED ON WARRANTY, CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, SHALL BE THOSE STATED HEREIN.

LIMITATION OF LIABILITY: The liability of Premier, its agents, employees, subcontractors and suppliers with respect to any and all claims arising out of the performance or nonperformance of obligations in connection with the design, manufacture, sale, delivery, storage, installation or use of the Products or the rendition of services, whether based on contract, warranty, tort (including negligence), strict liability or otherwise, shall not exceed the Contract Price and shall in no event include damages for loss of profits or revenue or the loss of use of either; loss by reason of plant shutdown or inability to operate at rated capacity; increased expense of operation of plant or equipment; increased costs of purchasing or providing equipment, materials, supplies or services outside of Seller's scope of supply; or incidental or consequential damages of any nature. No such claims shall be asserted against Seller, its agents, employees, subcontractors or suppliers, unless the injury, loss or damage giving rise to the claims is sustained prior to the expiration of the period of warranty specified herein, and no suit or action thereon shall be instituted or maintained unless it is filed in a court of competent jurisdiction within one (1) year after the date the cause of action accrues. This LIMITATION OF LIABILITY Article shall apply to and prevail over any and all provisions contained in any of the documents comprising the Contract.

PREMag® is a trademark of Premier Magnesia LLC.
300 Barr Harbor Drive, Suite 250, West Conshohocken, PA 19428
Telephone 1-800-227-4287 www.premiercpg.com

For orders call Premier CPG Customer Service at 1-800-227-4287, or your local distributor.

A.3 BASF MaterEmaco T 545

BASF
The Chemical Company

Technical Data Guide

3 | 03 01 00
Maintenance of Concrete

MasterEmaco® T 545 and T 545HT

Very rapid-setting chemical action mortar

FORMERLY SET® 45 AND SET® 45 HW

PACKAGING
50 lb (22.6 kg) polyethylene-lined bags

YIELD
A 50 lb (22.6 kg) bag of mixed with the required amount of water produces a volume of approximately 0.39 ft³ (0.011 m³); 60% extension using ½" (13 mm) rounded, sound aggregate produces approximately 0.58 ft³ (0.016 m³).

STORAGE
Store in unopened containers in cool, clean, dry conditions

SHELF LIFE
12 months when properly stored

VOC CONTENT
0 g/L less water and exempt solvents

DESCRIPTION
MasterEmaco T 545 is a one-component magnesium phosphate-based mortar. Offered in two formulations: T 545 for ambient and substrate temperatures below 85° F (29° C) and T 545 HT for ambient and substrate temperatures ranging from 85 to 100° F (29 to 38° C).

PRODUCT HIGHLIGHTS
- Single component to just add water and mix
- Reaches 2,000 psi compressive strength in 1 hour to rapidly return repairs to service
- Takes rubber tire traffic in 45 minutes
- Wide temperature use range from below freezing to hot weather exposures
- Very low drying shrinkage for improved bond to concrete for repair and anchoring applications
- Resistant to freeze/thaw cycles and deicing chemicals so it is usable in most environments
- Air cure only, no wet curing compounds required
- Coefficient of thermal expansion similar to Portland cement concrete for more permanent repairs
- Higher sulfate resistance than conventional mortars

APPLICATIONS
- Interior and exterior
- Horizontal and formed vertical or overhead repairs
- Applications requiring high early-strength gain
- Structural concrete repairs
- Partial and full-depth repairs
- Cold temperature repairs
- Grouting applications such as anchor bolts, rebar, dowel rods and precast applications

SUBSTRATES
- Concrete

HOW TO APPLY
SURFACE PREPARATION
1. Concrete must be structurally sound and fully cured (28 days).
2. Saw cut the perimeter of the area being repaired into a square with a minimum depth of ½" (13 mm).
3. The surface to be repaired must be clean, strong and roughened to a CSP of 8–9 following ICRI Guideline no. 310.2 to permit proper bond.
4. Any surface carbonation in the repair area will inhibit chemical bonding. Apply a pH indicator to the prepared surface to test for carbonation. If carbonation is present, abrade surface to a depth that is not carbonated.

MIXING
1. MasterEmaco T 545 must be mixed, placed, and finished within 10 minutes in normal temperatures (71° F [21° C]). Only mix quantities that can be placed in 10 minutes or less.
2. Do not deviate from the following sequence; it is important for reducing mixing time and producing a consistent mix. Use a minimum ½" slow-speed drill and mixing paddle or an appropriately sized forced-action mortar mixer. Do not mix by hand.

Master Builders Solutions by BASF
www.master-builders-solutions.basf.us

MASTER® BUILDERS SOLUTIONS

Technical Data Guide
MasterEmaco® T 545 and T 545HT

Technical Data

Composition

MasterEmaco T 545 is a magnesium-phosphate patching and repair mortar.

Test Data

PROPERTY	RESULTS			TEST METHOD
Typical Compressive Strengths*, psi (MPa)				ASTM C 109, modified
	Plain Concrete 72° F (22° C)	**T 545 72° F (22° C)**	**T 545 36° F (2° C)**	**T 545 HT 95° F (35° C)**
1 hour	—	2,000 (13.8)	—	—
3 hour	—	5,000 (34.5)	—	3,000 (20.7)
6 hour	—	5,000 (34.5)	1,200 (8.3)	5,000 (34.5)
1 day	500 (3.5)	6,000 (41.4)	5,000 (34.5)	6,000 (41.4)
3 day	1,900 (13.1)	7,000 (48.3)	7,000 (48.3)	7,000 (48.3)
28 day	4,000 (27.6)	8,500 (58.6)	8,500 (58.6)	8,500 (55.2)

Note: Only T 545 formula, tested at 72° F (22° C), obtains 2,000 psi (13.8 MPa) compressive strength in 1 hour.

PROPERTY	RESULTS		TEST METHOD
Modulus of Elasticity, psi (MPa)	**7 days**	**28 days**	ASTM C 469
MasterEmaco T 545	4.18×10^6 (2.88×10^4)	4.55×10^6 (3.14×10^4)	
MasterEmaco T 545 HT	4.90×10^6 (3.38×10^4)	5.25×10^6 (3.62×10^4)	
Freeze/thaw durability test, % RDM, 300 cycles, for MasterEmaco T 545 and T 545 HT		80	ASTM C 666, Procedure A (modified**)
Scaling resistance to deicing chemicals, MasterEmaco T 545 and T 545 HT			ASTM C 672
5 cycles		0	
25 cycles		0	
50 cycles		1.5 (slight scaling)	
Sulfate resistance			ASTM C 1012
MasterEmaco T 545 length change after 52 weeks, %		0.09	
Type V cement mortar after 52 weeks, %		0.20	
Typical setting times, min, for MasterEmaco T 545 at 72° F (22° C), and MasterEmaco T 545 HT at 95° F (35° C)			Gilmore ASTM C 266, modified
Initial set		9 – 15	
Final set		10 – 20	
Coefficient of thermal expansion,*** both MasterEmaco T 545 and T 545 HT			CRD-C 39
Hot Weather coefficients		7.15×10^{-6}/° F (12.8×10^{-6}/° C)	
Flexural Strength, psi (MPa), 3 by 4 by 16" (75 by 100 by 406 mm) prisms, 1 day strength,			ASTM C 78, modified
MasterEmaco T 545		550 (3.8)	
MasterEmaco T 545 with ⅜" (9 mm) pea gravel		600 (4.2)	
MasterEmaco T 545 with ⅜" (9 mm) crushed angular noncalcareous hard aggregate		650 (4.5)	

* All tests were performed with neat material (no aggregate)
**Method discontinues test when 300 cycles or an RDM of 60% is reached.
***Determined using 1 by 1 by 11" (25 mm by 25 mm by 279 mm) bars. Test was run with neat mixes (no aggregate). Extended mixes (with aggregate) produce lower coefficients of thermal expansion.
Test results are averages obtained under laboratory conditions. Expect reasonable variations.

Technical Data Guide
MasterEmaco® T 545 and T 545HT

HEALTH, SAFETY AND ENVIRONMENTAL

Read, understand and follow all Safety Data Sheets and product label information for this product prior to use. The SDS can be obtained by visiting www.master-builders-solutions.basf.us, e-mailing your request to basfbscst@basf.com or calling 1(800)433-9517. Use only as directed.
For medical emergencies only, call ChemTrec® 1(800) 424-9300.

LIMITED WARRANTY NOTICE

BASF warrants this product to be free from manufacturing defects and to meet the technical properties on the current Technical Data Guide, if used as directed within shelf life. Satisfactory results depend not only on quality products but also upon many factors beyond our control. BASF MAKES NO OTHER WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO ITS PRODUCTS. The sole and exclusive remedy of Purchaser for any claim concerning this product, including but not limited to, claims alleging breach of warranty, negligence, strict liability or otherwise, is the replacement of product or refund of the purchase price, at the sole option of BASF. Any claims concerning this product must be received in writing within one (1) year from the date of shipment and any claims not presented within that period are waived by Purchaser. BASF WILL NOT BE RESPONSIBLE FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFITS) OR PUNITIVE DAMAGES OF ANY KIND.

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A.4 Ceratech Pavemend TR

pavemend TR®

Extendable, Semi Leveling
RAPID REPAIR, TROWELABLE MORTAR

Product Data Sheet

pavemend

Updated 2.4.14

1 General Characteristics

Pavemend TR™ is a rapid setting slope grade (up to 60%) structural repair mortar with a gel like consistency suitable for troweling on horizontal and/or sloped grades and for aggregate extension. It is a single component powder that is water activated.

Pavemend TR™ has 15 to 20 minutes of working time and will reach compressive strengths of >2500 psi within 3 hours of final set; making it ***an exceptional choice for critical infrastructure repairs where workability and return to service are key factors.***

Pavemend TR™ can be applied in ambient temperature ranges from 40° to 120° Fahrenheit and ***can be re-animated repeatedly to a gel state prior to final set without additional water, providing ease of use and reduced material waste.***

RECOMMENDED USES: Designed specifically for use in horizontal and/or sloped applications, **Pavemend TR**™ is an ideal repair material for roads and bridges, airport runways, warehouse or manufacturing facility floors, loading dock ramps, parking garages, post-tension cable repairs, form and pour projects, overlayment of concrete surfaces, joint repair, pavements etc. Can be used as a temporary repair for asphalt.

2 Additional Physical Properties

UNIT WEIGHT (NEAT)
115 lb/ft³ (1842 kg/m³)

SETTING TIME
Set Times at 72°F/22°C at 1" (2.54 cm) material depth
Initial set: 10 - 15 minutes
Final set: 20 - 25 minutes

VOLUME YIELD
NEAT:
0.43 ft³ (0.012 m³) per 47 lb. (21.3 kg) unit
0.12 ft³ (0.003 m³) per 12 lb (5.4 kg) unit

Extended 50% (23 lbs) w 3/8" or 1/2" fractured aggregate:
0.62 ft³ (0.017 m³) per 47 lb. (21.3 kg) unit
0.14 ft³ (0.004 m³) per 12 lb (5.4 kg) unit

Extended 75% (35 lbs) w 3/8" or 1/2" fractured aggregate:
0.71 ft³ (0.022 m³) per 47 lb. (21.3 kg) unit
0.19 ft³ (0.005 m³) per 12 lb (5.4 kg) unit

Extended 100% (47 lbs) w 3/8" or 1/2" fractured aggregate:
0.80 ft³ (0.022 m³) per 47 lb. (21.3 kg) unit
0.24 ft³ (0.005 m³) per 12 lb (5.4 kg) unit

3 Material Specifications

Results provided by licensed engineering test laboratory and represent typical results from production materials. Actual results may vary from third party testing results; however, CERATECH's materials *meet and/or exceed* **ASTM C928**, and *exceed* established internal quality control standards, (available upon request). All samples were air cured.

Property	Results[1] - NEAT 2" Cubes	Results[2] - Extended W / 3/8" Pea Gravel (4" x 8" Cylinders)	Test Method
Compressive Strengths, **psi** (MPa)			
3 hours	> 2,800	> 3,000	ASTM C 109 / ASTM C 39
1 day - 24 hours	> 5,000	> 3,000	ASTM C 109 / ASTM C 39
7 days	> 6,000	> 3,000	ASTM C 109 / ASTM C 39
28 days	> 7,000	> 3,000	ASTM C 109 / ASTM C 39
Flexural Strength, **psi** (MPa)			
7 days	> 600	*TBD	ASTM C 78
28 days	> 1,400	*TBD	ASTM C 78
Splitting Tensile Strength, **psi**			
7 days	> 200	*TBD	ASTM C 496
28 days	> 400	*TBD	ASTM C 496
Bond Strength, **psi**			
1 day - 24 hours	> 1,200	*TBD	ASTM C 882
7 days	> 1,900	*TBD	ASTM C 882
Rapid Freeze Thaw Resistance (Durability Factor - Retained percentage of Dynamic Modulus)			
300 cycles	100%	*NTBT	ASTM C 672
Scaling Resistance, **lbs/ft²**			
25 cycles	0	*NTBT	ASTM C 672
Modulus of Elasticity, **msi**			
28 days	2.77	*TBD	ASTM C 469
Coefficient of Thermal Expansion, **in/in/°F**			
28 days	2.52	*NTBT	AASHTO-T336-11
Length Change, % of total length			
28 days soak / 28 days dry	TBD / -0.002	*NTBT	ASTM C 157

1 3rd party test results
2 Internal test results
TBD - To be determined
NTBT - Not to be tested

CERATECH
www.ceratechinc.com

Page 1 (3)

PFT Planet Friendly Technology!

1500 N. Beauregard St. Suite 320 Alexandria, VA 22311 • 800-581-8397 • sales@pavemend.com
Fax: 703-894-1068 • Technical Support: 888-341-2600

pavemend TR

Extendable,
Semi Leveling
RAPID REPAIR, TROWELABLE MORTAR

Product Data Sheet

pavemend

Updated 2.4.14

4 Site Preparation

Surfaces should be prepared in accordance with ICRI 03730, "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" and / or ACI 546R-96 "Concrete Repair Guide". Concrete surfaces should be prepared by appropriate mechanical methods to obtain an exposed aggregate surface with a minimum surface profile of +/- 1/16" (1.5 mm) in accordance with ICRI 03732. Pre-existing coatings or surface treatments should be completely removed. Dry, clean, stable surfaces are required. Remove all standing water. Reinforcing steel should have no loose scale. **Surfaces of host concrete must be damp.**

5 Mixing Instructions

Standard NEAT Procedures (Bucket Mixing with Drill & Paddle)

- Loosen material by tumbling bucket & dry mixing ***before*** adding water.
- To ensure product performance, **DO NOT divide or separate individual units into smaller portions. MIX ENTIRE CONTENTS AT ONE TIME.**
- A drill (6 amp minimum) with a mixer blade turning at least 500 to 800 rpm is required. Drills with speeds greater than 800 RPMs may entrain air in the mix.
- **DO NOT HAND MIX.**
- To begin the mixing process, add the proper amount of water.
- Ideal water temperature is between 65°F/18°C and 75°F/24°C.

For Each:	Add:
47 lb (21.3 kg) -5 gal. (18.9L) bucket 47 lb (21.3 kg) bag	1 U.S. gallon (3.8 L) of water
12lb (5.4 kg) -2 gal. (7.6L) bucket	1 U.S. quart (.95 L) of water

- ***After adding the water, it is very important to rapidly incorporate all of the dry Pavemend TR™ powders into water to achieve a uniform wet mixture within the first 30 seconds of mixing.***
- In ambient temperatures under 72°F/22°C, CERATECH highly recommends the use of a thermal gun or temperature probe to verify that a **Critical Mix Temperature of 90°F/32°C has been reached.** Place material into repair area when this temperature has been achieved.
- In ambient temperatures over 72°F/22°C and without using a thermal measuring gun or temperature probe, mix material for 4 1/2 minutes in ambient temperatures of 72°F /22°C to 80°F/27°C, mix for 3 1/2 minutes in ambient temperatures of 80°F/27°C to 90°F/32°C, mix for 3 minutes in ambient temperatures above 90°F/32°C and place.

For Aggregate Extension: (Bucket Mixing with Drill & Paddle)

- Use only 3/8" (1cm) clean washed pea gravel or 1/2" (1.3cm) No.7 stone up to 100% (47 lbs. / 21.3kg) maximum by weight.
- ***Add aggregate to material and water slurry after mixing for 30 seconds***. Continue mixing per NEAT instructions above.

For Aggregate Extension (Using Portable Rotating Drum Concrete Mixer)

- Use 3/8" clean washed pea gravel or 1/2" (1.3cm) No.7 stone at no more than 100% by weight. (For optimal finishing, do not extend **Pavemend TR™** by more than 28 lbs.or 60% by weight) Pre-mix pea gravel and water to create initial slurry mix. Add **Pavemend TR** and ***record temperature after 1 minute***. **Mix until critical mix temperature of 90°F is achieved but not less than 5 minutes.** Pour and apply desired finish.
- Contact Technical Support at 1-888-341-2600 for assistance.

MIXING NOTES:

1. **Pavemend TR™** undergoes an exothermic chemical reaction during blending. Heat, the by-product of the reaction, is the best indication that the reaction is complete and that the product is ready to be poured. **Pavemend TR™ has a Critical Mix Temperature of 90°F/32°C which MUST BE REACHED before pouring to obtain optimum performance.** *(In cold weather, it may be impossible to reach the Critical Mix Temperature, therefore a 40°F/22°C rise in material temperature is mandatory to ensure that the necessary chemical reactions have taken place to deliver the desired performance characteristics);* Mixing time to reach the **Critical Mix Temperature** will vary with ambient air and mix water temperatures, however, **never mix Pavemend TR™ for less than 2 minutes** Use a thermal gun or temperature probe to ensure that the **Critical Mix Temperature** has been achieved.

6 Packaging & Shelf Life

PACKAGING

46 lb (20.9 kg) 5 gallon (18.9 L) bucket - GSA P/N: C700
11lb (4.99 kg) 2 gallon (7.6 L) bucket - GSA P/N: C750

SHELF LIFE

Buckets - 3 years (when stored in original unopened bucket)

STORAGE

Buckets are environmentally sealed and require no special storage requirements

7 Limitations

- Not recommended for surface temperatures above **110°F**/43°C or below **40°F**/4°C.
- Will not bond to polymers.
- Cannot be pumped.
- Must be mixed with drill and paddle - **Pavemend TR™** cannot be mixed in grout mixer or rotating drum concrete mixers due to rapid set times.

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Fax: 703-894-1068 • Technical Support: 888-341-2600

PFT Planet Friendly Technology!

Extendable,
Semi Leveling
RAPID REPAIR, TROWELABLE MORTAR

Product Data Sheet

pavemend

Updated 2.4.14

8 Application & Finish

- Minimum NEAT profile thickness is 0.06" (1.5mm). There are no restrictions to the depth of the repair profile.
- For best results, CERATECH recommends monolithic placement of repair materials. Maintain a minimum thickness of 1.00 inch if repair material must be layered.
- Upon initial set, a broom finish can be applied. Upon final set, the material can be saw-cut, drilled, sanded and/or polished.
- Do not re-temper. The addition of water to the surface of the repair will negatively affect the materials final properties.
- **General loading in 2 to 3.5 hours for wheeled traffic and 60 minutes for foot traffic.** For applications 0.5" thick and greater, in ambient and/or surface temperatures below 50°F/10°C, extend the loading time by 30 minutes for each 10° below 50°F/10°C. For applications 1.00" thick and greater, in ambient and/or surface temperatures below 40°F/4°C extend the loading time by 30 minutes for each 10° below 40°F/4°C.
- **All previously existing joints must be re-established within 1-3 hours of final set.**
- **Self-curing.**
- Clean all tools and equipment with water prior to the material reaching final set.

9 Safety

- See **Material Safety Data Sheet (MSDS)**.
- This document does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.
- Dispose of water and materials in accordance with Federal, State and Local regulations.
- The use of a dust mask, safety goggles and gloves is recommended.
- Keep out of the reach of children.

WARRANTY:
CERATECH, Inc. ("CERATECH") warrants that its products are free from defects in materials and workmanship. If any CERATECH product fails to conform to this warranty, CERATECH will replace the product at no cost to the buyer or refund the purchase price, at CERATECH's election. Any warranty claim must be made within one (1) year from the date of the shipment of the product to the buyer. In no event shall CERATECH be liable to the buyer for any consequential or incidental damages of any nature. CERATECH MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, WRITTEN OR ORAL AS TO THE MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OF ITS PRODUCTS AND EXCLUDES THE SAME. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF.

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A.5 Boric Acid

THREE ELEPHANT BORIC ACID GRANULAR TECHNICAL

Material Safety Data Sheet

PESTICIDE: EPA Registration No. **64745-3** [Not for Food or Drug Use - - ONLY For Manufacturing Use]

Manufactured by:
Searles Valley Minerals
13200 Main Street
P.O. Box 367, Trona, CA 93592-0367

Sectrion I - CHEMICAL PRODUCT & COMPANY IDENTIFICATION

PRODUCT NAME: Three Elephant Boric Acid Granular Technical --- Pesticide: EPA Reg # 64745-3
MANUFACTURER:
Searles Valley Minerals
P.O. Box 367
Trona, CA 93592-0367
EMERGENCY PHONE NUMBER:
24 Hour Information Service: 760-372-2291
CHEMTREC: 800-424-9300
PREPARATION/REVISION DATE: May 2, 2006
Supersedes: Ap;ril 12, 2004, February 20, 2002 & October 22, 1999

Section II - COMPOSITION/INFORMATION ON INGREDIENTS

NOTE: See Section 15 for Exposure Limits.
PRODUCT NAME: Boric Acid Granular Technical
FORMULA: H_3BO_3
CHEMICAL NAME: Boric Acid
SYNONYMS: OrthoBoric Acid, Boracic Acid
COMPONENTS:
Material: Boric Acid
CAS Number: 10043-35-3
Percent: 99.755% (Label Claim = 100%)

Boric Acid is hazardous under the OSHA Hazard Communication Standard based on animal chronic toxicity studies of similar organic Borates; see Section 11 for details on Toxicological Data.

Section III - HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: Boric Acid is a white odorless, powdered substance that is not flammable, combustible, or explosive, and it presents no unusual hazard if involved in a fire. Boric Acid presents little or no hazard (to humans) and has low acute oral and dermal toxicities. Care should be taken to minimize the amount of Boric Acid released to the environment to avoid ecological effects.
ROUTES OF EXPOSURE: In the occupational setting, inhalation is the most important route of exposure. Dermal absorption is usually not important because Boric Acid is not absorbed through the intact skin.
INHALATION: Mild irritation to nose and throat may occur when the PEL or TLV are exceeded (see Section 15).
EYE CONTACT: Exposure to Boric Acid dust does not cause eye irritation in normal industrial use.
DERMAL CONTACT: Boric Acid is non-irritating to the intact skin. Can be readily absorbed through broken or abraded skin.
INGESTION: Boric Acid products are not intended for ingestion. Amounts greater than one teaspoonful, when ingested, may cause gastrointestinal problems.
CANCER: Boric Acid is not considered a carcinogen.
REPRODUCTIVE: A human study of occupationally exposed Borate worker population showed no adverse reproductive effects. Animal studies of similar organic Borates demonstrated reproductive effects in males.
TARGET ORGANS: No target organs have been determined in humans. High dose animal ingestion studies indicate that the testes is the target organ.
SIGNS AND SYMPTOMS OF EXPOSURE: Symptoms of accidental over-exposure to Boric Acid have been associated with ingestion or by absorption through large areas of damaged skin. These may include nausea, vomiting, and diarrhea, with delayed effects of skin redness and peeling.

See Section 4 also. See Section 11 for details on Toxicological Data.

Section IV - EMERGENCY & FIRST AID PROCEDURES

HAZARDS TO HUMANS AND DOMESTIC ANIMALS: CAUTION Harmful if swallowed or inhaled. Causes moderate eye irritation. Avoid contact with eyes or clothing. Avoid breathing dust. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash clothing before reuse.

Three Elephant Boric Acid Granular Technical Page 1 of 4 Searles Valley Minerals

STATEMENT OF PRACTICAL TREATMENT: If swallowed: Call a physician or poison control center. Drink 1 or 2 glasses of water and induce vomiting by touching back of throat with finger [or if available, by administering syrup of ipecac]. If person is unconscious, do not give anything by mouth and do not induce vomiting. **If Inhaled:** Remove victim to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. Get medical attention. **If In Eyes:** Flush eyes with plenty of water. Call a physician if irritation persists.

Section V - FIRE FIGHTING MEASURES

GENERAL HAZARD: Boric Acid is not flammable, combustible, or explosive. Boric Acid presents no unusual hazards when involved in a fire. This product is an inherent fire retardant.
UEL/LEL: Not Applicable
FLASH POINT: Not Applicable
AUTOIGNITION TEMPERATURE: Not Applicable
FLAMMABILITY CLASSIFICATION: Flammability Classification (29 CFR 1910.1200), Non-flammable solid.
EXTINGUISHING MEDIA: Any fire extinguishing media may be used on nearby fires.

Section VI - ACCIDENTAL RELEASE MEASURES

ENVIRONMENTAL HAZARD: Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance, contact your State Water Board or Regional Office of the EPA.

Section VII - HANDLING & STORAGE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling]

CAUTION: Keep out of Reach of Children

HYGIENIC PRACTICES: Wash hands thoroughly with soap and water after handling, and before eating, drinking, or smoking.
STORAGE AND DISPOSAL: Do not contaminate water, food or feed by storage or disposal. **STORAGE:** Store in a cool, dry area away from heat. **PESTICIDE DISPOSAL:** Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. **CONTAINER DISPOSAL:** completely empty bags into application equipment. Then dispose of empty bag in a sanitary landfill or by incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke. Observe all Federal, state and local regulations concerning disposal of waste pesticide and containers. **FORMULATORS AND REPACKAGERS USING THIS PRODUCT ARE RESPONSIBLE FOR OBTAINING ENVIRONMENTAL PROTECTION AGENCY (EPA) REGISTRATION FOR THEIR PRODUCTS**. [Refer to PR Notice 95-1 for the applicability of the ***Environmental Hazards*** statement to your product.) This product is a soluble inorganic powder which may be used for the formulation of products for the following **registered end-use patterns:** 1) Algaecides for water treatment in swimming pools; 2) Bacteriostats for use in impregnating or otherwise applying to absorbent material(s) to inhibit the growth of odor-causing bacteria when applied at a rate of 0.015 to 0.37% w/w (approximately) equivalent boron; 3) Insecticides for mop, spot and crack and crevice treatment in homes, residential, industrial, institutional and commercial buildings and in transportation equipment; 4) Insecticide/fungicide for wood treatment.

Section VIII - EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS: Use local exhaust ventilation to keep airborne levels below exposure limits (see Section 15).
EYE PROTECTION: Use goggles or vented safety glasses in excessively dusty conditions.
SKIN PROTECTION: (Not required under normal conditions.) Use protection if excessively dusty or if skin is damaged.
RESPIRATORY PROTECTION: Use appropriate NIOSH/MSHA certified respirators when levels are expected to exceed exposure limits (see Section 15).

Section IX - PHYSICAL & CHEMICAL PROPERTIES

SOLUBILITY IN WATER: 4.7% at 20□C; 27.5% at 100□C
APPEARANCE: White granular or powder solid, odorless.
MOLECULAR WEIGHT: 61.83
BOILING POINT: Not Applicable
MELTING POINT: 169□C
pH VALUE: At 20□C: 7.26 (100 ppm solution)
FLASH POINT: None
SPECIFIC GRAVITY (H_2O = 1 at 4□C): 1.44
VAPOR PRESSURE: Not Applicable
BULK DENSITY: 57.0 Lbs./ CuFt.

Section X - STABILITY & REACTIVITY DATA

STABILITY: Stable under normal conditions; forms partial hydrate in moist air. When heated, water is lost forming Metaboric Acid (HBO_2). On further heating, the material is converted to boric oxide (B_2O_3).
INCOMPATIBILITY: Boric Acid reacts as a weak acid that may cause corrosion of base metals. Reaction with strong reducing agents such as metal hydrides or alkali metals will generate hydrogen gas that could create an explosive hazard.
HAZARDOUS DECOMPOSITION PRODUCTS: None known.
HAZARDOUS POLYMERIZATION: Will not occur.

Section XI - TOXICOLOGICAL EFFECTS

EYES: Boric Acid, when applied to the eyes of albino rabbits (Draize test), produced effects of mild erythema, and mild to moderate discharge in 5 of 6 rabbits. All signs subsided by the fourth day after application. Fifty years of occupational exposure history indicates no human eye injury from exposure to Boric Acid.

SKIN: Boric Acid was applied to the skin of albino rabbits. Slight to no irritation persisted 72 hours after application. No evidence of tissue damage was found. Low acute dermal toxicity; LD_{50} for rabbits is expected to be greater than 2,000 mg/kg of body weight (test conducted per 16 CFR 1500.41). Boric Acid is not absorbed through intact skin.
INHALATION: Human epidemiological studies show no increase in pulmonary disease in occupational populations with chronic exposure to Boric Acid and Sodium Borate dust (See Section 4 also).
INGESTION: Low acute oral toxicity; LD_{50} for Sprague-Dawley rats is 3,500 to 4,100 mg/kg of body weight. (See Section 4 also).
CARCINOGENICITY: Boric Acid is not listed as a carcinogen by the Environmental Protection Agency (EPA), the State of California, or the International Agency for Research on Cancer (IARC). A report issued by the National Toxicology Program showed "no evidence of carcinogenicity" from a full two-year bioassay on Boric Acid on mice at feed doses of 2,500 to 5,000 ppm in the diet. No mutagenic activity was observed for Boric Acid in a recent battery of four short-term mutagenicity assays.
REPRODUCTIVE: A human study of occupationally exposed Borate worker population showed no adverse reproductive effects. Animal studies indicate that Boric Acid reduces or inhibits sperm production, causes testicular atrophy, and, when given to pregnant animals during gestation, may cause developmental changes. These feed studies were conducted under chronic exposure conditions leading to doses many times in excess of those that could occur through inhalation of dust in the occupational setting.

Dietary levels of Boric Acid of 6,700 ppm in chronic feeding studies in rats and dogs produced testicular changes {Weir, Fisher, 1972}. In chronic feeding studies of mice on diets containing 5,000 ppm Boric Acid, testicular atrophy was present, while mice fed 2,500 ppm Boric Acid showed no significant increase in testicular atrophy. In another chronic Boric Acid study, degeneration of seminiferous tubules was present together with a reduction of germ cells in mice fed 4,500 ppm Boric Acid. In a reproduction study on rats, 2,000 ppm of dietary Boric Acid had no adverse effect on lactation, litter size, weight and appearance [Weir, Fisher, 1972]. In a continuous breeding study in mice, there was a reduction in fertility rates in males receiving 4,500 ppm Boric Acid, but not for females receiving 4,500 ppm Boric Acid [Fail et al., 1992].

Boric Acid at dietary levels of 1,000 ppm administered to pregnant female rats throughout gestation caused a slight reduction in fetal weight, but was considered close to NOAEL. Doses of 2,000 ppm and above caused fetal malformations and maternal toxicity. In mice, the no effect level for fetal weight reduction and maternal toxicity was 1,000 ppm Boric Acid. Fetal weight loss was noted at dietary levels of 2,000 ppm and above. Malformations (agenesis or shortening of the thirteenth rib) were seen at 4,000 ppm [Heindal et al.,1992].

Section XII - ECOLOGICAL DATA

NOTE: Boron is the element in Boric Acid that is used to characterize Borate product ecological effects. To convert Boric Acid to boron multiply by 0.1748.

FISH TOXICITY: Boron naturally occurs in seawater at an average concentration of 5 mg B/liter. In laboratory studies the acute toxicity (96-hr LC_{50}) for under-yearling Coho salmon (Onchorhynchus kisutch) in seawater was determined as 40 mg B/L (added as Sodium Metaborate). The Minimum Lethal Dose for minnows exposed to Boric Acid at 20□C for 6 hours is 18,000 to 19,000 mg/l in distilled water, 19,000 to 19,500 in hard water.

Rainbow trout (S. gairdneri)

24-day LC_{50} = 150.0 mg/B/L
36-day NOEC-LOEC = 0.75-1 mg/B/L

Goldfish (Carassius auratus)

7-day NOEC-LOEC = 26.50 mg/B/L
3-day LC_{50} = 178 mg/B/L

BIRD TOXICITY: Dietary levels of 100 mg/kg resulted in reduced growth of female mallards. As little as 30 mg/kg fed to mallard adults adversely affected the growth rate of offspring.
INVERTEBRATE TOXICITY:

Daphnids

48-hour LC_{50} = 133 mg/B/L
21-day NOEC-LOEC = 6-13 mg/B/L

PHYTOTOXICITY: Although boron is an essential micro-nutrient for healthy growth of plants, it can be harmful to boron-sensitive plants in higher quantities. Plants and trees can easily be exposed by root absorption to toxic levels of boron in the form of water-soluble Borate leached into nearby waters or soil. Care should be taken to minimize the amount of boron released to the environment.
ENVIRONMENTAL FATE DATA:
Persistence/Degradation: Boron is naturally occurring and is commonly found in the environment. Boric Acid decomposes in the environment to natural Borate.
Soil Mobility: The product is soluble in water and is leachable through normal soil.

Section XIII - DISPOSAL CONSIDERATIONS

DISPOSAL GUIDANCE: See Section 7.

Section XIV - TRANSPORT REGULATIONS

US DEPARTMENT of TRANSPORTATION (DOT) IDENTIFICATION NUMBER: Boric Acid is not a DOT Hazardous Material or Hazardous Substance.
INTERNATIONAL TRANSPORTATION: Boric Acid has no U.N. number, and is not regulated under international rail, highway, water, or air transport regulations.

Section XV - REGULATORY INFORMATION

TSCA NUMBER: 10043-35-3
RCRA (40 CFR 261): Not listed under any section.
CERCLA (SUPERFUND): Not listed under any section.
CLEAN WATER ACT (CWA): Boric Acid is not regulated by any water quality criteria under Section 304, is not listed as priority pollutant under Section 307, and is not listed as a hazardous substance under Section 311.
SAFE DRINKING WATER ACT (SDWA): Not regulated under SDWA, 42 USC 300g-1, 40 CFR 141 et seq. Consult state and local regulations for possible water quality advisories involving boron.
OCCUPATIONAL EXPOSURE LIMITS: Boric Acid is listed/regulated by OSHA, CAL OSHA, or ACGIH as "Particulate Not Otherwise Classified" or "Nuisance Dust".
OSHA: Permissible Exposure Limit: 150mg/m^3, total dust
5 mg/m^3, respirable dust
ACGIH: Threshold Limit Value: 2 mg/m^3
CALIFORNIA OSHA: Permissible Exposure Limit: 5 mg/m^3

INTERNATIONAL AGENCY for RESEARCH on CANCER: Not listed as a carcinogen.
NTP ANNUAL REPORT ON CARCINOGENS: Not listed as a carcinogen.
OSHA CARCINOGEN: Not listed as an OSHA carcinogen.
CONEG MODEL LEGISLATION: Meets all CONEG requirements relating to heavy metal limitations on components of packaging materials.
CALIFORNIA PROPOSITION 65: Not listed as carcinogen or reproductive toxin.
FEDERAL DRUG AGENCY (FDA): Pursuant to 21 CFR 175.105, 176.180, and 181.30, Boric Acid (non-pesticide) is approved by the FDA for use in adhesive components of packaging materials, as a component of paper coatings on such materials, or for use in the manufacture thereof, which materials are expected to come in contact with dry food products.
WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEMS (WHMIS): Boric Acid is regulated as a Controlled Product and is classified as D2A because of reproductive toxicity.
FIFRA: This product is a ***PESTICIDE.***

Section XVI - OTHER INFORMATION

OTHER INFORMATION:
Product Label Text Hazard Information (see appropriate sections as relates to pesticide use):

- May be harmful if swallowed.
- May cause reproductive harm or birth defects based on animal data.
- Avoid contamination of food or feed.
- Not for food or drug use
- Practice good housekeeping.
- Refer to all sections of this MSDS.
- KEEP OUT OF THE REACH OF CHILDREN.

National Fire Protection Association (NFPA) Classification:
4 = Severe, 3 = Serious, 2 = Moderate, 1 = Slight, 0 = Minimal

Health	0
Flammability	0
Reactivity	0

Hazardous Materials Information Systems (HMIS):
4 = Extreme, 3 = High, 2 = Moderate, 1 = Slight, 0 = Insignificant

Blue: (Acute Health)	1*
Red: (Flammability)	0
Yellow: (Reactivity)	0

* Chronic Effects (for explanation see Section 11)

NOTICE

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Appendix B: Laboratory Data Reports

B.1 T545 Mix 2, 5, and 6 Worksheets

Mix 2.

MPC Mixture Evaluation Report					
Product Name:		T545 (Modified)	**Laboratory ID:**	T545- Mix 2	
Manufacturer's Information	**Name**	Master Emco			
	Address	889 Valley Park Drive, Shakopee, MN 55379			
	Phone	800-243-6739			
Mix Details					
Standard manufacture w/c ratio, 0% retarder					
Product extended with 50% 3/8" pea gravel aggregate.					
Testing Results					
Property		**Test Specifics**	**Test Age**	**Lab Test Result**	
Compressive Strength (psi)	ASTM C39	-	1 day	4,190	
		-	7 day	5,090	
		-	28 day	6,040	
Flexural Strength (psi)	ASTM C78	-	28 day	610	
Bond Strength (psi)	ASTM C882	Repair Material to Ordinary PCC	1 day	1,240	
Repair Material to Ordinary PCC			7 day	1,530	
Bond Strength (psi)		Repair Material to Repair Material	1 day	1,600	
Repair Material to Repair Material			7 day	1,780	
Splitting Tensile (psi)	ASTM C496	-	28 day	550	
Modulus of Elasticity (ksi)	ASTM C469	-	28 day	5,350	
Time of Set (min)	ASTM 403	-	Initial	11	
		-	Final	16	
Slump (inch)	ASTM C143	Within 5 min of added water	Inch	7	
Length Change (%)	ASTM C157	Stored in air	28 day	0.013	
			64 weeks	-0.003	
Length Change (%)	ASTM C157	Stored in water	28 day	0.025	
			64 weeks	0.040	
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1	-	7	
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles	Durability Factor @ # cycles	DF 18 @ 78 cycles	

Mix 5.

MPC Mixture Evaluation Report					
Product Name:	T545 (Modified)		**Laboratory ID:**	T545- Mix 5	
Manufacturer's Information	**Name**	Master Emco			
	Address	889 Valley Park Drive, Shakopee, MN 55379			
	Phone	800-243-6739			
Mix Details					
Standard Manufacturer Recommended Water Plus 1% Borax Retarder					
Product extended with 50% 3/8" pea gravel aggregate.					
Testing Results					
Property		**Test Specifics**	**Test Age**	**Lab Test Result**	
Compressive Strength (psi)	ASTM C39	-	1 day	3,490	
		-	7 day	4,340	
		-	28 day	5,810	
Flexural Strength (psi)	ASTM C78	-	28 day	555	
Bond Strength (psi)	ASTM C882	Repair Material to Ordinary PCC	1 day	1,010	
Repair Material to Ordinary PCC			7 day	1,290	
Bond Strength (psi)		Repair Material to Repair Material	1 day	1,150	
Repair Material to Repair Material			7 day	1,390	
Splitting Tensile (psi)	ASTM C496	-	28 day	540	
Modulus of Elasticity (ksi)	ASTM C469	-	28 day	4,650	
Time of Set (min)	ASTM 403	-	Initial	32	
		-	Final	35	
Slump (inch)	ASTM C143	Within 5 min of added water	Inch	7	
Length Change (%)	ASTM C157	Stored in air	28 day	0.026	
			64 weeks	0.012	
Length Change (%)	ASTM C157	Stored in water	28 day	0.042	
			64 weeks	0.055	
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1	-	6.5	
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles	Durability Factor @ # cycles	DF 9 @ 44 cycles	

Mix 6.

MPC Mixture Evaluation Report				
Product Name:	T545 (Modified)		**Laboratory ID:**	T545- Mix 6
Manufacturer's Information	**Name**	Master Emco		
	Address	889 Valley Park Drive, Shakopee, MN 55379		
	Phone	800-243-6739		
Mix Details				
20% Less Water Than Standard Manufacturer Recommended, Plus 1% Borax				
Product extended with 50% 3/8" pea gravel aggregate.				
Testing Results				
Property		**Test Specifics**	**Test Age**	**Lab Test Result**
Compressive Strength (psi)	ASTM C39	-	1 day	4,750
		-	7 day	5,360
		-	28 day	6,190
Flexural Strength (psi)	ASTM C78	-	28 day	655
Bond Strength (psi) Repair Material to Ordinary PCC	ASTM C882	Repair Material to Ordinary PCC	1 day	1,050
			7 day	1,340
Bond Strength (psi) Repair Material to Repair Material		Repair Material to Repair Material	1 day	1,450
			7 day	1,660
Splitting Tensile (psi)	ASTM C496	-	28 day	560
Modulus of Elasticity (ksi)	ASTM C469	-	28 day	5,200
Time of Set (min)	ASTM 403	-	Initial	38
		-	Final	41
Slump (inch)	ASTM C143	Within 5 min of added water	Inch	4
Length Change (%)	ASTM C157	Stored in air	28 day	0.015
			64 weeks	0.005
Length Change (%)	ASTM C157	Stored in water	28 day	0.036
			64 weeks	0.053
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1	-	8.1
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles	Durability Factor @ # cycles	DF 16 @ 55 cycles

B.2 Pavemend TR Mix 11, 14, and 15 Worksheets

Mix 11.

MPC Mixture Evaluation Report					
Product Name:		Pavemend TR (Modified)		**Laboratory ID:**	Pavmend TR- Mix 11
Manufacturer's Information	**Name**	Ceratech			
	Address	1500 N. Beauregard Street, Alexandria, VA 22311			
	Phone	800-581-8397			
Mix Details					
Standard manufactor w/c mix, 0% retarder					
Product extended with 50% 3/8" pea gravel aggregate.					
Testing Results					
Property		**Test Specifics**		**Test Age**	**Lab Test Result**
Compressive Strength (psi)	ASTM C39	-		1 day	3,890
		-		7 day	4,350
		-		28 day	5,220
Flexural Strength (psi)	ASTM C78	-		28 day	560
Bond Strength (psi) Repair Material to Ordinary PCC	ASTM C882	Repair Material to Ordinary PCC		1 day	1,790
				7 day	1,920
Bond Strength (psi) Repair Material to Repair Material		Repair Material to Repair Material		1 day	1,560
				7 day	1,770
Splitting Tensile (psi)	ASTM C496	-		28 day	440
Modulus of Elasticity (ksi)	ASTM C469	-		28 day	4,650
Time of Set (min)	ASTM 403	-		Initial	10
		-		Final	32
Slump (inch)	ASTM C143	Within 5 min of added water		Inch	11
Length Change (%)	ASTM C157	Stored in air		28 day	0.019
				64 weeks	0.008
Length Change (%)	ASTM C157	Stored in water		28 day	0.032
				64 weeks	0.055
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1		-	7.2
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles		Durability Factor @ # cycles	DF 10 @ 69 Cycles

Mix 14.

MPC Mixture Evaluation Report				
Product Name:	Pavemend TR (Modified)		**Laboratory ID:**	Pavmend TR- Mix 14
Manufacturer's Information	**Name**	Ceratech		
	Address	1500 N. Beauregard Street, Alexandria, VA 22311		
	Phone	800-581-8397		
Mix Details				
Standard manufactor w/c mix, 1% retarder				
Product extended with 50% 3/8" pea gravel aggregate.				
Testing Results				
Property		**Test Specifics**	**Test Age**	**Lab Test Result**
Compressive Strength (psi)	ASTM C39	-	1 day	2,250
		-	7 day	3,580
		-	28 day	4,630
Flexural Strength (psi)	ASTM C78	-	28 day	560
Bond Strength (psi)	ASTM C882	Repair Material to Ordinary PCC	1 day	600
Repair Material to Ordinary PCC			7 day	1,060
Bond Strength (psi)		Repair Material to Repair Material	1 day	950
Repair Material to Repair Material			7 day	1,330
Splitting Tensile (psi)	ASTM C496	-	28 day	430
Modulus of Elasticity (ksi)	ASTM C469	-	28 day	3,650
Time of Set (min)	ASTM 403	-	Initial	160
		-	Final	325
Slump (inch)	ASTM C143	Within 5 min of added water	Inch	11
Length Change (%)	ASTM C157	Stored in air	28 day	0.027
			64 weeks	0.019
Length Change (%)	ASTM C157	Stored in water	28 day	0.048
			64 weeks	0.076
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1	-	6.3
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles	Durability Factor @ # cycles	DF 5 @ 32 cycles

Mix 15.

MPC Mixture Evaluation Report				
Product Name:	Pavemend TR (Modified)		**Laboratory ID:**	Pavmend TR- Mix 15
Manufacturer's Information	**Name**	Ceratech		
	Address	1500 N. Beauregard Street, Alexandria, VA 22311		
	Phone	800-581-8397		
Mix Details				
20% Less Water Than Standard Manufacturer Recommended, Plus 1% Borax				
Product extended with 50% 3/8" pea gravel aggregate.				
Testing Results				
Property		**Test Specifics**	**Test Age**	**Lab Test Result**
Compressive Strength (psi)	ASTM C39	-	1 day	3,100
		-	7 day	3,640
		-	28 day	4,710
Flexural Strength (psi)	ASTM C78	-	28 day	585
Bond Strength (psi)	ASTM C882	Repair Material to Ordinary PCC	1 day	1,030
Repair Material to Ordinary PCC			7 day	1,310
Bond Strength (psi)		Repair Material to Repair Material	1 day	1,120
Repair Material to Repair Material			7 day	1,610
Splitting Tensile (psi)	ASTM C496	-	28 day	490
Modulus of Elasticity (ksi)	ASTM C469	-	28 day	3,700
Time of Set (min)	ASTM 403	-	Initial	150
		-	Final	300
Slump (inch)	ASTM C143	Within 5 min of added water	Inch	6
Length Change (%)	ASTM C157	Stored in air	28 day	0.022
			64 weeks	0.013
Length Change (%)	ASTM C157	Stored in water	28 day	0.036
			64 weeks	0.063
Coeff. of Thermal Expansion	ASTM C 531	in/in/ °F-1	-	8.5
Freeze-Thaw Resistance	ASTM C666	Proceedure A, based on 300 cycles	Durability Factor @ # cycles	DF 11 @ 43 cycles

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters

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14. ABSTRACT
Magnesium phosphate cements (MPCs) have been used for decades in proprietary products for pavement repairs. However, products with high exothermic temperatures have short working times, and research is needed to overcome these unfavorable characteristics. The effects of different boric acid and water contents on the fundamental properties of concrete was investigated through 34 trial batch modifications on the following commercially available MPC products: (1) Premier Magnesia's PREMag PGDM, (2) BASF Master Builder's MasterEmaco T545, and (3) CeraTech Inc.'s Pavemend TR. Overall results indicated that the increase of boric acid and water content produced favorable decreased temperatures and increased set times but retardation in the early age development of compressive strength.

Modifications in the PREMag PGDM product resulted in poor workability, inaccurate time of setting due to a thixotropic nature, and unacceptable compressive strength loss. The Pavemend TR product was significantly affected by the addition of boric acid resulting in non-recoverable compressive and bond strength loss, excessive expansions, failure at low freezing and thawing cycles, and unacceptable times of setting for rapid-repair applications. The T545 product showed promising performance with 28-day recovery in compressive, flexural, and bond strengths and minimal differences in other properties when compared to the control mixture.

15. SUBJECT TERMS
Magnesium phosphate cement (MPC)
Proprietary products
Water
Magnesium phosphate
Concrete--retarders
Concrete--mixing
Concrete--trial batching
Boric acid
Runways (Aeronautics)—Maintenance and repair
Concrete--mechanical properties
Strength properties
Setting time
Cement--mechanical properties
Military bases

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