Report No. CDOT-2006-4
Final Report

EVALUATION OF PRODUCTS THAT PROTECT CONCRETE AND REINFORCING STEEL OF BRIDGE DECKS FROM WINTER MAINTENANCE PRODUCTS

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DEPARTMENT OF TRANSPORTATION
RESEARCH

December 2006

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOT-2006-4		

4. Title and Subtitle	5. Report Date
EVALUATION OF PRODUCTS THAT PROTECT CONCRETE AND REINFORCING STEEL OF BRIDGE DECKS FROM WINTER MAINTENANCE MATERIALS	December 2006
	6. Performing Organization Code
7. Author(s) William S. Caires, CET Stanley R. Peters, P.E.	8. Performing Organization Report No. CDOT-2006-4
9. Performing Organization Name and Address Construction Technical Services 7108 S. Alton Way, Suite B Centennial, Colorado 80112	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222	13. Type of Report and Period Covered Final Report, October 2004-December 2005 14. Sponsoring Agency Code Study # 80.15

15. Supplementary Notes

Prepared in cooperation with the US Department of Transportation, Federal Highway Administration

16. Abstract:

The Colorado Department of Transportation (CDOT) is faced with a conflicting challenge: (1) provide winter driving safety, which is enhanced by applying effective deicers such as magnesium chloride and (2) provide a durable, cost-effective transportation system, which is adversely affected by these same deicers. While nationwide research is underway on the effects of magnesium chloride, CDOT must continue deicer application, and simultaneously design, build, and maintain durable structures before this research is complete.

This study was initiated to develop performance-based testing procedures to aid CDOT's concrete selection and protection process. The study was also to evaluate commercially available products developed to resist deicer deterioration in parking garages, which may extend the service life of concrete bridge decks, and lower their life-cycle costs. Two parameters were tested that are significant to bridge deck and steel deterioration: chloride intrusion (that causes corrosion in the reinforcing steel), and loss of surface abrasion resistance (wear).

Implementation:

The results of this study indicate that surface abrasion testing can readily be implemented on both laboratory samples and on field projects, to assess the resistance of various concrete mixtures and coatings to vehicular traffic wear. The rapid chloride permeability test proved valuable to assess the resistance to chloride penetration of these same concrete mixtures and coatings. This test can also be used on laboratory and field-based samples.

17. Keywords	18. Distribution Statement
concrete abrasion resistance, chloride intrusion, C1202 rapid chloride permeability, magnesium chloride, ponding	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	89	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Report No. CDOT-2006-4

Sponsored by the
Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

December 2006

Colorado Department of Transportation
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ACKNOWLEDGEMENTS

The Colorado Department of Transportation (CDOT) and the various product manufacturers provided funding for this study. The laboratory work began at Lafarge North America's Western US Laboratory, where concrete specimens were fabricated using approved CDOT mix designs as the baseline concrete. Lafarge helped bring a commercially-available approach to this product evaluation that we desired. Very special thanks go to Matt Nilsen who coordinated Lafarge's mixture modifications with the various manufacturers, mimicking what would normally occur in practice. Substantial help and support to this research were provided by the research oversight committee chaired by Naser Abu-Hejleh and including Greg Lowery, Rich Griffin, Matt Greer, Gary DeWitt, Ahmad Ardani, Ali Harajli and later Glenn Frieler. Special thanks to Greg Lowery (formerly with CDOT), who championed this study. Thank you all.

Executive Summary

CDOT is faced with a conflicting challenge: to provide winter driving safety, which is enhanced by applying effective deicers such as magnesium chloride, and provide a durable, cost-effective transportation system, which is adversely affected by these same deicers. While there is research underway nationwide on the effects of magnesium chloride on concrete, especially "first year" concrete placed in the fall months, CDOT needs to continue applying magnesium chloride for public safety, and build and maintain durable concrete structures before the findings and recommendations of the nationwide, long-term research are known.

OBJECTIVES

The objectives of this study were to identify commercially available products and/or systems that could readily be utilized to improve the durability of CDOT's bridge decks in resisting the effects of deicing products. Construction Technical Services (CTS) was to determine physical effectiveness and relative costs, whereas CDOT would later determine cost effectiveness of the options. Many commercially available products have been developed for special concrete applications, such as parking garages, which increase the concrete's resistance to deterioration caused by magnesium chloride and other deicing salts. While these products add to the initial cost of the concrete, they are often considered cost-effective in increasing the service life of the structure, or at least reducing premature deterioration. Several of these products were tested in comparison to four CDOT bridge deck systems. The principal mechanisms of bridge deck failure are surface deterioration and corrosion of the reinforcing steel, due to chloride ion intrusion. The principal tests utilized in this study were resistance to surface abrasion, rapid chloride permeability (RCP), and long-term ponding with full strength magnesium chloride solution.

IMPLEMENTATION

The results of this study confirm the performance of the baseline CDOT bridge deck mixes/systems, indicate some new products that show promise for implementation, and suggest that combinations of products might be the best approach to protection for Colorado bridge decks exposed to deicing chemicals. One of the products evaluated (Degussa's Degadeck) is being considered for a trial bridge deck near Eagle, Colorado.

This study has also shown the ability of the rapid chloride test American Society for Testing and Materials (ASTM) C1202 to quickly evaluate the effectiveness of coatings and surface treatments available to CDOT. The ASTM C1202 test results correlated well with the chloride penetration results of the traditional ponding test, for both topical and integral materials. The advantages of the ASTM C1202 evaluation re both time savings and the flexibility of testing core samples from in-situ treatments. Multiple products could be applied to a particular bridge deck as test patches, cored and tested by ASTM C1202 to determine the most cost-effective treatment. The time-related effectiveness of the treatment could also be evaluated, as well as determining when additional applications are warranted as part of a preventive maintenance program.

This study has led to the modification of standard testing for chloride ion content, and suggests that a third mechanism of bridge deck deterioration (surface cracking, either shrinkage or flexural) should be considered in future studies for more durable bridge deck systems.

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1.0 INTRODUCTION

Numerous concrete additives and protection systems have been developed to prolong the useful life of concrete parking structures. Several of these products and systems were tested in comparison to four current CDOT bridge deck systems to evaluate their effectiveness.

The principal mechanisms of bridge deck failure are surface deterioration, and corrosion of the reinforcing steel due to chloride ion intrusion. The test parameters evaluated in this study were resistance to surface abrasion, rapid chloride permeability (RCP), long-term ponding with full strength magnesium chloride solution, and water soluble chlorides. The objectives of this study are to compare the effectiveness of these products in reducing surface deterioration (surface abrasion resistance before and after ponding with deicers) and reduction of chloride intrusion (rapid chloride permeability and chloride ion testing at various depths). Some preliminary unit cost information was obtained within the scope of this study, but the final life-cycle cost analysis of these products will be evaluated by CDOT.

1.1 CDOT Baseline Mixes and Systems

The primary concrete mix design tested was CDOT's Class D concrete. Class D is a dense, medium-strength structural concrete, with a cementitious content range of 615 to 660 lbs (6.5 to 7.0 sack equivalent). Fly ash substitutions of up to 20% (with Class C) or 30% (with Class F) are allowed. Typically Class F fly ash is used when the aggregate constituent tests positive for potential ASR, based on the CDOT modified ASTM C1260 test (CP 4202). An approved water-reducing admixture is required to meet the maximum water-cementitious ratio of 0.44. Total air content range is between 5% and 8% for this concrete using a ¾" nominal maximum aggregate. The required minimum 28-day compressive field strength is 4,500 psi. Since the aggregates used in all testing were not prone to potential ASR problems, Class C fly ash was utilized in all concrete mixtures tested, as currently allowed by CDOT specifications.

Two of the four CDOT baseline mixes tested incorporated currently specified coatings placed topically on the base Class D concrete. First, CDOT's standard bridge decks are constructed utilizing Class D concrete covered with an approved asphaltic membrane (AM) covered by a protective felt paper protecting the membrane while paving, then covered by a hot mix asphalt (HMA) wearing course. This study incorporated the asphalt membrane and protective paper, installed by an approved CDOT contractor. The CDOT approved contractor (ABCO) applied these materials to both the primary concrete panel and the ASTM C1202 rapid chloride permeability (RCP) specimen. The second CDOT baseline system tested involved a coating of high molecular weight methacrylate (HMWM) placed on the concrete test panels upon completion of the specified curing period. HMWM coatings are required when surface cracks are encountered in a concrete deck, prior to the application of the asphaltic membrane (AM) in the field. Attempts to purposely induce plastic shrinkage cracks, by forcing air across the surface of the test panel were partially successful but not as prevalent as desired to verify the depth of penetration into the cracks.

The final CDOT baseline concrete mixture tested was Class H concrete with silica fume. Class H is intended for bridge decks that will not receive coatings as described above. Cementious contents required are: 450-500 lbs of Type II Portland cement, 90-125 lbs of fly ash (type not specified), and 20-30 lbs of silica fume; total content of these three components shall be 580-640 lbs. The required minimum 56-day compressive field strength is 4,500 psi. The laboratory mixture must not exceed 2,000 coulombs at 56 days as determined by the ASTM C1202 RCP test, and shall not exhibit a crack within 14 days when tested by the crack tendency test (AASHTO PP34). Since this Class H mix design had previously passed the crack tendency test, this test was not repeated for the purpose of this study.

An additional CDOT concrete mixture was included with this study. The Rocky Mountain Concrete Promotion Council funded testing of Class B concrete, which observations made on construction projects indicate it may be less resistant to deicer applications than Class D or Class P concretes, both with higher strength requirements (4,500 psi and 4,200 psi) and minimum cement contents, and maximum water-to-cement (w/c) ratio of 0.44 for both mixes. Conversely, Class B requires only 3,000 psi for field strength, has a minimum cement content of 565 lbs/CY (6.0 sack), has no specified w/c ratio, but similar 5-8% air content requirements. In fairness, Class B applications are mainly in flatwork applications. Therefore, on-site water additions are common to facilitate placement and finishing characteristics. However, in doing so, placing practices often decrease the Class B's resistance to deicer attack. Class B commonly achieves 3,000 psi or greater based on laboratory tested cylinders even as field placement practices of adding water continue.

1.2 Commercial Products Evaluated

Micron3 is an ultra-fine Class F fly ash, produced by air classification to an average size of three microns. It is used commercially as an alternate to silica fume, where low permeability and greater resistance to chloride penetration is required. It does not create the "sticky" surface of the concrete paste that makes silica fume mixtures relatively difficult for contractors to finish.

Type K is shrinkage-compensating cement used to control or eliminate shrinkage cracks in bridge decks and other structural slabs, where cracks or control joints are detrimental.

Caltite is a liquid integral water-proofing admixture added to concrete during batching. Manufacturer claims indicate that Caltite provides freeze-thaw resistance to concrete without entrained air.

Hycrete is an integral water-proofing admixture. Its chemistry creates entrained air. A de-foaming agent is utilized to control the air content to levels desired.

Two late entries to this program came from Degussa. Degussa's silane sealer product was initially tested for chloride permeability and surface abrasion tests to determine how it compared to the Class D panel coated with HMWM. While the silane outperformed the HMWM in the RCP test and offered significantly better abrasion resistance, Degussa decided to enter the full evaluation process with their DegaDeck MMA bridge deck overlay system and the silane sealer was discontinued.

DegaDeck MMA is “a rapidly curing methacrylate reactive resin formulated as an overlay and traffic wearing surface for concrete structures”. It is applied in a three-part process, including small, highly abrasion resistant aggregates, embedded in and sealed with the methacrylate resin, resulting in an overlay layer approximately a quarter-inch thick. It reportedly has been used by several western state Departments of Transportation (DOT), with up to 20 years of service.

One manufacturer’s surface coating system began the initial evaluation but dropped out at the 3-month period, in accordance with the study panels’ agreements, when it was found not having any significant advantages over other products being tested.

More information of these products can be found in Appendices 6.3.1 through 6.3.5. CTS did not review nor confirm any of the information provided by the manufacturers, but included them for the convenience of the readers of this research report.

2.0 TESTING PROGRAM

2.1 Sample Preparation

Since the intent of this study was to evaluate the performance of commercially available products, the baseline CDOT samples were fabricated using currently approved CDOT Class D and Class H mix designs produced by Lafarge. In an effort to maintain consistency in the eight Class D panels determined for testing, CTS purchased a half-truckload of Lafarge's CDOT Class D mixture. Class H and Class B concretes were batched in a laboratory mixer according to the current CDOT approved mix designs. With the exception of requiring one additional person to assist finishing the eight Class D panels, all test panels were finished by Mr. Peters to provide as much surface consistency as possible.

Product panels other than the CDOT panels were included for comparison. Lafarge's Class D mixture was used with modifications as necessary in accordance with the manufacturers' recommendations. Class H was the starting point for the Micron3 product evaluation. Any and all concrete mixture adjustments were made by Mr. Nilsen of Lafarge.

A sufficient number of 4" by 8" test cylinders were fabricated for RCP and subsequent compressive strength testing. The test panels for ponding and abrasion testing measured 22" by 32" by 3.5" thick. Test panels for Class H, Micron3 and Type K concretes were wet-cured for 14 days, per both CDOT and manufacturer's recommendations. All other panels received a double application of a liquid curing compound from CDOT's approved products list. A mat of #3 reinforcing bars were placed at mid-depth in the Type K test panel, to provide the initial restraint to expansive forces, as recommended by the manufacturer's representative. The Type K mixture had a higher w/c ratio than the Class D specification permits (0.48 vs. 0.44 maximum); this was recommended by the manufacturer to provide sufficient moisture to aid the cement hydration during first seven days.

The Class B mixture was developed to a 3.5" slump at a w/c of 0.48 (without utilizing a water reducer normally added by Lafarge). In hindsight, additional water should have been added to achieve a greater than 4" to 6" slump, better replicating the field mixtures that often have problems.

In an effort to simulate a bridge deck construction worst-case scenario (opening to traffic within two weeks, and deicer application within another two weeks) the research oversight committee agreed to terminate curing within two weeks and begin ponding operations within four weeks of panel fabrication. Termination of the three wet-cured panels was straightforward. The liquid curing compound was removed at 14 days by light sand blasting. The topical coatings, AM, HMWM, and DegaDeck MMA, were applied to the sandblasted surfaces. One Class D panel was saved as a control, without ponding.

2.2 Conventional Testing and Results

The fresh property test results, the actual mix designs used, and compressive strengths are listed individually in Appendix 8.2 and collectively summarized in Appendix 8.1. Class D achieved its highest strength by 56 days, whereas most of the other mixtures continued to show modest strength gains from 56 to 168 days. Base-level chloride ion contents were based on drilled samples from test cylinders cast from each mixture.

2.3 Study-Specific Testing and Results

2.3.1 Rapid Chloride Permeability (RCP) Test, ASTM C 1202

Samples for this test were obtained by sawing off the top 2 inches of test cylinders that were wet-cured for 14 days and then allowed to air-dry for an additional 14 days prior to sample preparation. This designed short curing period retarded the hydration of the test panels and ASTM C1202 test specimens; resulting in higher permeability and coulombs passed than would normally have been achieved if standard 28 or 56 day curing had occurred based on previously published test data. As previously mentioned, manufacturer's representatives and ABCO installed the various topical coatings submitted for testing. The results of Class D were based on the average of two specimens tested; a single sample was tested for all other mixes. ASTM C1202 reporting requirements include listing the (relative) Chloride Ion Penetrability, as found in the test procedure's Table 2.1, summarized below:

Table 2.1 - Relative Chloride Ion Penetrability Levels

Charge Passed (coulombs)	Chloride Ion Penetrability
> 4,000	High
2,000 - 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very Low
<100	Negligible

These test results and relative chloride ion permeability are reported individually and summarized collectively with the conventional testing results.

2.3.2 Resistance to Surface Abrasion, ASTM C779, Procedure C

The ASTM C779 test procedure involves abrading the concrete surface with eight hardened steel balls held in a retaining ring mounted on a drill or coring rig. The abrading process is completed by loading the abrasion rig to a net weight of 27 pounds (total pounds force on abrasion surface), rotating the abrasion head using free flowing water cooling and lubrication until one or both of the following is achieved: twenty minutes or an abrasion depth of 0.120". Time versus depth measurements are plotted for at least three trials and the laboratory is to determine and use the "average" line for interpretations. The "velocity of wear" (VOW) (depth at 20 minutes, divided by 20 minutes) was determined. Abrasion trials lasting the full twenty minutes made calculating the VOW simple, for tests terminated prior to 20 minutes due to attaining a depth of 0.120" a similar velocity of wear could be calculated, but it would be a dissimilar linear representation. Clearly the abrasion plots were curvilinear, best represented by the logarithmic function. The data reporting we felt most appropriate involved plotting the data as required by C 779. We calculated the average depth at each time interval until the point at which a trial exceeded a depth of 0.120”. This average of trials was then projected out to the 20-minute limit. The projected depth was listed for each abrasion plot presented, representing the “average” amount of wear that would be anticipated to occur if all trials tested out to the 20 minutes.

Since concrete with more abrasion resistance would result in a shallower depth of abrasion at 20 minutes and a lower abrasion velocity (inches/minute), we calculated an “Abrasion Index” (AI, minutes/inch), which is equal to the numerical inverse of the 20-minute projected average velocity. Hence, the higher the AI, the more resistant the concrete is to abrasion.

The abrasion test was performed on the various concrete panels before and after 6-months of magnesium chloride ponding. On the After-Ponding graphs, a percentage of abrasion resistance retained is reported in the title information, which was calculated as the ratio of the after-ponding AI to the before-ponding AI. Graphical presentations of these test results are attached with the individual conventional test results and collectively summarized.

2.3.3 Long-Term Ponding and Chloride Ion Content, AASHTO T259 and ASTM C1218

After the initial abrasion resistance tests were performed, shallow dams were constructed around the edges of each test panel with a liquid-tight seal provided by a concrete joint sealing compound. A foam rubber seal was added to the top of the dam material to prevent moisture loss between the glass cover plate and the dam.

The notable deviation from the AASHTO method was the use of full-strength magnesium chloride as sampled from the CDOT maintenance facility on Santa Fe Drive. Magnesium chloride was selected for use in this study because it is commonly used as the deicing chemical in the Denver area, therefore being applied in service to the corresponding concrete mixtures that were being tested. AASHTO test procedure states that a three percent sodium chloride solution be used. Test results provided to CTS by CDOT maintenance staff indicated that the delivered magnesium chloride deicer was a 29% concentration by weight of magnesium chloride with a freezing point of 0^{o}F meeting CDOT's criteria of 28% or greater concentration.

The as received magnesium chloride was added to each dammed panel to full coverage (ponding) then covered with a glass plate. Chloride ion sampling required CTS to remove the ponded solution; this was accomplished by vacuuming it off. The target sampling area was cleared with compressed air, prior to cleaning with ethyl alcohol as specified by ASTM C1218 for cleaning the sampling tools. The target sampling area was selected at least four inches away from previously sampled or tested areas to prevent potential lateral contamination from previous test holes (holes were filled with a latex type self leveling concrete joint filler/sealer after testing to prevent or minimize exposure). Rubber gloves were used to prevent contamination by skin contact. Two holes per panel were sufficient to obtain the required amount of material for laboratory testing. Upon completion of sampling, the joint filler/sealer was used to fill each hole. Test holes were filled to overflowing and allowed to cure before reinstating the magnesium chloride deicer for the next month ponding. As requested by the research oversight committee, fresh magnesium chloride was used for each month's ponding process.

As discussed at the mid-research review meeting, test results at one and two months were erratic and exhibited signs of possible vertical contamination as dust from upper levels of sampling fell to lower levels. Based on this observation, a change in the sampling was implemented for month no. three to conclusion. Compressed air was used to remove all residual dust from each hole and the surrounding surface area prior to drilling to and sampling the next depth. The main cause of variation in test results at month nos. three and four was attributed to the effects the larger coarse aggregate (¾”) and drilling only two ½” holes, sampling at ½” intervals. Based on this observation, CTS agreed to increase the number of drill holes for sampling to five per panel for the fifth and final sixth month results. The research committee requested that the final 6 month chloride ion samples on the four CDOT baseline panels also be sampled by coring the panels and cutting slices from the 4” diameter cores to the required depth intervals. The slices obtained from each tested depth interval were pulverized and tested in association with the drilled samples so that drilled sample versus cored sample comparisons could be made.

Prior to the after-ponding abrasion testing and chloride ion sampling on the AM panel, the membrane was mechanically removed and the concrete surface chemically cleaned. Therefore, for all intensive purposes, all traces of magnesium chloride on the surface of the test panel were eliminated.

2.4 Test Results

2.4.1 Summary Table

The test results of each baseline and specific product evaluated are summarized in Appendix 7.1. Fresh physical properties and compressive strengths out to six months are reported, as well as the abrasion resistance, rapid chloride permeability and monthly chloride ion contents at the deepest interval sampled during ponding.

The summary table also lists the chloride ion contents of the four CDOT baseline systems when sampled by coring vs. drilling methods previously described. Since the asphalt membrane prevented any chlorides from penetration, the adjustment of drilled vs. cored results was based on the remaining three comparison samples.

The test results of 0.005% were assumed to have a value of 0.003%, when calculating the average difference of 0.010% between drilled samples vs. cored samples for chloride ion. This adjustment was applied to the drilled test results of the proprietary products tested to estimate what the six-month full depth chloride ion results could be if cored and tested.

2.4.2 Individual Mix and System Results, with ASTM C779 Graphs

The concrete mix proportions for each mix tested, fresh physical properties, and compressive strength results are found in Appendix 7.2 along with details of abrasion testing and monthly chloride ion test results at various depths. Also found in Appendix 7.2 are the ASTM C779 abrasion resistance test graphs, completed before and after ponding. These graphs plot each abrasion trial performed, as well as the logarithmic projection.

3.0 COST ANALYSIS

The first step in the cost analysis was to request typical pricing of the propriety products tested, if sold to Lafarge in quantities suitable for a typical bridge deck. The vendors provided the typical unit costs, which were converted into an incremental cost per cubic yard.

Typically the unit cost of bridge deck concrete is project specific, depending on shipping distance, times of placement, truck cycle times, and other factors. We contacted Mr. Matt Riebe, Concrete Sales Manager for Lafarge North America, for typical "contractor" pricing for their CDOT approved Class D concrete from their Quivas Street location (the same location of the aggregates and Class D concrete used in this study). Lafarge already markets Class H mixes to CDOT contractors, as well as mixes with Micron3 and Caltite to commercial contractors. Mr. Riebe incorporated the material cost per cubic yard (previously calculated for the other products) and added typical handling costs and administrative mark-up, to arrive at a comparable "contractor price". See Table 3.1 below.

Table 3.1 - Cost Comparison of Concrete Protection Products

Product	**Approximate Cost, $/CY**	**Approximate Cost, $/CY (Average)**	**8" Thick Deck Cost, $/SY**	**Cost % of Class D**
Class D	85	85	$18.89	100%
Class H	130	130	$28.89	153%
Micron3	135	135	$30.00	159%
Type K	130-140	135	$30.00	159%
Caltite	205	205	$45.56	241%
Hycrete-1	130-135	132.5	$29.44	156%
Hycrete-2	150-160	155	$34.44	182%
DegaDeckMMA	NA	N/A	$99.00	624%
Notes :	Degussa's DegaDeck product was estimated at $10-$12/SF; $11/SF used DegaDeck is installed over an existing concrete deck. Cost % includes Class D deck material. Approximate Cost, $/CY column provides the typical contractor pricing for existing mixes; ranges for new mixes/materials.			

4.0 THRESHOLD LIMITS OF CHLORIDE ION CONTENT

Extensive literature review was conducted and reported in the CDOT-DTD-R-2004-1 Final Report, dated January 2004. Their summary of critical chloride contents is listed in Table 4.1, below.:

Table 4.1 - Critical Chloride Content Levels

	Critical Chloride Content	**Critical Chloride Ion Content**
Berke (1986)	0.9 – 1.0*	0.040% - 0.052%
Browne (1982)	0.4% (weight of cement)	0.058% - 0.068%**
FHWA	0.3% (weight of cement)	0.044% - 0.051%**
ACI (1994)	0.15% (weight of cement)	0.022% - 0.026%**
Cady & Weyers, (1992)	Not Reported	0.025% - 0.050%**

* kg of chloride content per cubic meter
** Based on 565-660lb cementitious contents of mixtures studied, and concrete of an average 3,870 lbs/CY

Based on the drilled sample data, comparing the six month chloride ion contents at the 1.5”-2.0” depth, all of the mixtures and systems studied would be in substantial compliance with the American Concrete Institute (ACI) 318 guidelines. If a drill-core sampling adjustment is used, all test results are well within these ACI guidelines for chloride ion contents at the depth aforementioned.

Estimates of the service life modeled by the six months of ponding with full strength deicer are somewhat arbitrary. Assuming deicers would be applied to a bridge deck once a week, through a typical three-month snowy winter, each season would result in approximately 12 applications. The six-month ponding occurred over approximately 180 days, indicating approximately 15 years of applications. However, the full strength concentration was on the panels 24 hours per day, whereas the deicer on the deck may only be at full strength for two to twelve hours before being diluted by melting snow. Similarly, more than one application per week may be more typical of many bridges. Insufficient data exists to further improve this estimate.

Likewise, extrapolating this data to the deicer’s impact for fifty years is also difficult. Chloride penetration is not a linear function, which means it is not directly proportional to time of exposure. Chloride penetration rates should decrease with both time and depth, as best predicted by ACI 365 methods. Such predictions were beyond the scope of this product evaluation study.

5.0 SUMMARY AND CONCLUSIONS

5.1 Abrasion Resistance

Various Class D panels (without deicer applications) were tested for abrasion at three different ages, as summarized in the Table 5.1 below.

Table 5.1 - Abrasion Index Data and Basic Statistical Analysis

Panel Description	Age Tested, ~months	Abrasion Index (AI) , minute/inch
CDOT Baseline Panel	1	190
CTS Freeze-Thaw Panel	1	149
CTS Bare-Control	1	174
DegaDeck MMA Control	4	185
CTS Bare- Control	7	172
Average / Standard Deviation / COV%		174.0 / 15.9 / 9.1%

The ASTM C779-00 precision and bias statement indicates a within laboratory, single operator coefficient of variation (COV) of 17.74% being acceptable. The test results summarized above represent four different panels, tested by two operators at three different ages. The COV of 9.1% demonstrates the repeatability of the test procedure.

CDOT panels performed substantially the same before and after ponding, with the exception of the HMWM panel. The HMWM panel's surface was softened by the HMWM application in some manner, achieving an AI of 120, lower than the observed values for the Class D ranging from 149 to 190. Upon completion of the six months of ponding, the HMWM panel attained an abrasion resistance of 177, falling in line with the Class D panels. Otherwise, the Class D, B and H panels retained 80% to 96% of their initial abrasion resistance after ponding.

Micron3 & Type K performed slightly better than CDOT panels prior to ponding with AI values of 200 and 217 respectively. The integral waterproofing admixture panels (Caltite & Hycrete) exhibited significantly better AI values (compared to that of CDOT panels prior to ponding) with AI values of 274, 282 and 364. The DegaDeck MMA bridge overlay product attained ~2.5 times more wear resistance than CDOT panels prior to ponding with an AI value of 465 and after ponding achieved an AI value of 571.

The denser mixes (Class H & Micron3) retained a higher percentage of their abrasion resistance after ponding with retained abrasion percentages of 87% and 96%.

The integral waterproofing admixture panels (Caltite & Hycrete) exhibited significant loss of abrasion resistance after ponding (33 to 58 percent retained). A possible cause: a chemical reaction between the magnesium chloride and the chemistry of the microscopic crystals formed within the concrete capillaries, other wise the cause is not known by the research team at this time.

The silane treatment tested on the Class D concrete improved the abrasion resistance from an average of 174 to 238, an increase of 37%.

5.2 Rapid Chloride Permeability

All numerical results of coulombs passed in six hours were grouped into the qualitative ranges (summarized below) as suggested by ASTM C1202-97.

Table 5.2 - Relative Chloride Ion Penetrability

Charge Passed, coulombs	**Chloride Ion Penetrability**
> 4,000	High
2,000 to 4,000	Moderate
1,000 to 2,000	Low
100 to 1,000	Very Low
< 100	Negligible

The HMWM and silane coatings significantly reduced the permeability from High to Moderate. The AM and DegaDeck MMA coatings reduced the permeability from High to Negligible (both achieved "0" coulombs). Class H and Hycrete-2 exhibited low permeability with remaining products exhibiting Moderate permeability.

5.3 Chloride Ion Content by Ponding

As previously discussed, we conclude that the results of testing in month nos. one and two were adversely affected by unforeseen sampling variables which were substantially reduced in subsequent months. Chloride ion contents decreased with depth; substantially concentrated in top 1/2".

Based on the information gathered, it appears that the chloride ion penetration at 1.5 to 2.0" occurs in the first three months. No significant increases in concentrations were observed from 3 to 6 months. This suggests that in the future a 90-day product evaluation may suffice.

Chloride samples from the AM panel were obtained by drilling through the membrane in month nos. one through five. The membrane was mechanically removed and the concrete surface chemically cleaned prior to six month abrasion and chloride sampling. Drilled and cored chloride ion results from the AM panel indicate that the membrane is effective in preventing the migration of chlorides into the concrete.

Comparison of drilled versus cored samples indicates there may still be issues with surface and/or hole enlargement variability, in spite of efforts to clean and protect against this condition. In the future, although drilling for chloride ion samples is acceptable, cored samples should be used to minimize variability and increase consistency. However, the cost of coring and sample processing is substantially greater than drilling. Based on the three CDOT panels tested by coring we've calculated an adjustment to the drilled-only samples that should be considered when evaluating the final results.

Industry sources state that 1 to 1.5 pounds per cubic yard (pcy) is the chloride ion thresholds for the initiation of rebar corrosion. This equates to ~0.025 to 0.04 percent. In review of the final data of CDOT core samples and the adjusted drilled samples, all products were effectively under the aforementioned thresholds.

6.0 RECOMMENDATIONS

Evaluations of bridge deck systems need to include shrinkage in addition to abrasion resistance, chloride ion testing by coring, and rapid chloride permeability testing. Concrete mixes need to be developed to minimize drying shrinkage and permeability (high density, low shrinkage) as a second line of defense against chloride intrusion. However, membranes appear to be the most effective method of preventing the direct intrusion of deicing chemicals through cracks that always occur.

The concrete panels used in this study were too small to allow for shrinkage, nor were any flexural loads applied that would develop structural cracks. Thus, the acceptable chloride ion results achieved in this study at depth may be somewhat misleading. Future evaluations should include the use of or solely use small laboratory beam specimens representative of a standard cross section of a bridge deck where cracking can be induced and chloride intrusions measured at the crack location.

Additional research could incorporate beams developed to mimic the cross section of a bridge deck (6” wide, 6” or variable depth with applicable reinforcing and comparable cover). Cracking would be induced with center point loading allowing for precise location of cracking for core sampling and evaluation. Beams would be subjected to 90 days of ponding with and without membranes. Membranes should be applied before induction of cracks to determine their ability to survive cracking. These test beams could readily be cycled in a freeze-thaw chamber to determine temperature effects on the membranes. Abrasion resistance could readily be measured on the top surfaces of these test beams as well. This should best evaluate the system for its ability in preventing the intrusion of detrimental levels of chlorides through cracks.

7.0 REFERENCES

1. ASTM C 779-00 Standard Test Method for Abrasion Resistance of Horizontal Concrete Surfaces
2. ASTM C1202-97 Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
3. AASHTO T 259-02 Standard Test Method for Resistance of Concrete to Chloride Ion Penetration
4. ACI 365.1R-00 Service-Life Prediction – State-of-the-Art Report
5. Babaei, K. and Hawkins, N. (1987) "Evaluation of Bridge Deck Protective Strategies", NCHRP Report 297
6. Whiting, D., Ost, B., Nagi, M., Cady, P. (1992) "Methods for Evaluating the Effectiveness of Penetrating Sealers", Volume 5 of Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, SHRP-S/FR-92-107
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8.0 Appendices

8.1 Summary Table of Laboratory Test Results

6160	6160	6160	7005	4460	6140	4940	6980	6125	6140	6160	6160
6565	6565	6565	7975	5240	7850	5970	8025	6865	6525	6565	6565
6500	6500	6500	7660	5305	7910	5955	8210	6850	7010	6500	6500
6540	6540	6540	7610	5525	8165	6385	8915	7170	6920	6540	6540
0.105"	NA	0.166"	0.106"	0.123"	0.100"	0.092"	0.073"	0.55"	0.071"	0.134"	0.043
190	NA	120	189	163	200	217	274	364	282	149	465
0.132"	0.127"	.113"	0.111"	0.153"	0.115"	0.131"	0.140"	0.165"	0.122"	0.092"	0.035"
152	157	177	182	130	174	153	143	121	164	217	571
80%	NA	148%	96%	80%	87%	71%	52%	33%	58%	146%	123%
Class D	Class D w/AM	Class D-HMWM	Class H	Class B	Micron 3	Type K	Caltite	Hycrete-1	Hycrete-2	Class D-CTS-F/T	DegaDeck
7409	0	2889	1298	4845	2209	3738	2278	2161	1820	7409	0
High	Negligible	Moderate	Low	High	Moderate	Moderate	Moderate	Moderate	Low	High	Negligible
<0.005%	<0.005%	<0.005%	0.005%	0.005%	<0.005%	<0.005%	0.005%	0.005%	0.008%	<0.005%	<0.005%
0.215	0.138	0.171	0.253	0.239	0.02	0.038	0.034	0.081	0.059	0.005	0.005
0.306	0.165	0.413	0.260	0.281	0.496	0.330	0.101	0.058	0.144	NA	0.005
0.007	0.022	0.014	0.049	0.027	0.023	0.027	0.011	0.024	0.025	NA	0.005
0.009	0.030	0.014	0.021	0.022	0.027	0.011	0.035	0.018	0.031	NA	0.006
0.007	0.063	0.019	0.005	0.005	0.005	0.015	0.008	0.028	0.020	NA	0.006
0.011	<0.005	0.021	0.015	0.029	0.028	0.021	0.024	0.022	0.026	NA	<0.005%
<0.005	<0.005	<0.005	0.010	NA	NA	NA	NA	NA	NA	NA	<0.005%
NA	NA	NA	NA	0.019	0.018	0.011	0.014	0.012	0.016	NA	NA

8.2 Individual Mix and System Results, ASTM C779 Graphs

CDOT Concrete Product Evaluation

Mix/System: CDOT Class D - Control

Date Cast: 2/11/2005

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Holcim I/II	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.105"	190	0.132	152	80%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	7409	High

Water-Soluble Chlorides C1218 (After Ponding)

							Drilled	Cored
Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	6 months
0 - 0.5"		0.260	0.368	0.247	0.452	0.179	0.482	0.207
0.5 - 1.0"		0.187	0.334	0.043	0.057	0.099	0.134	0.007
1.5 - 2.0"		0.215	0.306	0.007	0.009	0.007	0.011	<0.005
Average	<0.005%							

CDOT Concrete Product Evaluation

Mix/System: CDOT Class D, with HMWM

Date Cast: 2/11/2005

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Holcim I/II	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.166	120	0.113	177	148%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	2889	Moderate

Water-Soluble Chlorides C1218 (After Ponding)

							Drilled	Cored
Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	6 months
0 - 0.5"		0.15	0.393	0.168	0.176	0.397	0.198	0.036
0.5 - 1.0"		0.11	0.429	0.036	0.023	0.212	0.018	0.005
1.5 - 2.0"		0.171	0.413	0.014	0.014	0.019	0.021	<0.005
Average	<0.005%							

CDOT Concrete Product Evaluation

Mix/System: CDOT Class D, with Asphalt Membrane

Date Cast:

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Cemex I/II	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
		NA	0.127	157	NA

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	0	Negligible

Water-Soluble Chlorides C1218 (After Ponding)

							Drilled	Cored
Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	6 months
0 - 0.5"		0.213	0.348	0.379	0.225	0.074	<0.005	<0.005
0.5 - 1.0"		0.111	0.592	0.029	0.065	0.097	<0.005	<0.005
1.5 - 2.0"		0.138	0.165	0.022	0.030	0.063	<0.005	<0.005
Average	<0.005%							

CDOT Concrete Product Evaluation

Mix/System: CDOT Class D - CTS Freeze-Thaw Method

Date Cast: 2/11/2005

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Cemex I/II	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.134"	149	0.092	217	146%

Rapid Chloride Permeability C1202

	Coulombs	Equivalent, Range
Before Ponding	7409	High

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months
0 - 0.5"							
0.5 - 1.0"							Not
1.5 - 2.0"							Tested
Average	<0.005%						

Mix/System	CDOT Class D - Bare Control (no Magnesium chloride)
Date Cast:	2/11/2005

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Cemex I/II	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

	Before Ponding		WITHOUT Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.115"	174	0.116	172	99%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	7409	High

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months
0 - 0.5"							
0.5 - 1.0"							
1.5 - 2.0"							
Average	<0.005%	NA	NA	NA	NA	NA	NA

CDOT Concrete Product Evaluation

Mix/System: CDOT Class H

Date Cast: 2/11/2005

Fresh Properties

Slump	3.5	in.
Air Content	6.0	%
Unit Weight	143.0	pcf
Temperature	69	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
Cement Holcim I/II	470	lb.
Fly Ash:PlainsPozz,Type C	110	lb.
Water	236	lb.
	28.3	gallons
AEA:Grace AT-60	7.5	oz/cy
HWRA:GraceDC-19	12	oz/cwt
SilicaFume:Force10,000	25	lb.

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	5200	6960	7800	7630	8650
B	5310	7050	8150	7690	6570
Average	**5255**	**7005**	**7975**	**7660**	**7610**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.106	189	0.111	182	96%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	1298	Low

Water-Soluble Chlorides C1218 (After Ponding)

							Drilled	Cored
Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	6 months
0 - 0.5"		0.233	0.582	0.459	0.288	0.308	0.271	0.324
0.5 - 1.0"		0.223	0.477	0.130	0.044	0.009	0.011	0.014
1.5 - 2.0"		0.253	0.260	0.049	0.021	0.005	0.015	0.010
Average	0.005%							

CDOT Concrete Product Evaluation

Mix/System: CDOT Class B

Date Cast: 2/11/2005

Fresh Properties

Slump	3.5	in.
Air Content	5.5	%
Unit Weight	141.8	pcf
Temperature	141.8	F
W/CM Ratio	0.48	

Mix Proportions per cy

3/4 Aggregate	1780	lb.
Concrete Sand	1280	lb.
Cement Holcim I/II	452	lb.
Fly Ash:PlainsPozz,Type C	113	lb.
Water	274	lb.
	32.9	gallons
AEA:Grace AT-60	3.5	oz/cy
WRA	0	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	3430	4550	5250	5220	5670
B	3360	4370	5230	5390	5380
Average	**3395**	**4460**	**5240**	**5305**	**5525**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.123	163	0.153	130	80%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	4845	High

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.094	1.34	0.322	0.318	0.530	0.421	0.293
0.5 - 1.0"		0.15	0.510	0.035	0.058	0.019	0.046	0.000
1.5 - 2.0"		0.239	0.281	0.027	0.022	0.005	0.029	0.019
Average	0.005%							

CDOT Concrete Product Evaluation

Mix/System: Micron3

Date Cast: 2/11/2005

Fresh Properties

Slump	3.25	in.
Air Content	5.7	%
Unit Weight	143.2	pcf
Temperature	69	F
W/CM Ratio	0.37	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1170	lb.
Cement Holcim I/II	470	lb.
Fly Ash:PlainsPozz,Type C	110	lb.
Water	230	lb.
	27.6	gallons
AEA:Grace AT-60	8	oz/cy
HWRA:GraceDC-19	12	oz/cwt
Boral's Micron3	38	lb.

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	5120	6320	7700	8100	8010
B	5130	5960	8000	7720	8320
Average	**5125**	**6140**	**7850**	**7910**	**8165**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.100	200	0.115	174	87%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	2209	Moderate

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.270	2.12	0.423	0.401	0.186	0.312	0.184
0.5 - 1.0"		0.230	0.576	0.064	0.135	0.037	0.104	0.058
1.5 - 2.0"		0.020	0.496	0.023	0.027	0.005	0.028	0.018
Average	<0.005%							

CDOT Concrete Product Evaluation

Mix/System: Type K Cement

Date Cast: 2/11/2005

Fresh Properties

Slump	5	in.
Air Content	5.7	%
Unit Weight	68	pcf
Temperature	139.6	F
W/CM Ratio	0.48	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1105	lb.
Cement GCC Type K	516	lb.
Fly Ash:PlainsPozz,Type C	129	lb.
Water	308	lb.
	37.0	gallons
AEA, Brand	4.6	oz/cy
WRA	0	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	3370	4900	6030	5780	6560
B	3310	4980	5910	6130	6210
Average	**3340**	**4940**	**5970**	**5955**	**6385**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.092	217	0.131	153	71%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	3738	Moderate

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.435	0.411	0.958	0.691	0.294	0.362	0.234
0.5 - 1.0"		0.106	0.305	0.093	0.057	0.022	0.075	0.029
1.5 - 2.0"		0.038	0.133	0.027	0.011	0.015	0.021	0.011
Average	<0.005%							

CDOT Concrete Product Evaluation

Mix/System: Caltite
Date Cast: 2/11/2005

Fresh Properties

Slump	4.5	in.
Air Content	3.3 (n/a)	%
Unit Weight	147.0	pcf
Temperature	67	F
W/CM Ratio	0.40	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1260	lb.
Cement Holcim I/II	516	lb.
Fly Ash:PlainsPozz,Type C	129	lb.
Water	216 / 260*	lb.
	31.2*	gallons
HRWR:Grace 19	8	oz/cwt
WPA - Caltite	6	gal/cy

* water with Caltite

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	5840	7140	8370	8100	8930
B	5790	6820	7680	8320	8900
Average	**5715**	**6980**	**8025**	**8210**	**8915**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.073	274	0.140	143	52%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	2278	Moderate

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.287	0.297	0.163	0.282	0.114	0.177	0.049
0.5 - 1.0"		0.075	0.140	0.026	0.074	0.044	0.058	0.012
1.5 - 2.0"		0.034	0.101	0.011	0.035	0.008	0.024	0.014
Average	0.005%							

CDOT Concrete Product Evaluation

Mix/System: Hycrete - 1

Date Cast: 2/11/2005

Fresh Properties

Slump	3.75	in.
Air Content	5.3	%
Unit Weight	143.2	pcf
Temperature	69	F
W/CM Ratio	0.43*	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1130	lb.
Cement Holcim I/II	660	lb.
Fly Ash:PlainsPozz,Type C	0	lb.
Water	279 / 287*	lb.
	34.5	gallons
AEA	0	oz/cy
WR:Grace DA-64	5	oz/cwt
WPA:Hycrete	1	gal/cy

* water with Hycrete

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	5100	6230	6790	6670	7380
B	5200	6020	6940	7030	6960
Average	**5150**	**6125**	**6865**	**6850**	**7170**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.055"	364	0.165	121	33%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	2161	Moderate

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.288	0.278	0.156	0.283	0.134	0.165	0.037
0.5 - 1.0"		0.101	0.073	0.085	0.027	0.018	0.040	-0.006
1.5 - 2.0"		0.081	0.058	0.024	0.018	0.028	0.022	0.012
Average	0.005%							

CDOT Concrete Product Evaluation

Mix/System: Hycrete - 2

Date Cast: 2/11/2005

Fresh Properties

Slump	2.75	in.
Air Content	3.5	%
Unit Weight	145.8	pcf
Temperature	70	F
W/CM Ratio	0.44*	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1130	lb.
Cement Holcim I/II	660	lb.
Fly Ash:PlainsPozz,Type C	0	lb.
Water	274 / 291*	lb.
	34.9	gallons
AEA	0	oz/cwt
WRA:GraceWRDA-64	5	oz/cwt
WPA:Hycrete	2	gal/cy

* water with Hycrete

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	5040	6150	6370	7090	6550
B	4970	6130	6680	6930	7290
Average	**5005**	**6140**	**6525**	**7010**	**6920**

Abrasion Testing, C779

	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.071"	282	0.122	164	58%

Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	1820	Low

Water-Soluble Chlorides C1218 (After Ponding)

Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	"Adjusted" 6 Months
0 - 0.5"		0.218	0.343	0.226	0.213	0.347	0.252	0.124
0.5 - 1.0"		0.087	0.138	0.048	0.062	0.053	0.057	0.011
1.5 - 2.0"		0.059	0.144	0.025	0.031	0.020	0.026	0.016
Average	0.008%							

CDOT Concrete Product Evaluation

Mix/System: Class D with Degussa's DegaDeck bridge overlay
Date Cast: 2/11/2005

Fresh Properties

Slump	4.25	in.
Air Content	5.5	%
Unit Weight	142.4	pcf
Temperature	73	F
W/CM Ratio	0.39	

Mix Proportions per cy

3/4 Aggregate	1800	lb.
Concrete Sand	1180	lb.
142.4	514	lb.
Fly Ash:PlainsPozz,Type C	135	lb.
Water	251	lb.
	30.1	gallons
AEA:Grace AT-60	10	oz/cy
WRA:Grace27	3.9	oz/cwt

Compressive Strengths, psi

	7 day	28 day	56 day	84 day	168 day
A	4760	6220	6330	6370	6320
B	4690	6100	6640	6750	6770
C	4400		6730	6370	6540
Average	**4620**	**6160**	**6565**	**6500**	**6540**

Abrasion Testing, C779

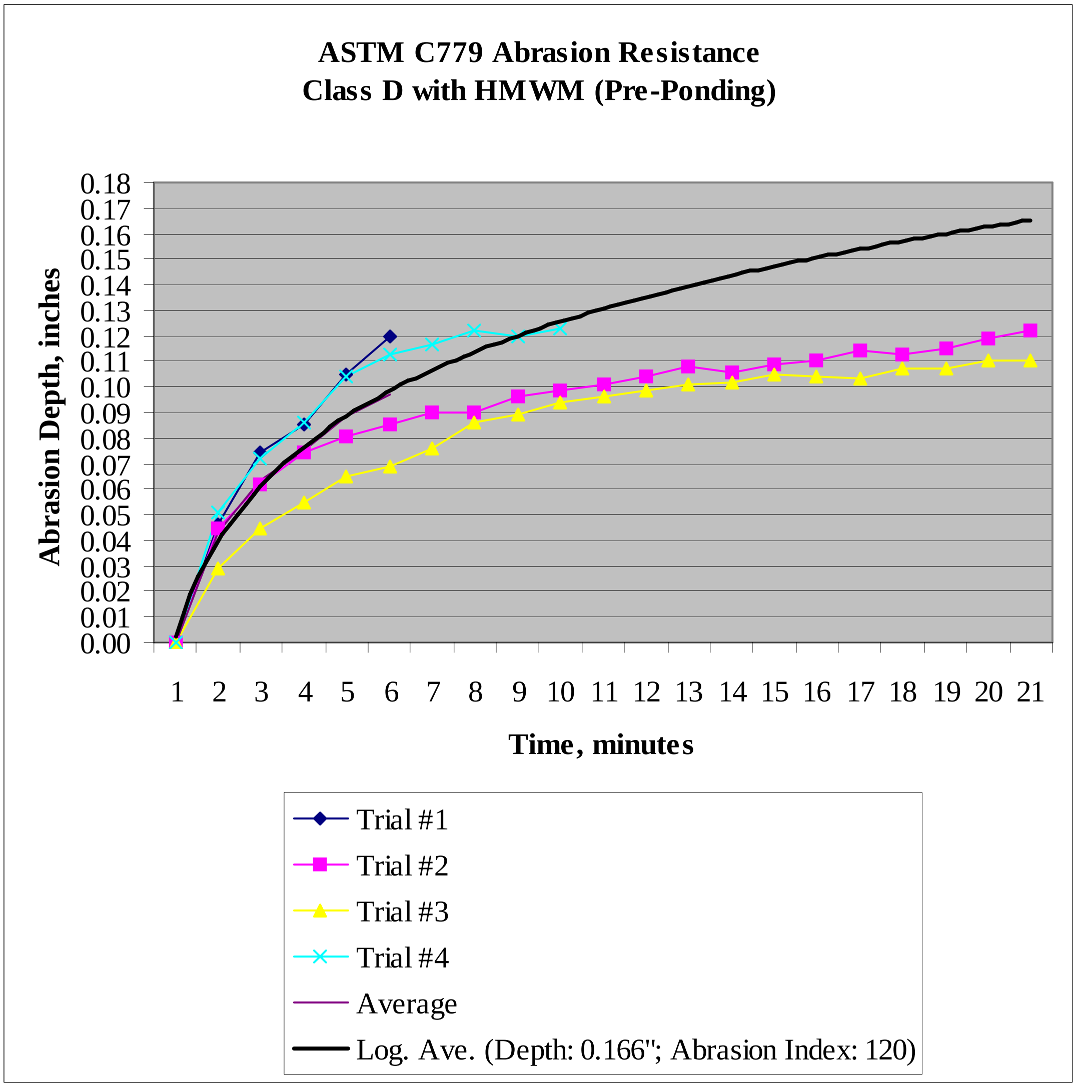
	Before Ponding		After Ponding		Percentage
	Depth @ 20 min.	Abrasion Index	Depth @ 20 min.	Abrasion Index	Retained A.I.
	0.043"	465	0.035"	571	123%

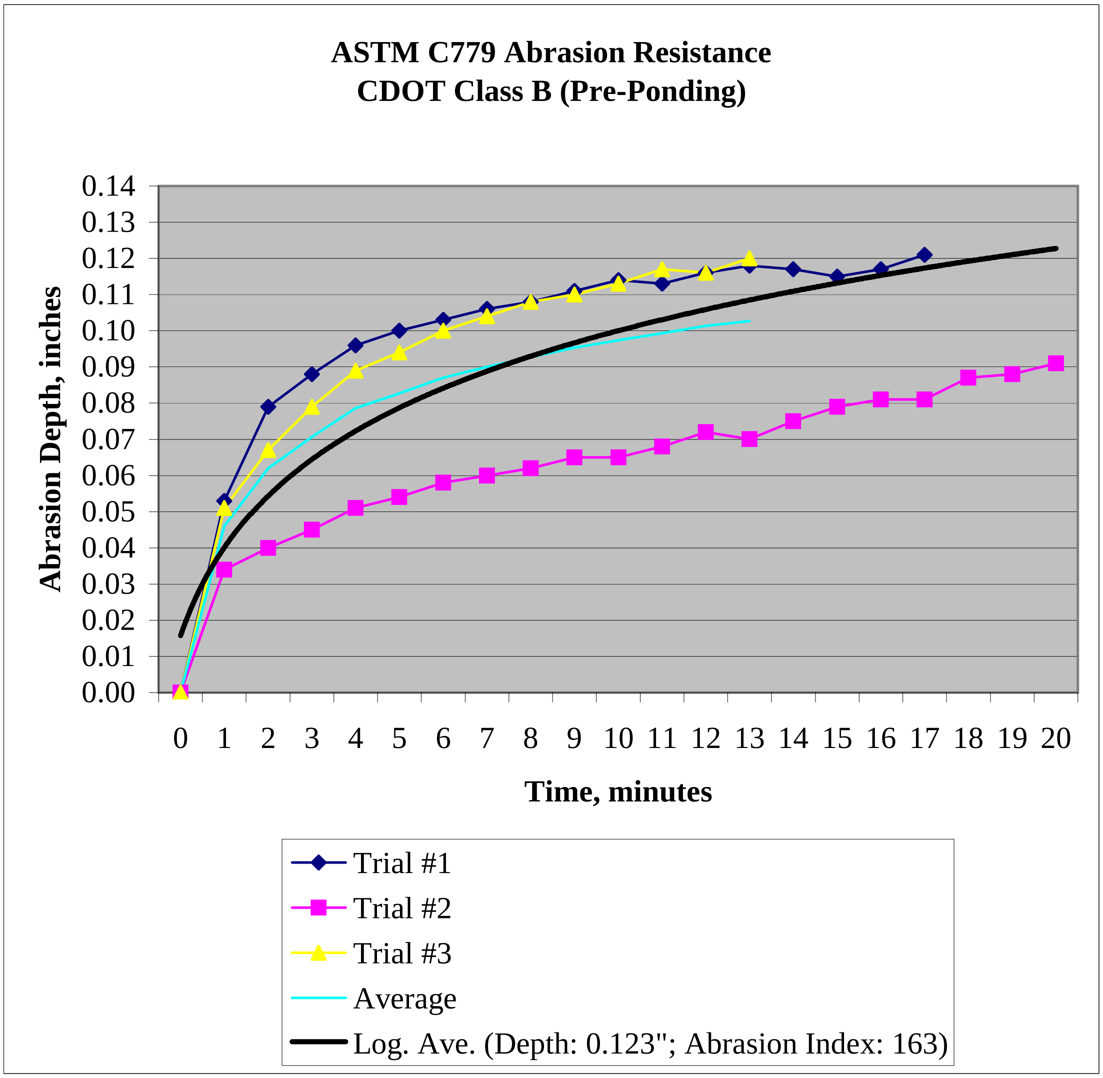
Rapid Chloride Permeability C1202

	Coulombs	Chloride Penetrability
Before Ponding	0	High

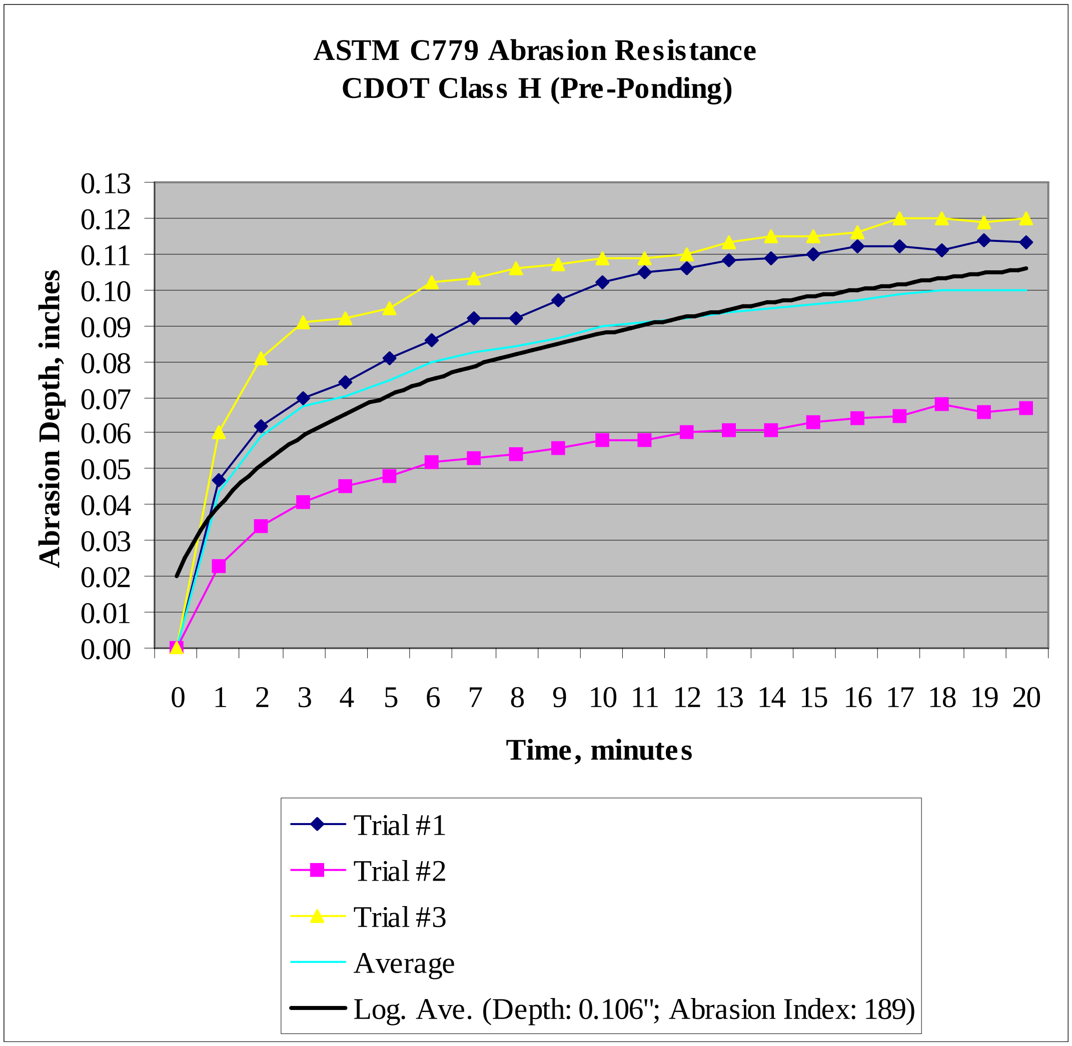
Water-Soluble Chlorides C1218 (After Ponding)

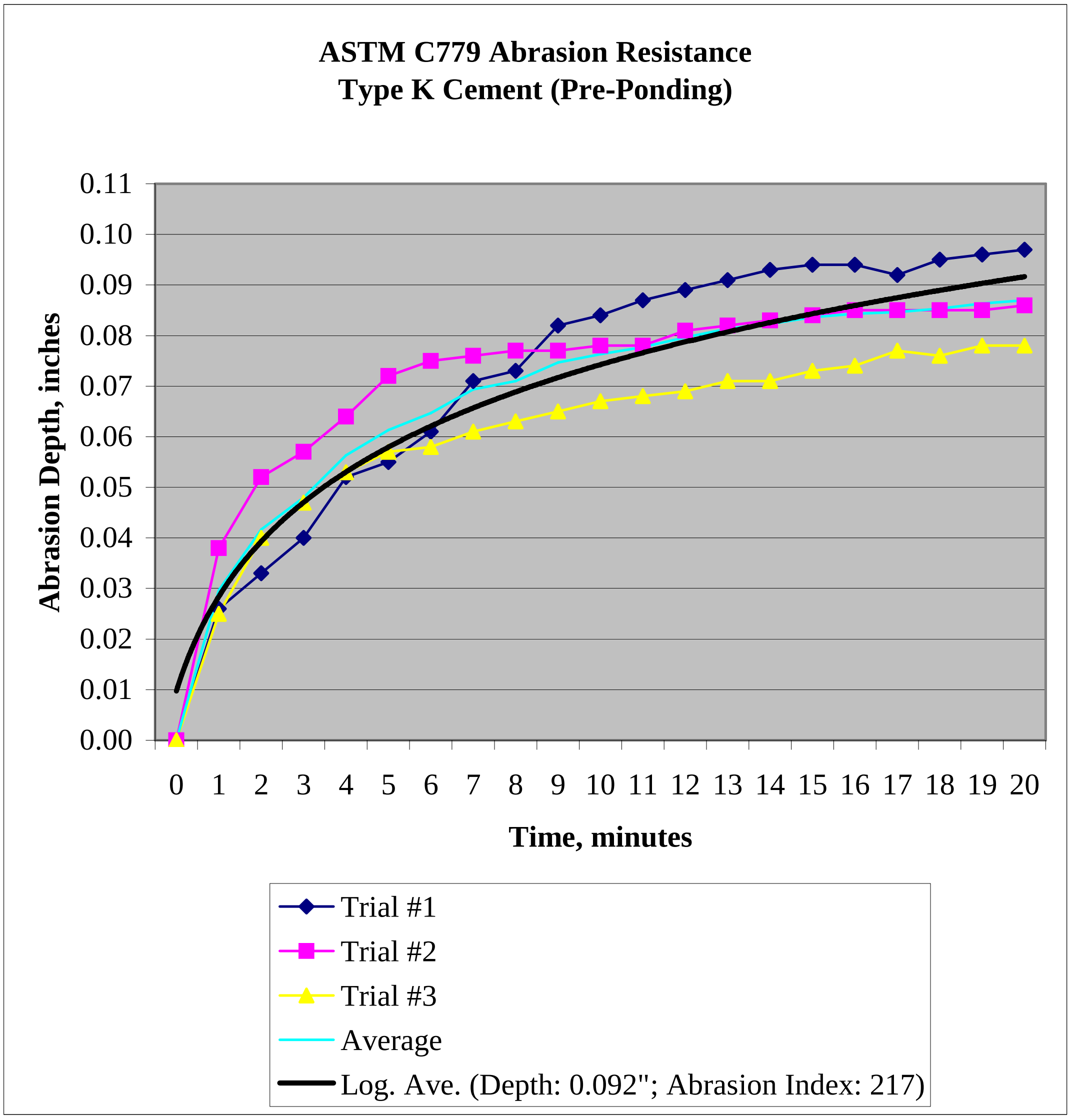
							Drilled	Cored
Depth	Base Level	1 month	2 months	3 months	4 months	5 months	6 months	6 months
0 - 0.5"		0.026	0.060	0.076	0.083	0.099	0.007	<0.005
0.5 - 1.0"		0.034	0.016	0.018	0.015	0.016	<0.005	<0.005
1.5 - 2.0"		0.005	0.005	0.005	0.006	0.006	<0.005	<0.005
Average	<0.005%							


ASTM C779 Abrasion Resistance
Class D with HMWM (Pre-Ponding)
Abrasion Depth, inches
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. Ave. (Depth: 0.166"; Abrasion Index: 120)

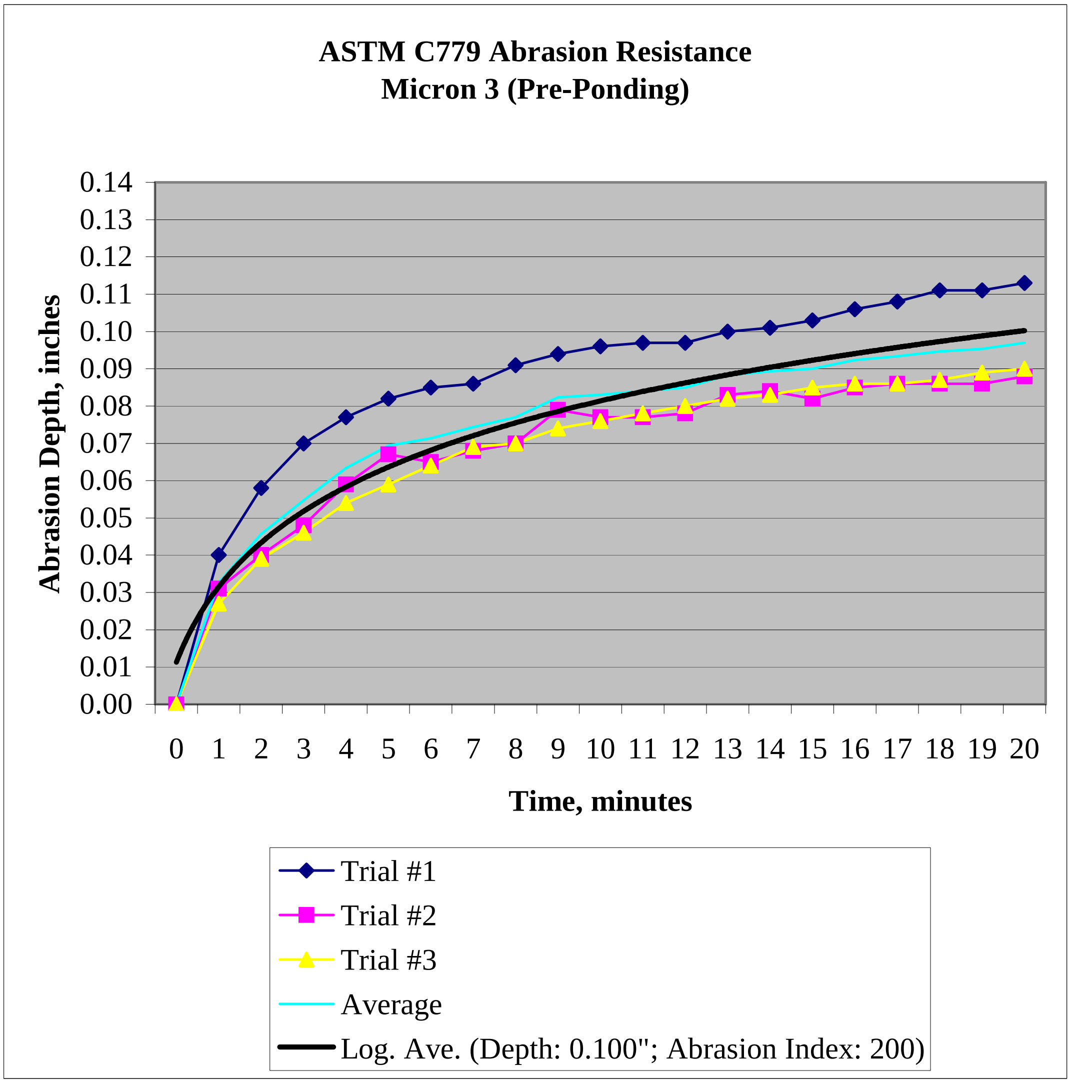


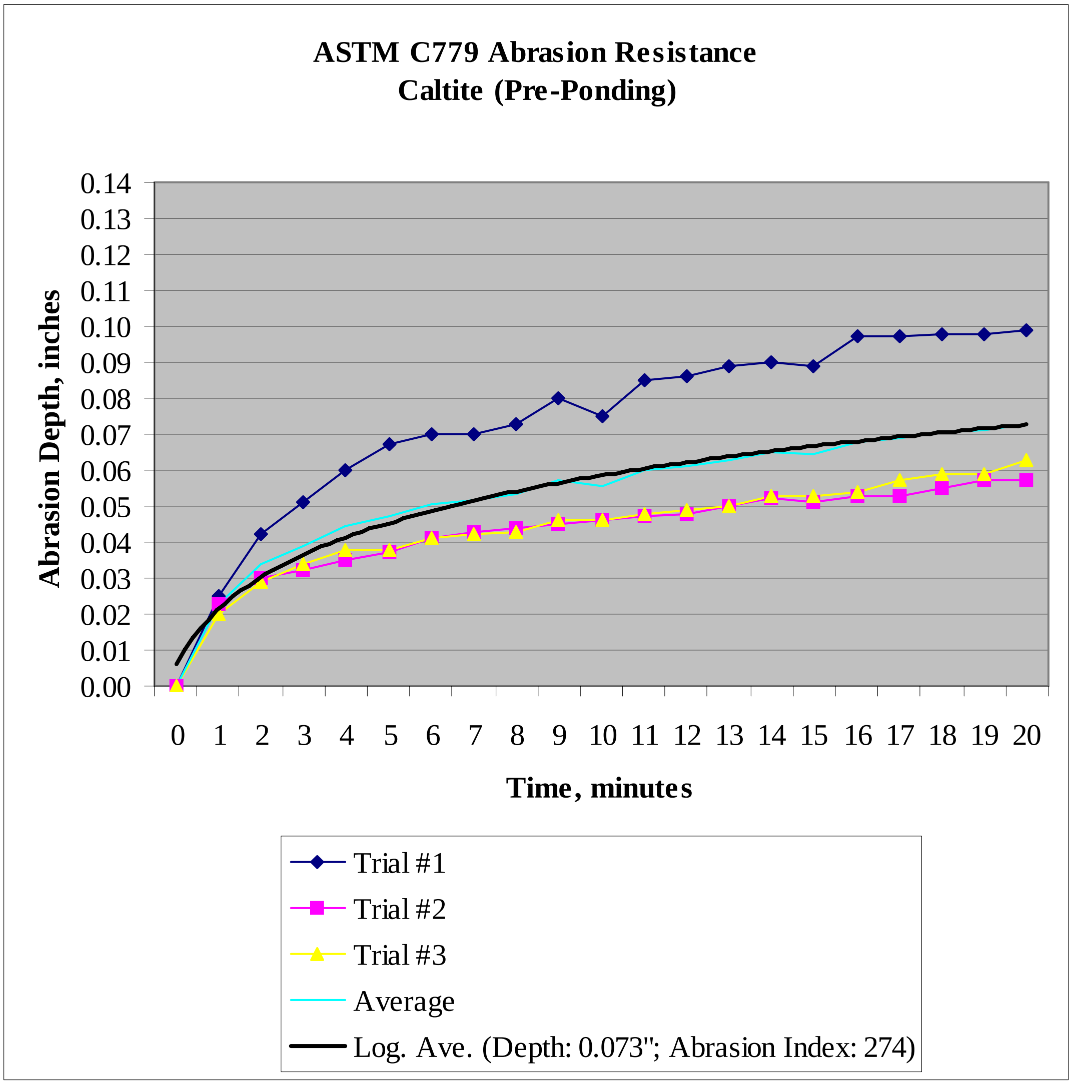
ASTM C779 Abrasion Resistance
CDOT Class B (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.123"; Abrasion Index: 163)


ASTM C779 Abrasion Resistance
CDOT Class H (Pre-Ponding)
Abrasion Depth, inches
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.106"; Abrasion Index: 189)

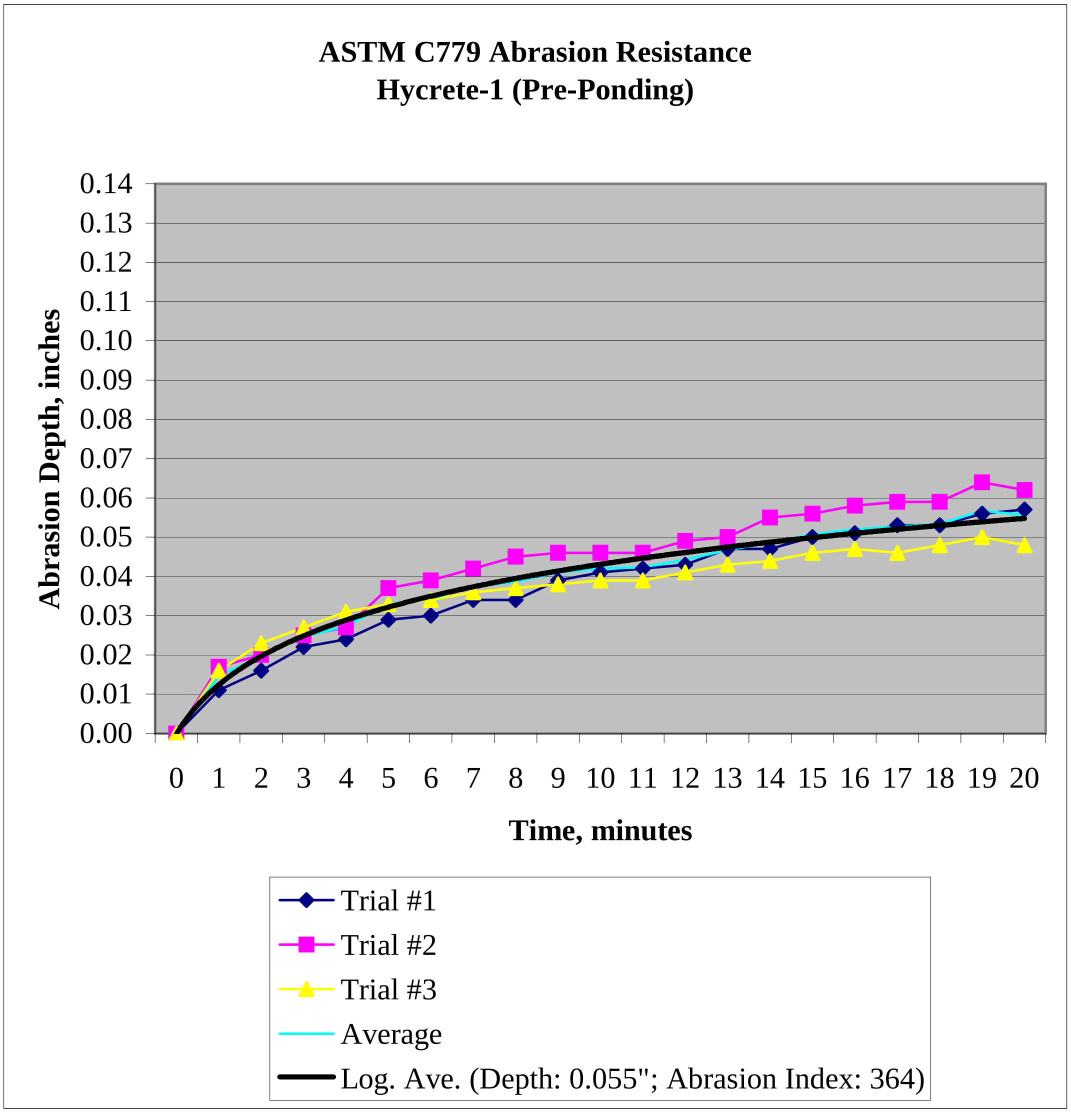


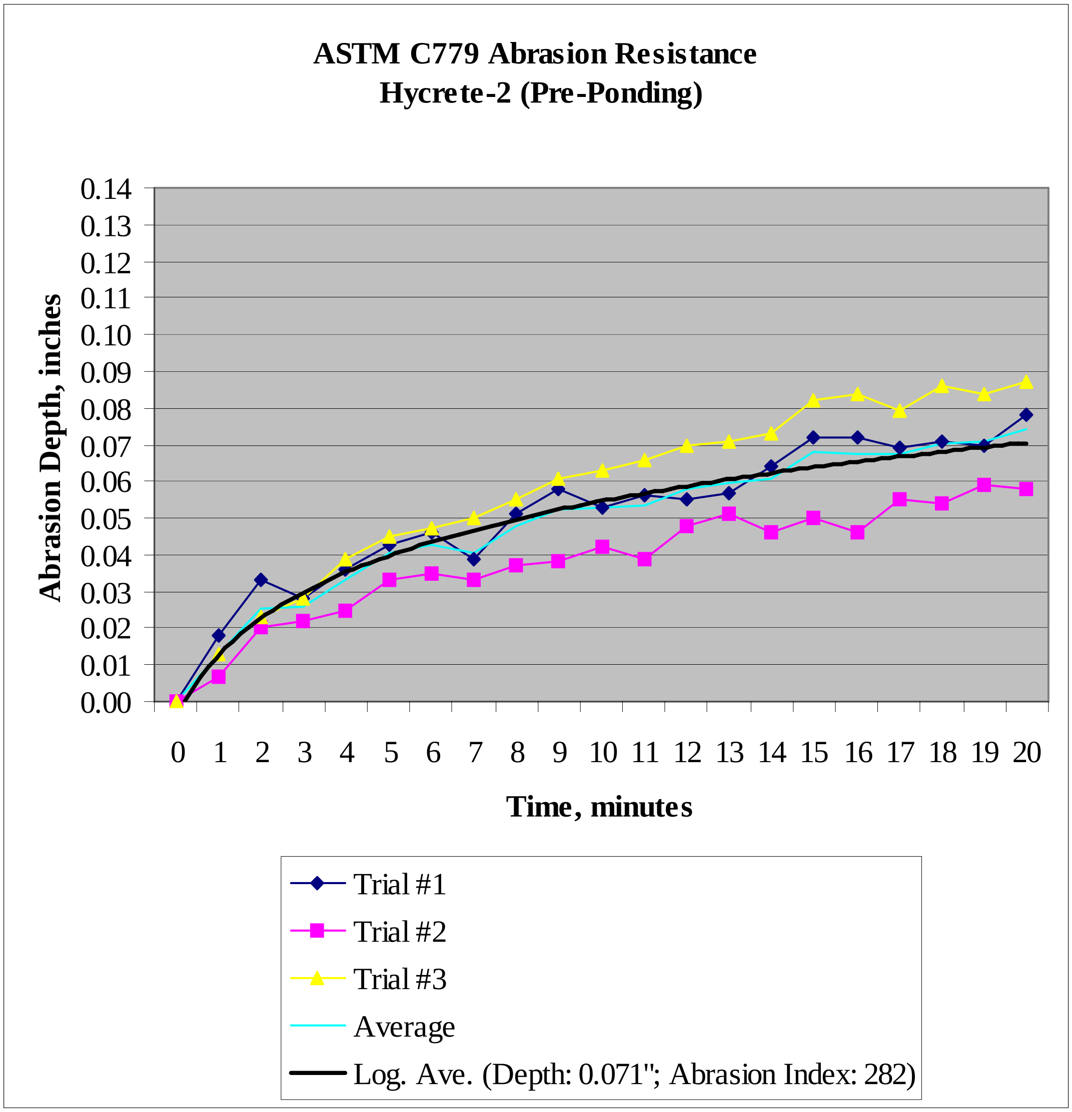
ASTM C779 Abrasion Resistance
Type K Cement (Pre-Ponding)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Abrasion Depth, inches
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.092"; Abrasion Index: 217)

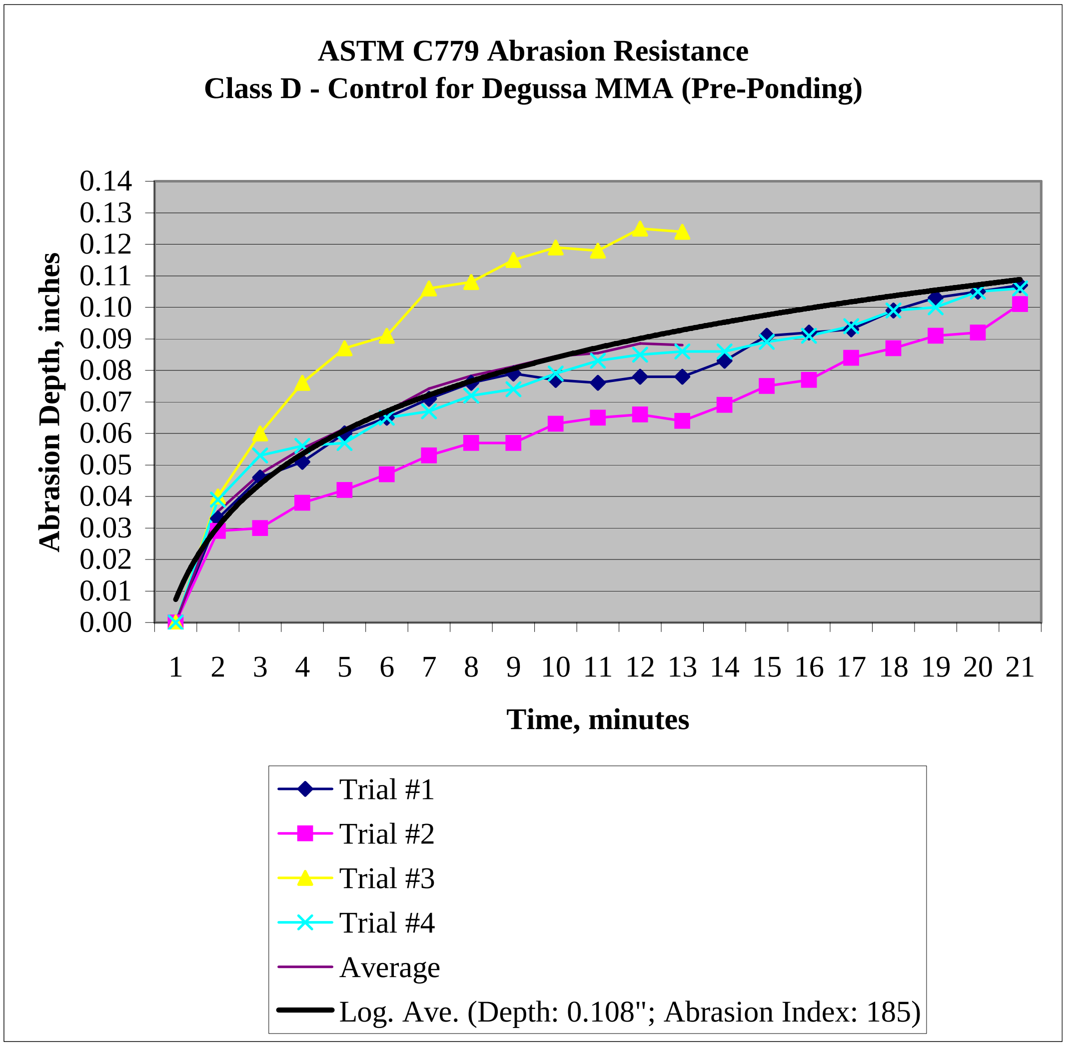

ASTM C779 Abrasion Resistance
Micron 3 (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.100"; Abrasion Index: 200)

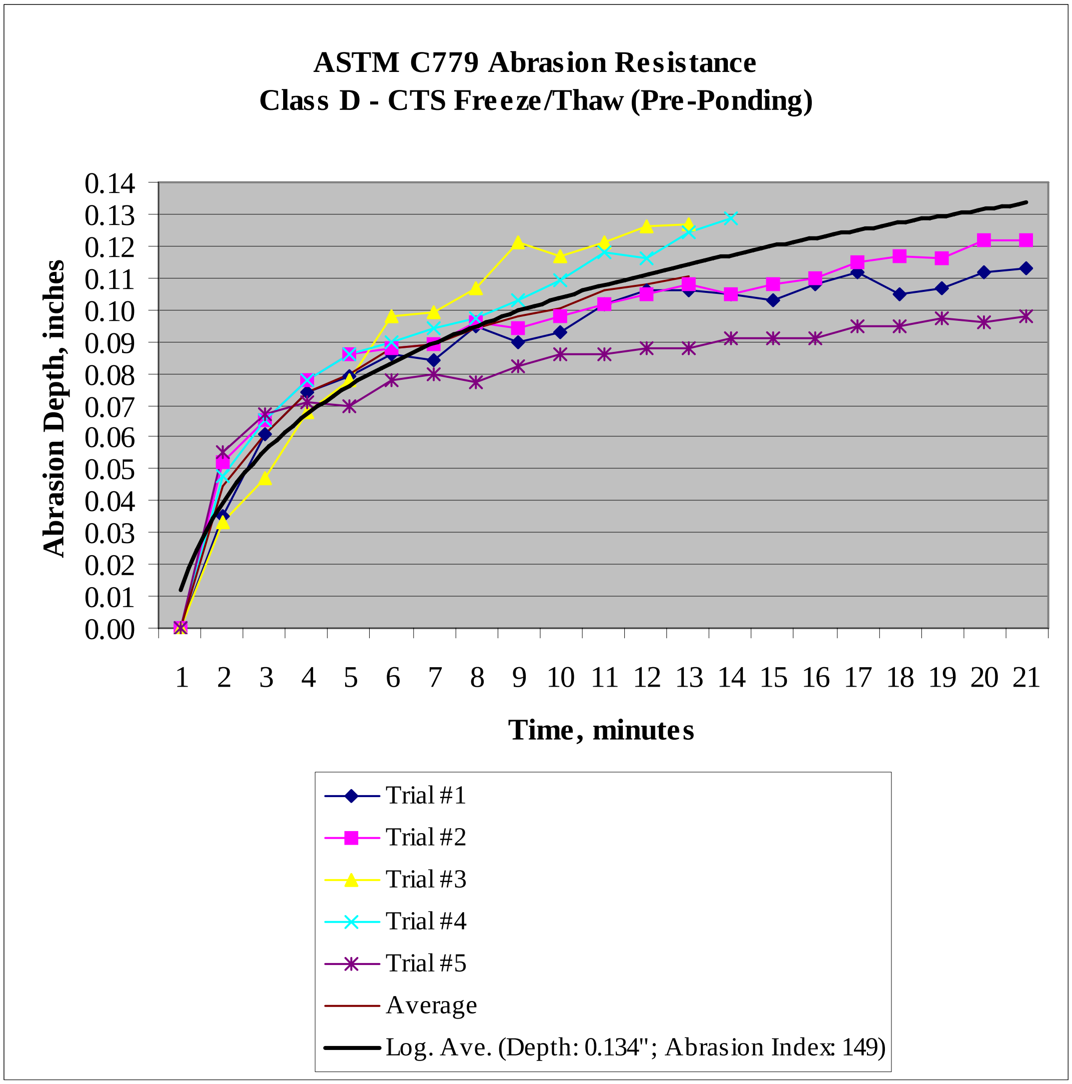


ASTM C779 Abrasion Resistance
Caltite (Pre-Ponding)
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Abrasion Depth, inches
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.073"; Abrasion Index: 274)

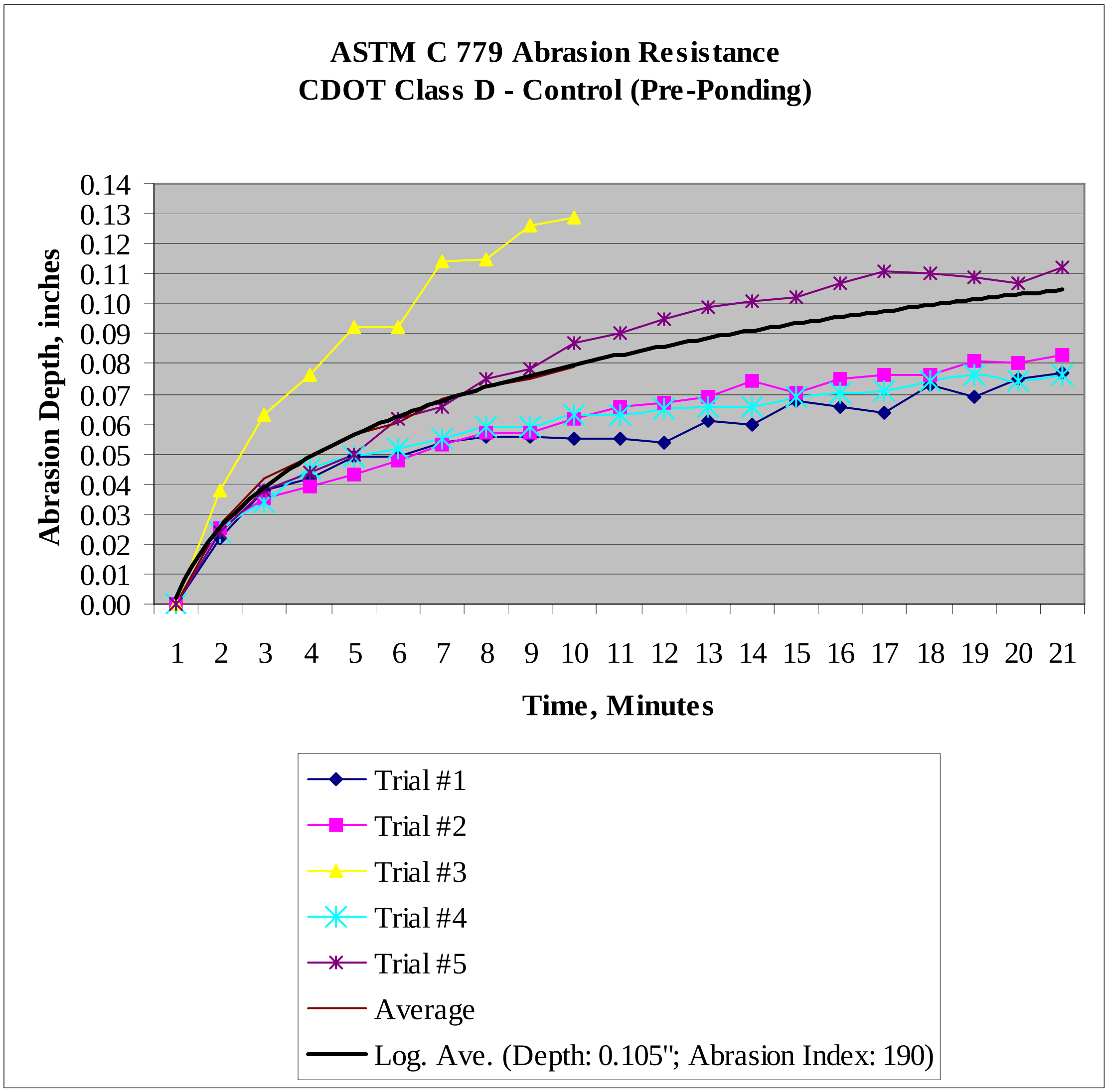

ASTM C779 Abrasion Resistance
Hycrete-1 (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.055"; Abrasion Index: 364)

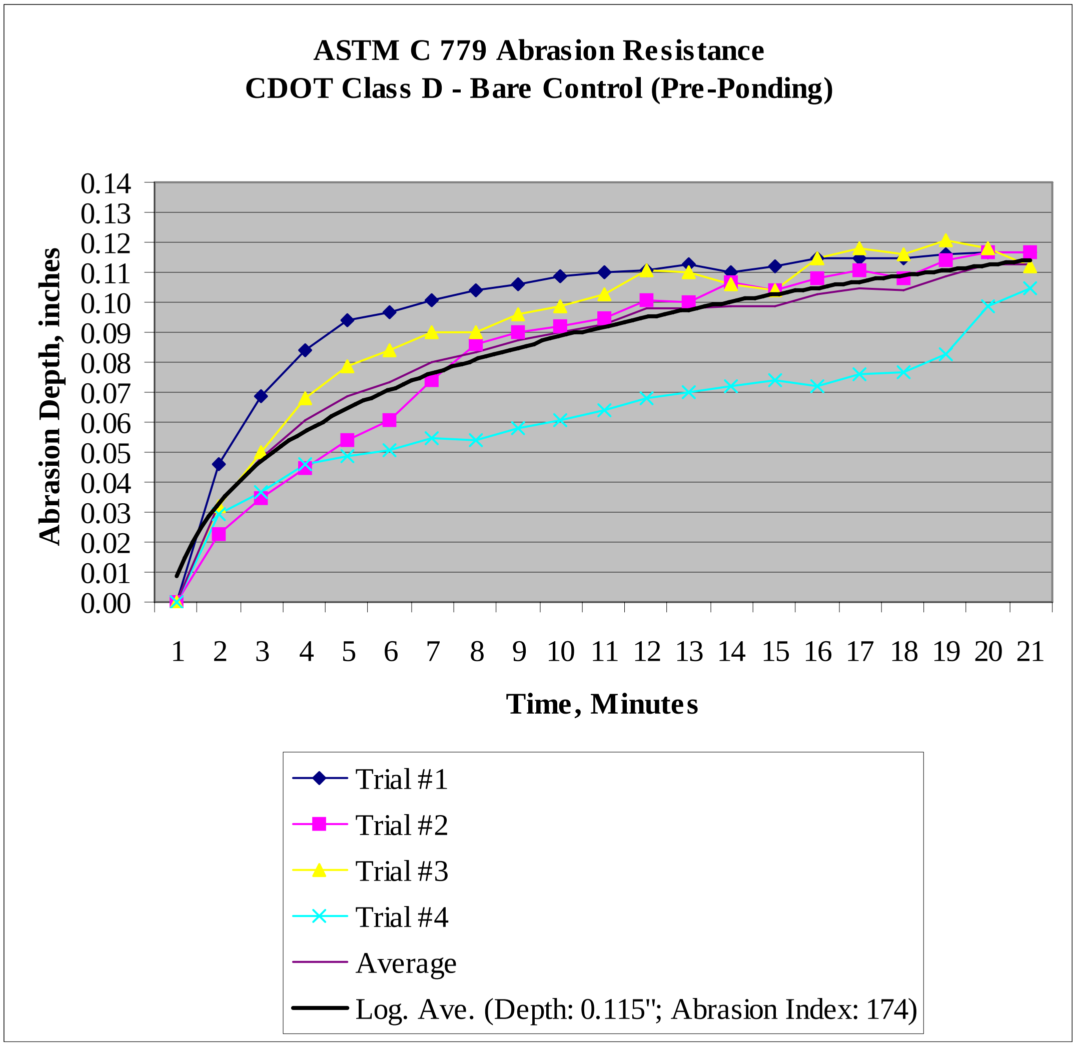

ASTM C779 Abrasion Resistance
Hycrete-2 (Pre-Ponding)
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Abrasion Depth, inches
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. Ave. (Depth: 0.071"; Abrasion Index: 282)

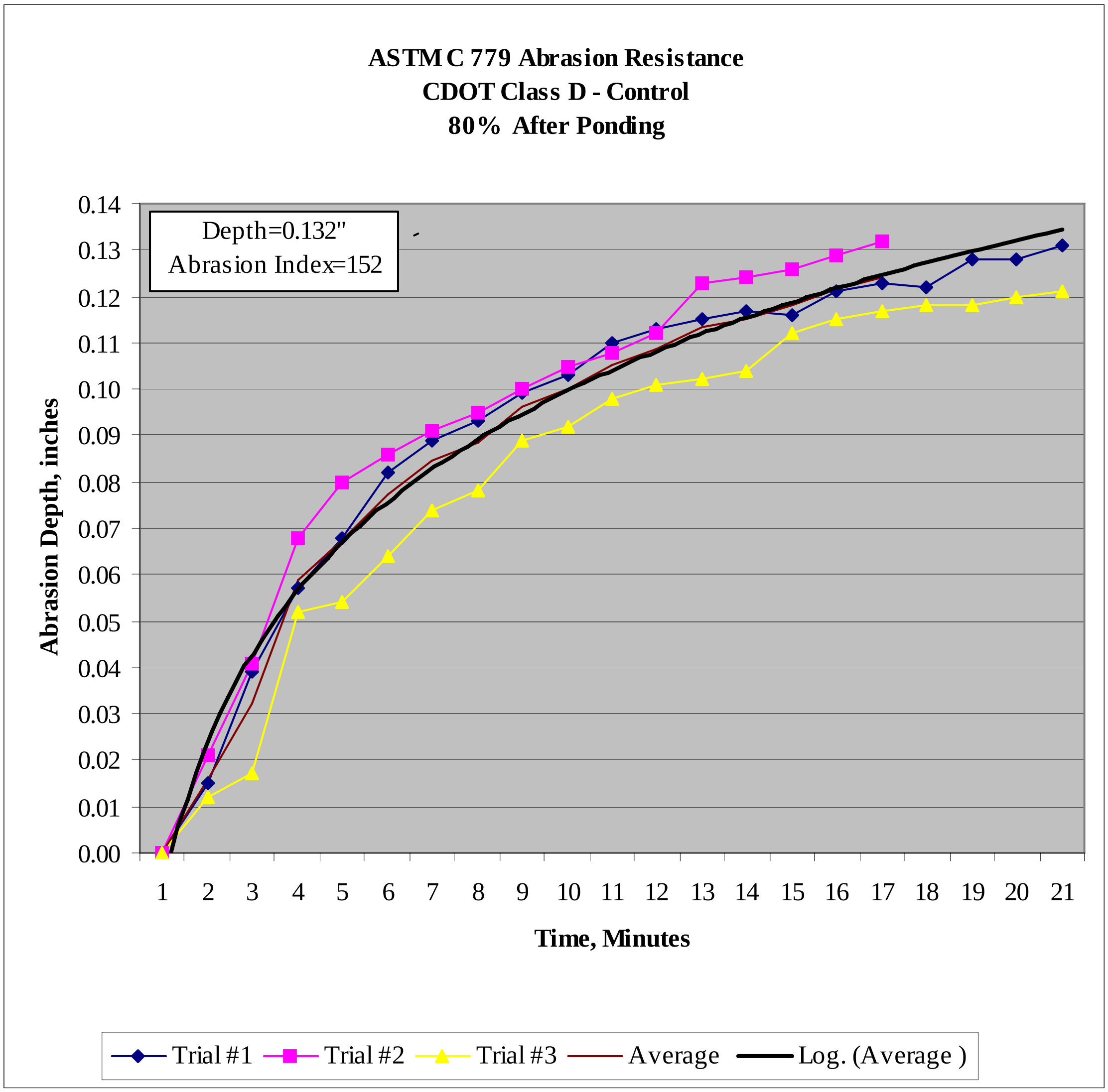

ASTM C779 Abrasion Resistance
Class D - Control for Degussa MMA (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. Ave. (Depth: 0.108"; Abrasion Index: 185)

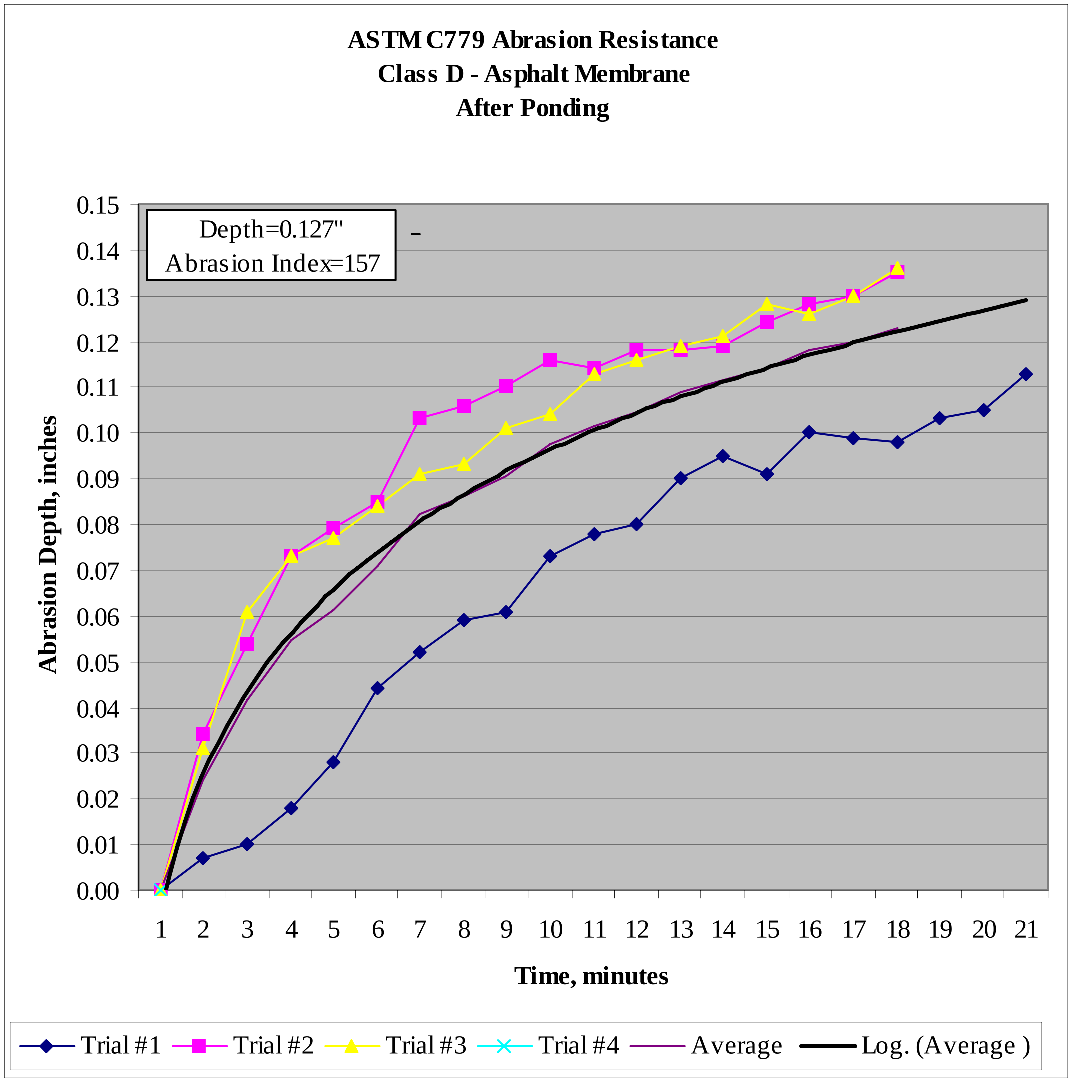


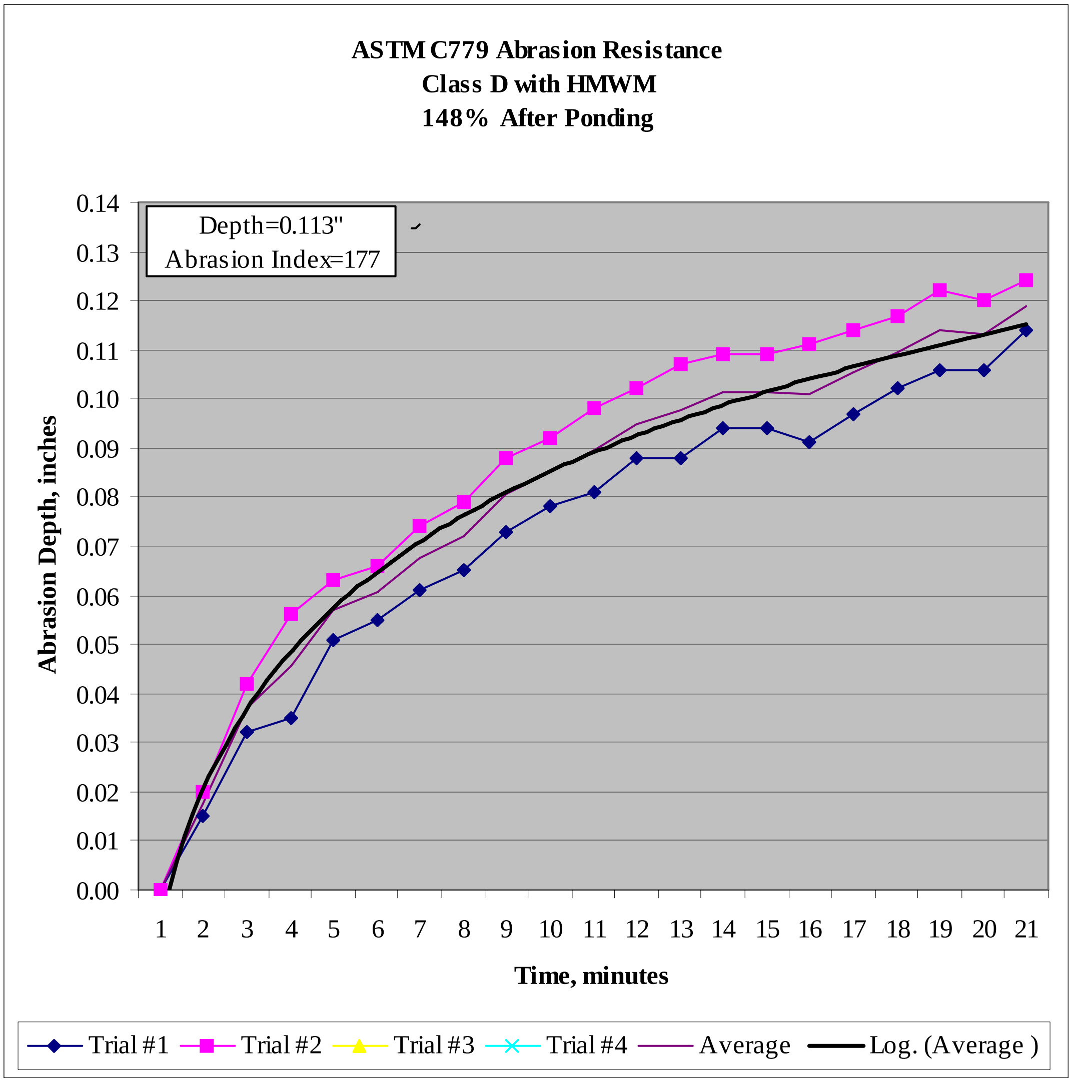
ASTM C779 Abrasion Resistance
Class D - CTS Freeze/Thaw (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Trial #5
Average
Log. Ave. (Depth: 0.134"; Abrasion Index: 149)

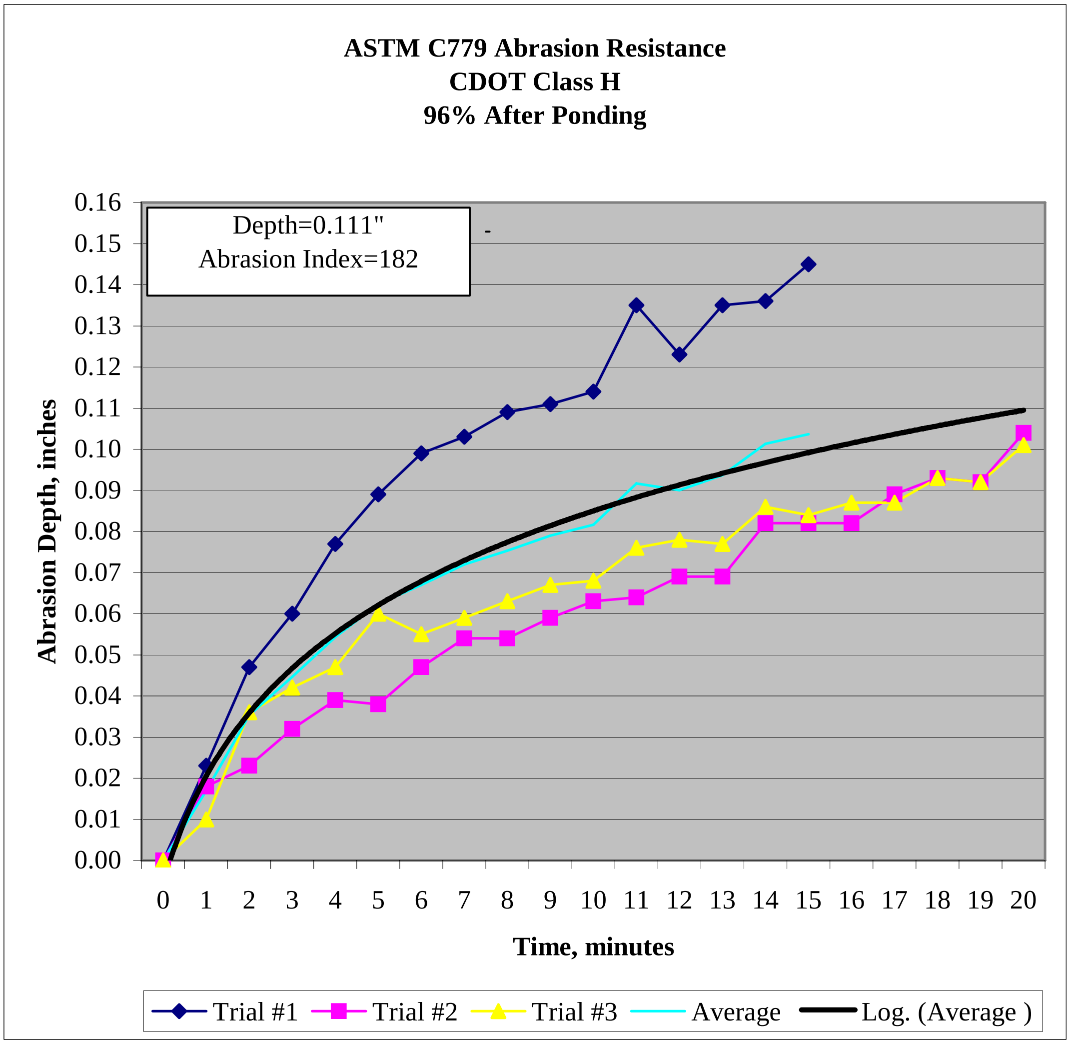

ASTM C 779 Abrasion Resistance
CDOT Class D - Control (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, Minutes
Trial #1
Trial #2
Trial #3
Trial #4
Trial #5
Average
Log. Ave. (Depth: 0.105"; Abrasion Index: 190)


ASTM C 779 Abrasion Resistance
CDOT Class D - Bare Control (Pre-Ponding)
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, Minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. Ave. (Depth: 0.115"; Abrasion Index: 174)

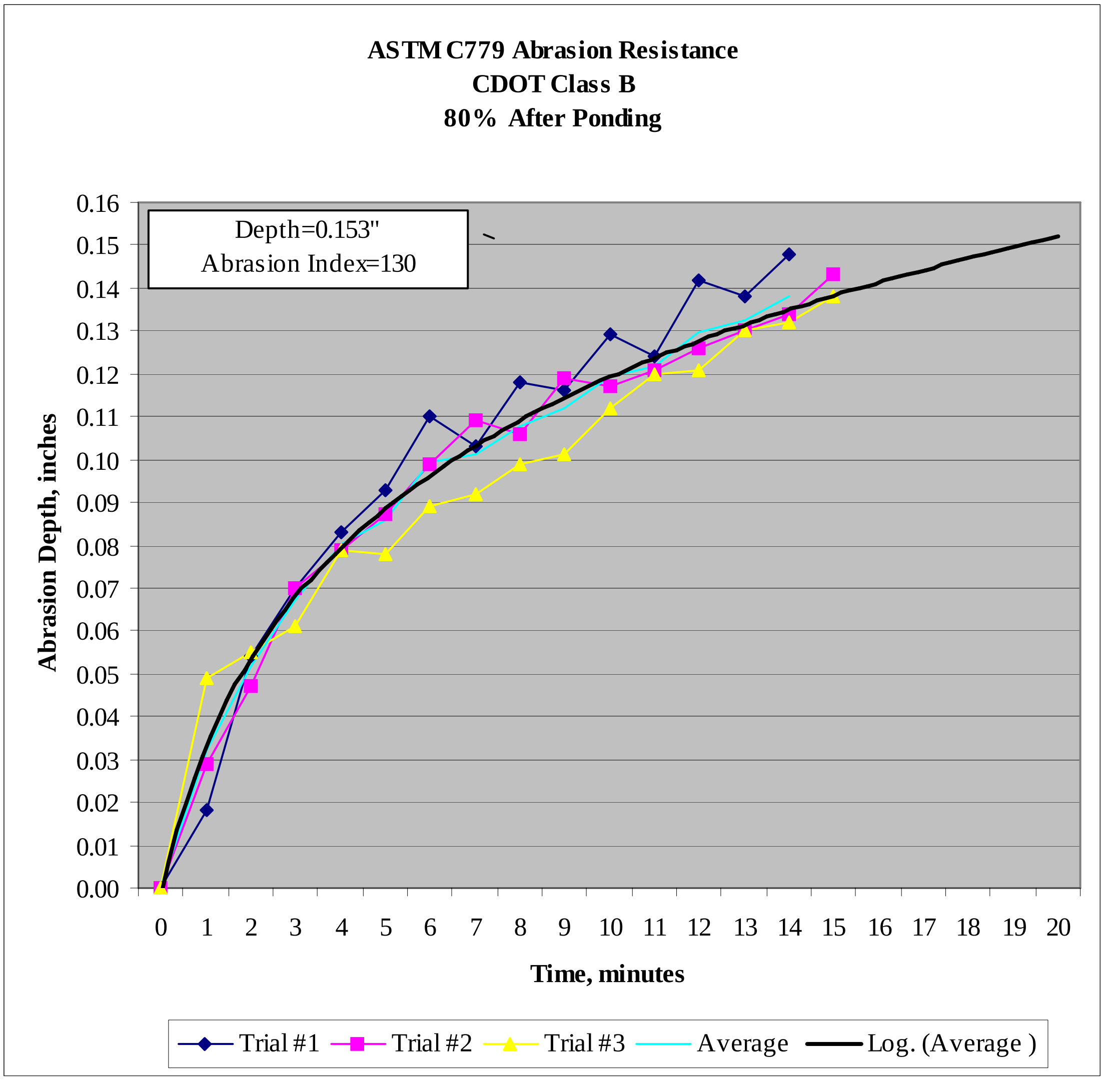

ASTM C 779 Abrasion Resistance
CDOT Class D - Control
80% After Ponding
Depth=0.132"
Abrasion Index=152
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, Minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)

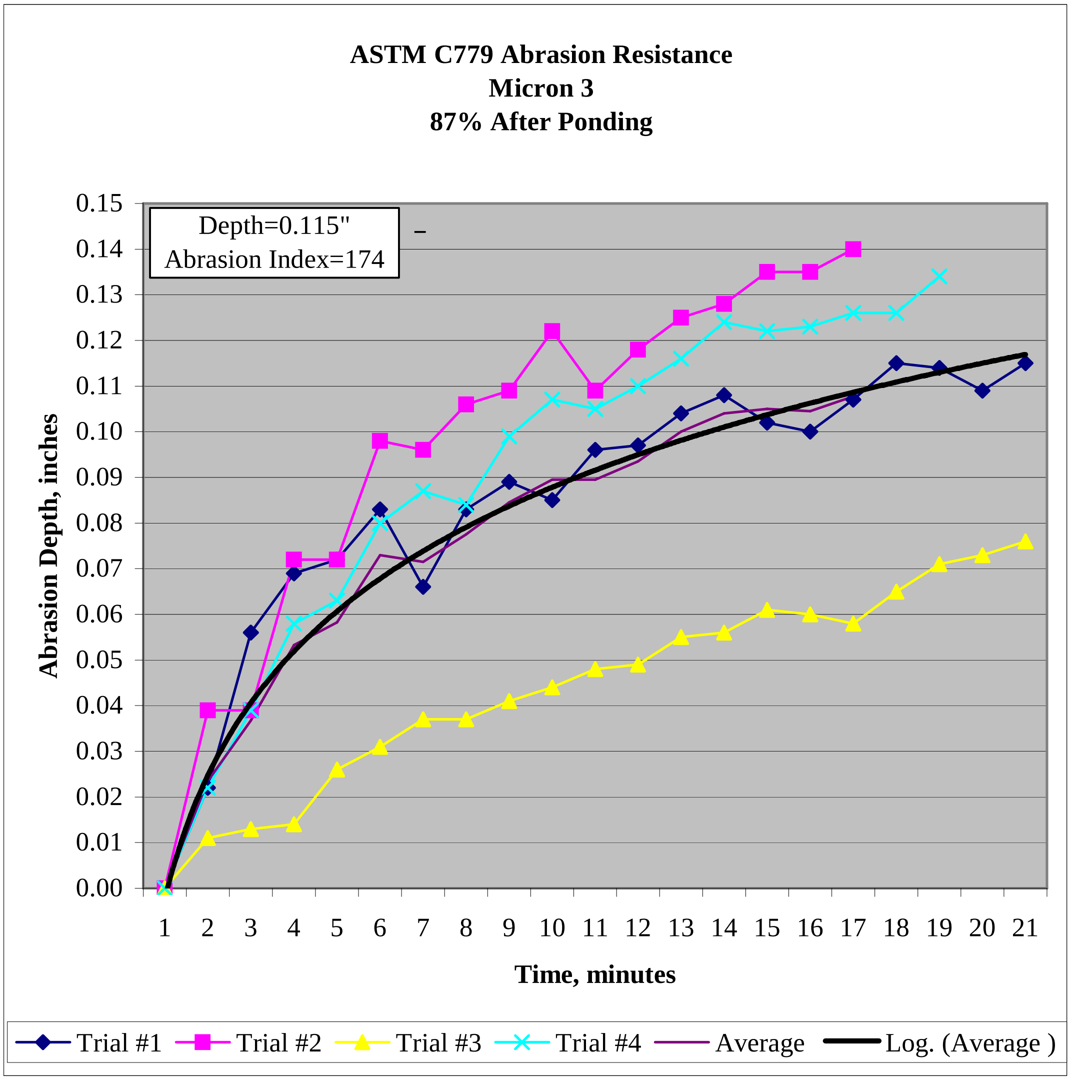

ASTM C779 Abrasion Resistance
Class D - Asphalt Membrane
After Ponding
Depth=0.127"
Abrasion Index=157
Abrasion Depth, inches
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. (Average)

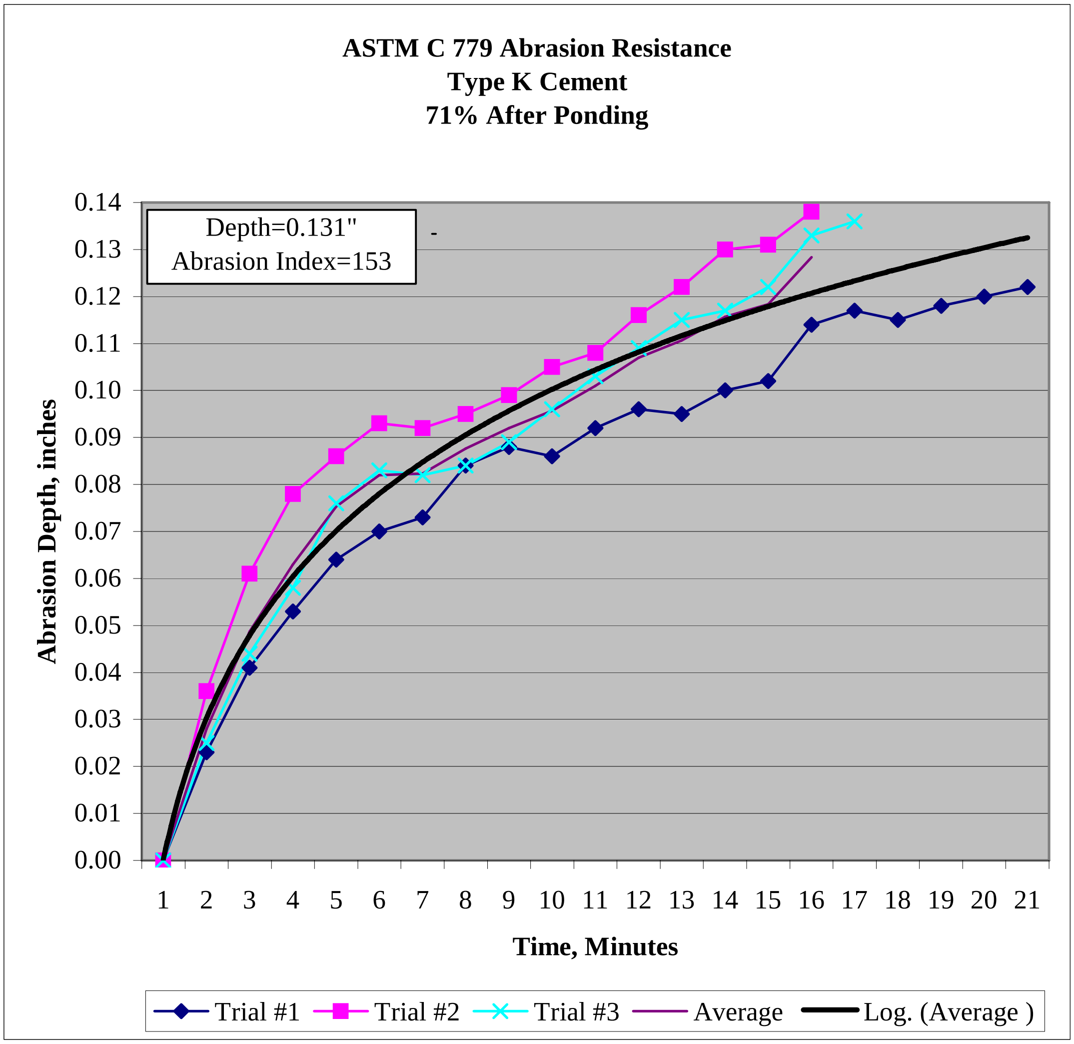

ASTM C779 Abrasion Resistance
Class D with HMWM
148% After Ponding
Depth=0.113"
Abrasion Index=177
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. (Average)

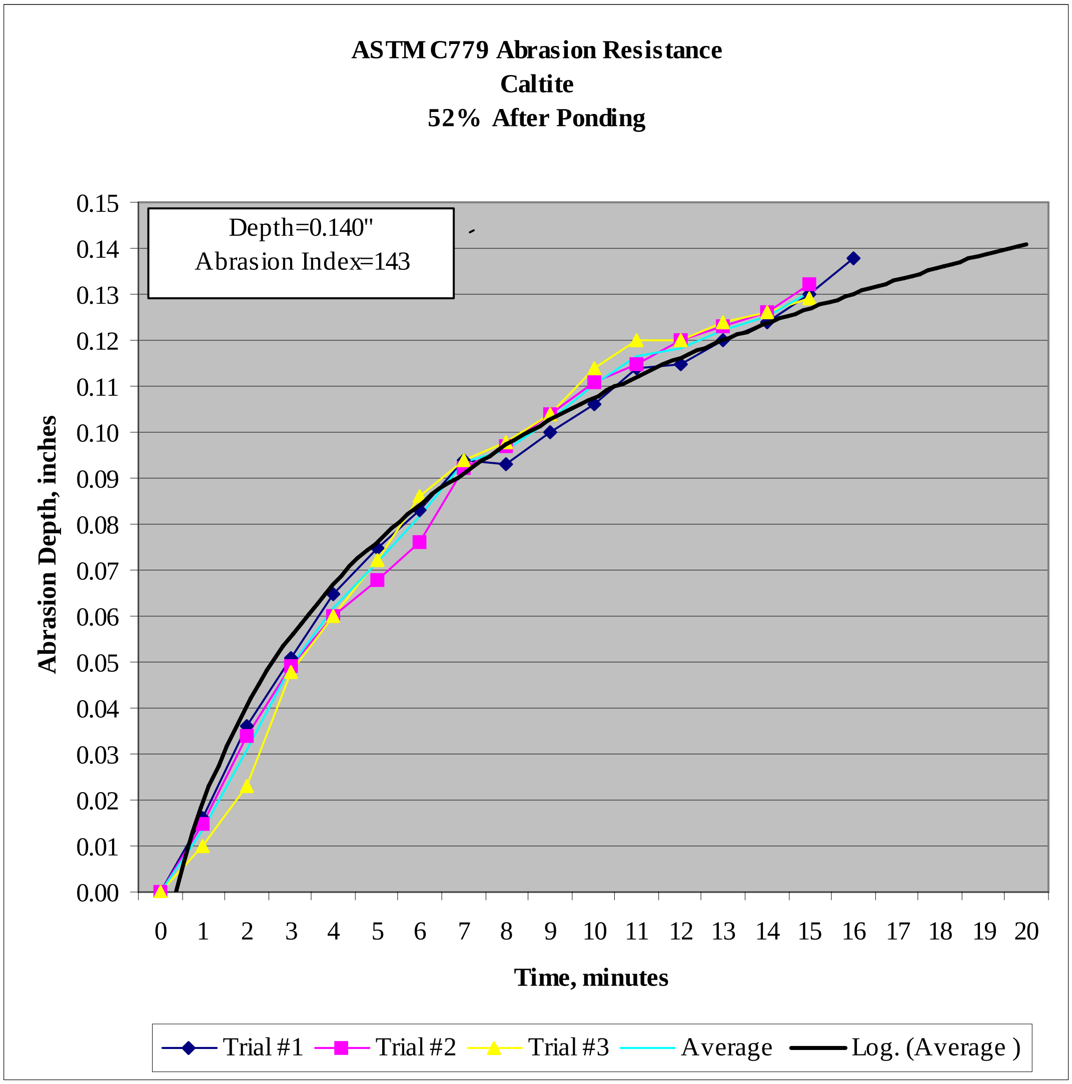


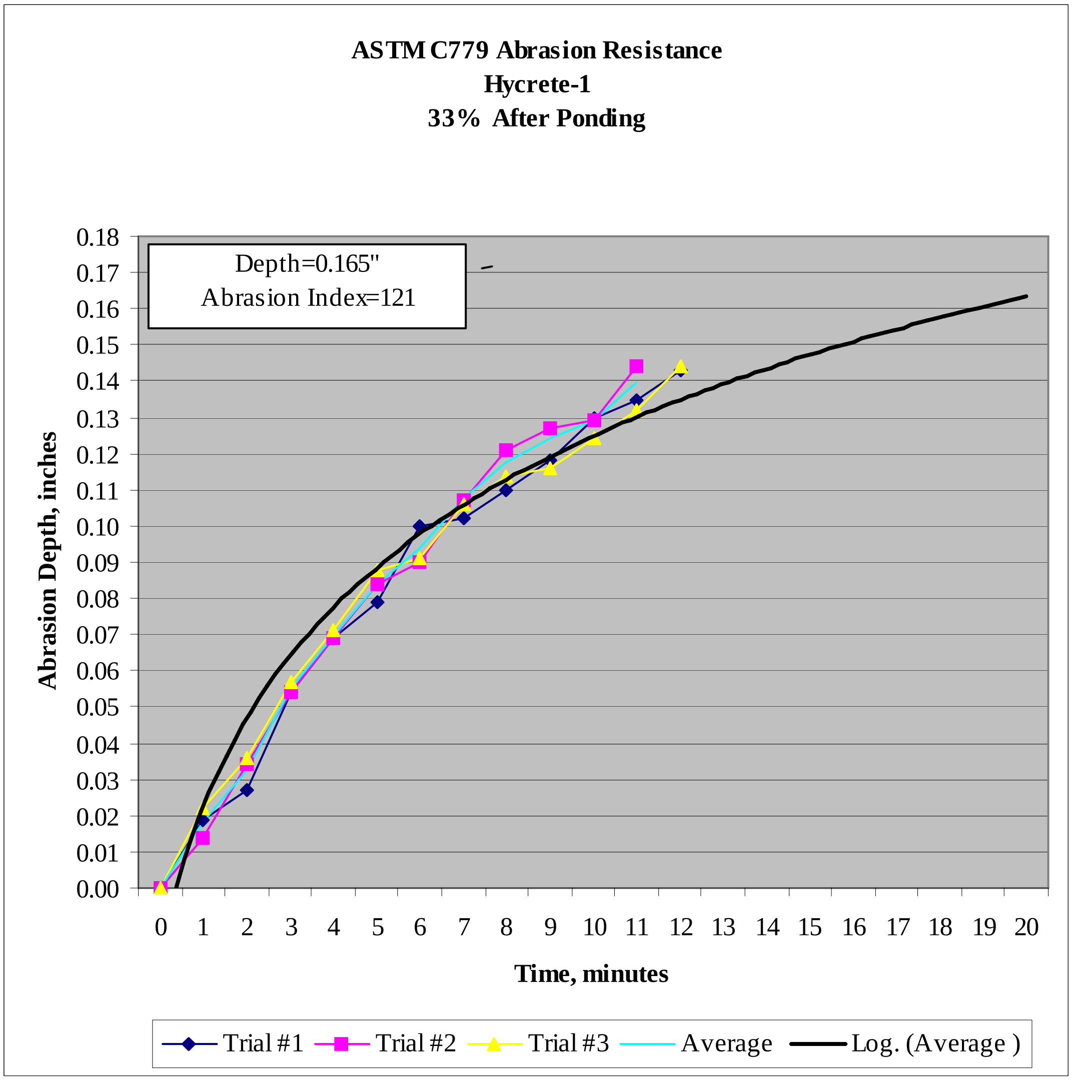
ASTM C779 Abrasion Resistance
CDOT Class H
96% After Ponding
Depth=0.111"
Abrasion Index=182
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Abrasion Depth, inches
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)

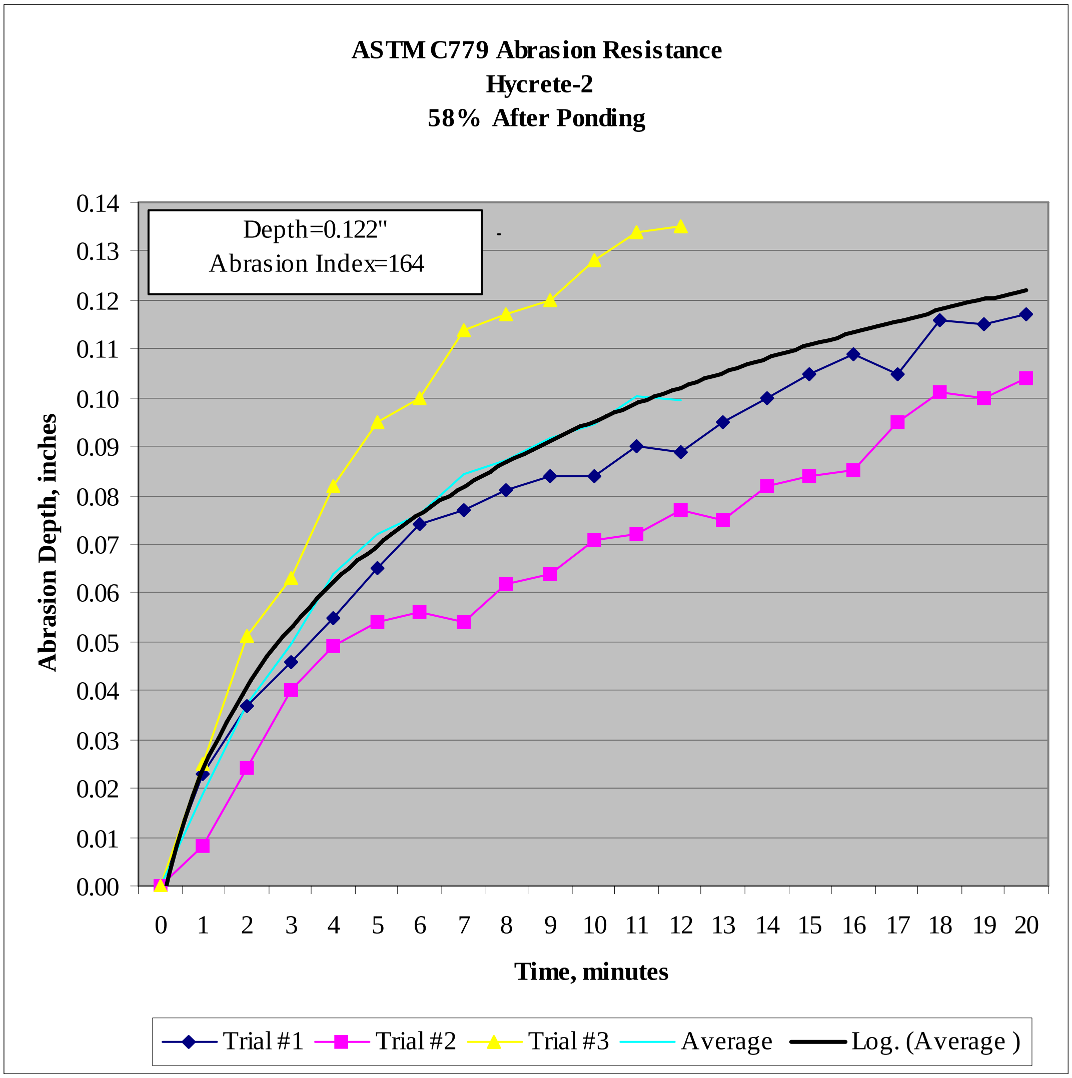

ASTM C779 Abrasion Resistance
CDOT Class B
80% After Ponding
Depth=0.153"
Abrasion Index=130
Abrasion Depth, inches
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)


ASTM C779 Abrasion Resistance
Micron 3
87% After Ponding
Depth=0.115"
Abrasion Index=174
Abrasion Depth, inches
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Trial #4
Average
Log. (Average)

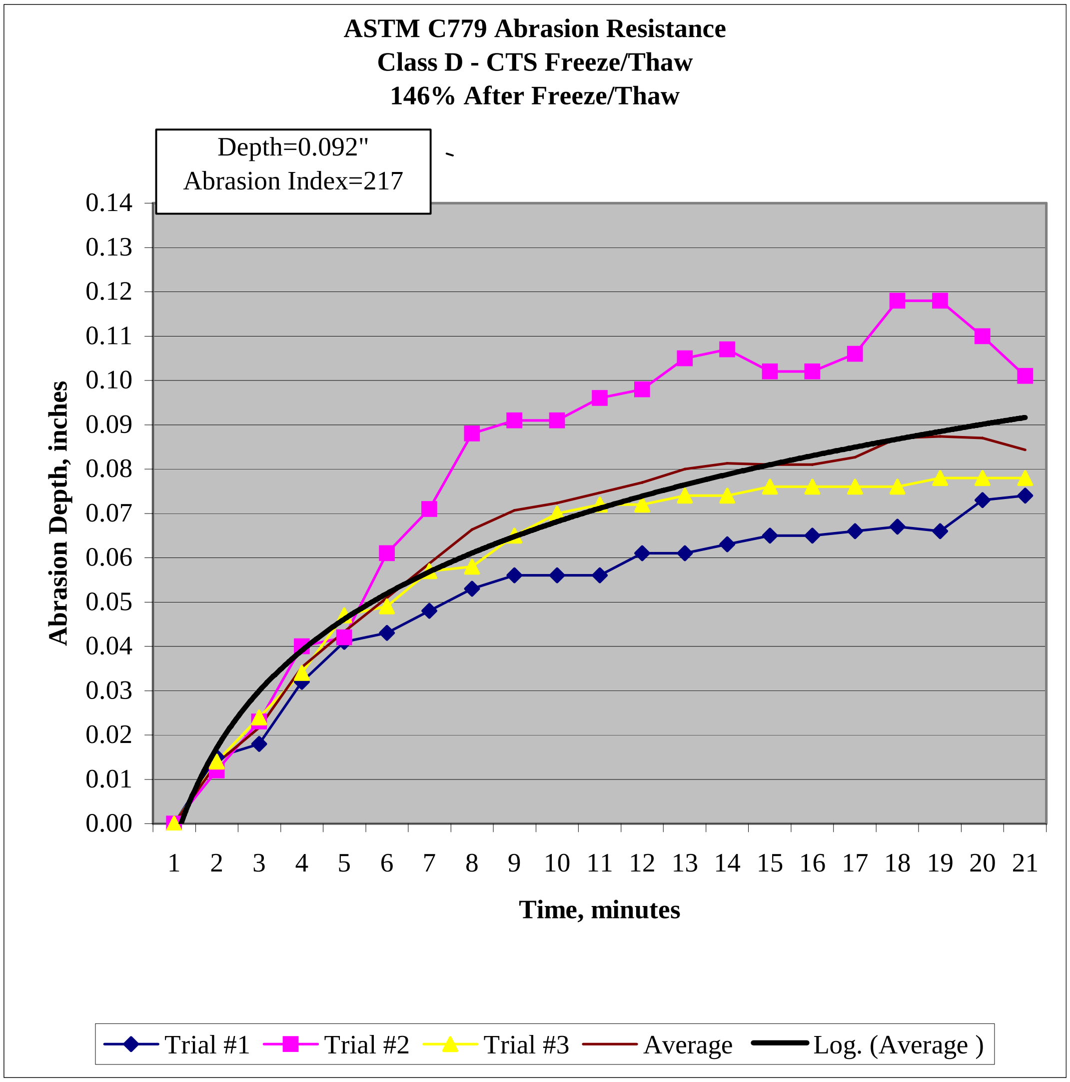

ASTM C 779 Abrasion Resistance
Type K Cement
71% After Ponding
Depth=0.131"
Abrasion Index=153
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, Minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)

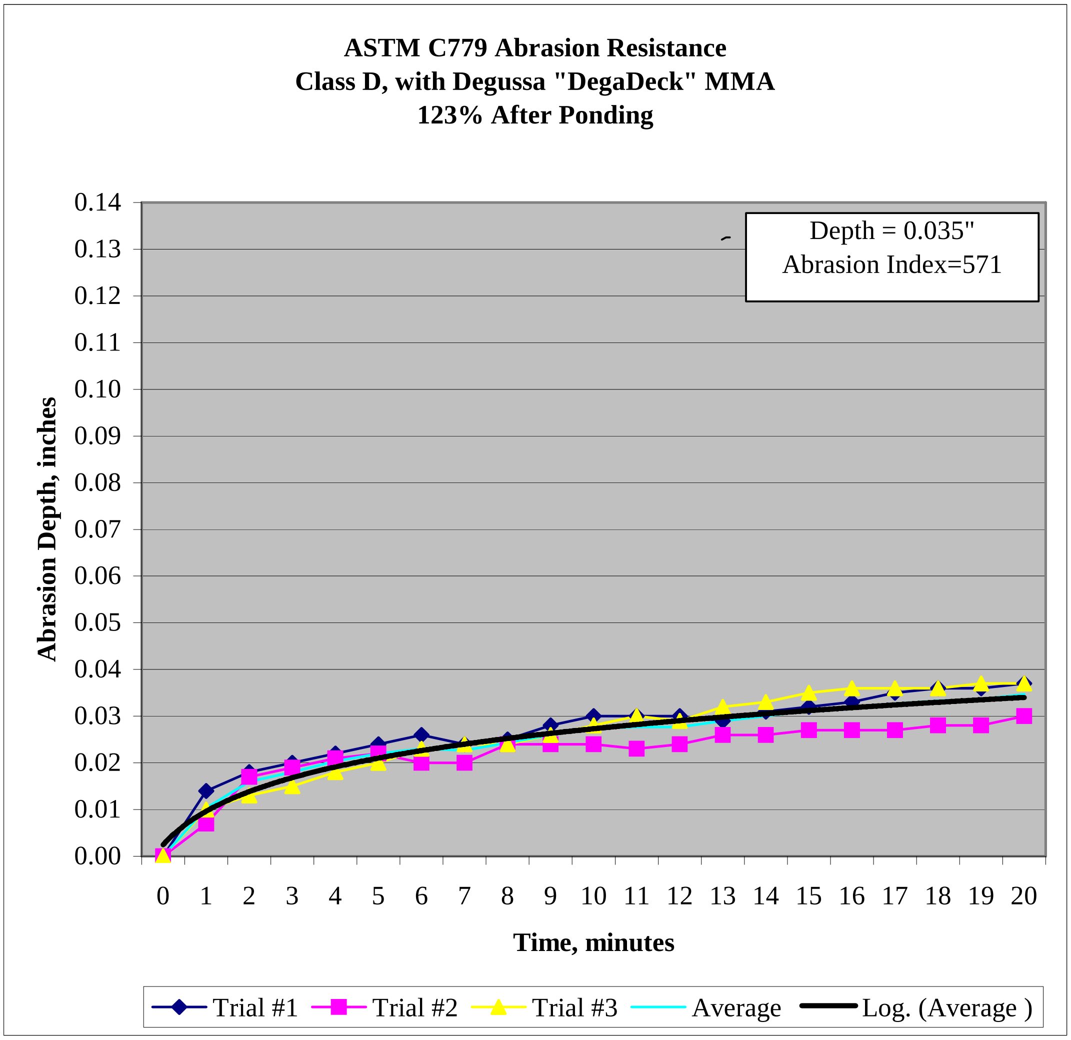

ASTM C779 Abrasion Resistance
Caltite
52% After Ponding
Depth=0.140"
Abrasion Index=143
Abrasion Depth, inches
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)


ASTM C779 Abrasion Resistance
Hycrete-1
33% After Ponding
Depth=0.165"
Abrasion Index=121
Abrasion Depth, inches
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)



ASTM C779 Abrasion Resistance
Hycrete-2
58% After Ponding
Depth=0.122"
Abrasion Index=164
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)


ASTM C779 Abrasion Resistance
Class D - CTS Freeze/Thaw
146% After Freeze/Thaw
Depth=0.092"
Abrasion Index=217
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Abrasion Depth, inches
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)


ASTM C779 Abrasion Resistance
Class D, with Degussa "DegaDeck" MMA
123% After Ponding
Depth = 0.035"
Abrasion Index=571
Abrasion Depth, inches
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time, minutes
Trial #1
Trial #2
Trial #3
Average
Log. (Average)

8.3 Manufacturer's Information on Proprietary Products

8.3.1 Micron3

Technical Bulletin

BORAL MICRON³™

Resistance to Corrosion, Alkali Silica Reaction, and Sulfate Attack

Durability of concrete is a key consideration in the design of structures. Durable concrete results in fewer repairs over a structure's service life, leading to lower life cycle costs. Increased service life translates to reduced consumption of natural resources, and less waste bound for landfill disposal. Highly refined pozzolans, such as Micron³, may be used to dramatically increase concrete durability. This bulletin discusses the ways Micron³ improves concrete durability, particularly with respect to corrosion, alkali silica reaction (ASR), and sulfate attack.

Corrosion

Exposure to chloride ions is the most common cause of premature deterioration of steel in reinforced concrete. Chlorides, originating from deicing salts and sea-water, can migrate throughout concrete, attacking the passivating oxide layer that coats steel reinforcement. An electrochemical reaction ensues leading to formation of ferric hydroxides, which is accompanied by an increase in volume. Tensile stresses develop within the concrete, ultimately leading to cracking and delamination. The steel cross sectional area is also reduced thereby decreasing the load carrying capacity of the structure. It is widely accepted that corrosion initiates when the chloride level at the steel reinforcement reaches 1 to 1.5 lb/yd³.

Chloride Diffusion Coefficient

Micron³ reduces chloride ingress into concrete, due to pozzolanic reaction and improved micro-filler effect, which lowers concrete permeability and disconnects the integral pore network. Pozzolanic reaction products may also contribute to increased chloride binding. Chloride diffusion coefficients were recently measured in concrete using varying dosages of Micron³ (Figure 1). The total cementitious contents, and the w/cm were the same for all mixtures, and concrete specimens were moist cured for 28 days. Further testing details are reported elsewhere.[1] Compared to the control concrete without pozzolan, concrete with Micron³ reduces chloride diffusion 2.5 to 3.5 times when tested after ninety days of chloride ponding and 7 to 11 times when tested after two years of chloride ponding. The ninety day, and two year test results show that 10% Micron³ achieves similar chloride diffusion coefficients as 8% silica fume. This implies that the chloride content located at the steel reinforcement would be the same using these

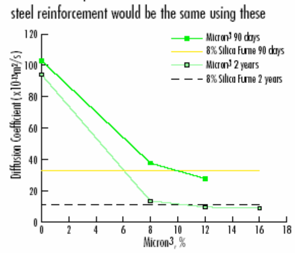


Figure 1. Effect of Micron³ on Chloride Diffusion Coefficient of Concrete

respective dosages. In this test program, no advantage was taken of the water reducing properties of Micron³. If the concrete mixtures containing Micron³ had been designed with a lower w/cm then parity could have been attained at even lower dosages.

The chloride diffusion coefficient is a controlling parameter for predicting service life of reinforced concrete structures, when using service life models such as Life-365 (being developed by ACI Committee 365-Service Life). Since Micron³ decreases chloride diffusion coefficients it will increase the service life of reinforced concrete significantly.

Rapid Chloride Permeability Testing (RCPT)

RCP testing was conducted in accordance to ASTM C 1202, which measures concrete conductivity. The RCPT value is generally believed to have a correlation with the chloride diffusion coefficient.

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ASTM C 1202 relates the charge passed (in coulombs) to the chloride ion penetrability as follows: >4000 = High; 2000-4000 = Moderate; 1000-2000 = Low; 100-1000 = Very Low; <100 = Negligible. Some question the results from this test; however, due to the relative ease of of this test, the RCPT value is more widely specified than the more direct chloride diffusion coefficient. The RCPT values obtained from concrete mixtures tested in different locations with local materials are summarized in Table 1.

Concrete with RCPT values less than 1000 coulombs, corresponding to ASTM C 1202 "Very Low" chloride penetrability, may be achieved using Micron^3. The use of fly ash in conjunction with Micron^3 decreases the amount of Micron^3 required to attain a given RCPT value. Early age (28 days) RCPT values tend to be relatively higher for concrete containing Micron^3 as opposed to concrete with silica fume at similar replacement levels. However, concrete with 8% Micron^3 had a lower RCPT value than 8% silica fume when tested at 90 days or later.[1]

When designing concrete for chloride resistance some engineers specify RCPT values less than a given value by a set age, such as 1000 coulombs by 28 or 56 days.

Table 1. RCPT Results of Micron^3 Concrete at Various Locations

Location	Salt Lake City, UT		San Antonio, TX				Pascagoula, MS	
Cement	700	600	600	600	525	600	564	564
Class F Fly Ash	-	100	-	-	125	100	-	-
Class C Fly Ash	-	-	-	-	-	-	141	141
Micron^3	100	100	-	75	50	100	80	120
Silica Fume	-	-	50	-	-	-	-	-
Water	251	267	250	225	230	230	250	250
w/cm	0.31	0.33	0.39	0.33	0.33	0.29	0.32	0.30
Type A	3	3	-	-	-	-	-	-
Type B	-	-	-	-	-	-	27	29
Type F	15	15	19.8	11.2	7.2	9.4	73	83
AEA	-	-	0.8	0.8	0.8	0.8	4	3.5
Slump, in.	5.25	9.25	7.25	8.0	7.25	7.25	7.5	8
Air, %	-	1.5	6.0	5.1	5.3	3.7	4.7	4.5
U.W., lb/ft^3	-	-	142.4	144.8	144.0	146.6	147.08	147.8
Compressive Strength, psi								
1 day	-	-	-	-	2434	3504	-	-
3 day	-	-	6191	6451	4599	6204	-	-
7 day	8465	7525	-	-	5821	6833	-	-
28 day	11590	11385	9480	9721	7458	8671	-	-
56 day	12425	12860	-	-	-	-	-	-
90 day	-	-	-	-	9045	10420	-	-
Rapid Chloride Permeability, Coulombs								
28 day	1425	1386	958	1218	1584	1128	1527	1021
56 day	596	578	888	932	959	692	777	567
90 day	348	354	-	-	-	-	529	436

- Cement, fly ash, silica fume, Micron^3, water weights are in lb/yd^3; 1 lb/yd^3=0.593 kg/m^3
- Admixture dosages are in oz/100lb of cementitious; 1 oz/100lb=65.46 ml/100kg

Boral Micron^3

This approach, however, does not consider the reduction in chloride permeability at later ages. In order to achieve low permeability at an early age, the concrete producer must use a very low w/cm, high cementitious content, and large amounts of highly reactive pozzolans. This results in expensive concrete with potential workability and cracking problems in the field.

The Virginia Department of Transportation (VDOT) offers a good solution. They specify 28-day RCPT limits, but the curing procedure involves artificially aging the concrete specimens by subjecting them to a higher temperature for a period of time.[2]

Resistivity

Corrosion is an electro-chemical process involving the flow of electrons through concrete. If concrete electrical resistivity is increased, the rate of macrocell corrosion decreases. Direct Current (DC) resistivity tests were performed on concrete mixtures containing various levels of Micron^3 and silica fume. Further test details are discussed elsewhere.[1] Figure 2 summarizes the test data.

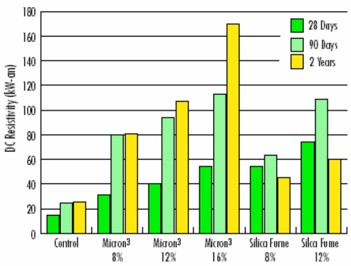

Figure 2. Effect of Micron3 on Electrical Resistivity of Concrete

After two years, concrete containing Micron^3 had 3.1 to 6.6 times higher electrical resistivity than the control concrete containing no pozzolan. The mixtures containing Micron^3 had slightly lower resistivities than mixtures with silica fume after 28 days curing, but generally exhibited improved performance after 91 days. At later ages the concrete containing Micron^3 had significantly higher resistivities than the concrete with silica fume. Higher resistivity will result in reduced corrosion rate.

Summary

1. The use of small amounts of Micron^3, as a cement replacement, significantly reduces chloride ingress in concrete, thereby increasing the time to corrosion initiation of reinforced concrete structures. Ten percent Micron^3 achieves similar chloride diffusion coefficients as 8% silica fume in concrete mixture at the same w/cm. If the water reducing properties of Micron^3 are taken advantage of, then parity may be attained at lower dosages.
2. Micron^3 increases the concrete resistivity significantly, thus reducing the rate of macrocell corrosion.
3. Due to the increase in time to corrosion initiation, and the reduction in corrosion rate (after initiation), the use of Micron^3 will significantly increase the service life of reinforced concrete structures.

References

1. Obla, K.H., Hill, R., Thomas, M.D.A., and Hooton, R.D., "Durability of Concrete Containing Fine Pozzolan", PCI/FHWA/FIB International Symposium on High Performance Concrete, Orlando, FL, September 25-27, 2000.
2. Ozyildirim, Celik, "Effects of Temperature on the Development of Low Permeability in Concrete." Virginia Transportation Research Council, VTRC 98-R14, Charlottesville, VA, Feb. 1998.

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8.3.2 <u>Type K Cement</u>

CTS Type-K

Cement For Shrinkage Compensating Concrete

Shrinkage Compensating Concrete

1. PRODUCT NAME
CTS Type-K
Cement for Shrinkage Compensating Concrete

2. MANUFACTURER
CTS Cement Manufacturing Corp.
11065 Knott Avenue, Suite A
Cypress, CA 90630
Phone: (714)379-8260
Fax: (714)379-8270
Web: www.ctscement.com

3. PRODUCT DESCRIPTION
CTS Type-K is a hydraulic cement designed for use in shrinkage compensating concrete. CTS Type-K provides an effective and economical way to minimize the cracking caused by drying shrinkage in Portland cement concrete. By producing controlled compressive stresses in the concrete, CTS Type-K reduces the detrimental tensile stresses which lead to shrinkage cracking in concrete. CTS Type-K is designed to keep the concrete in compression through the life of the concrete. Figure 1 illustrates how cracking can be eliminated by keeping the concrete in compression.

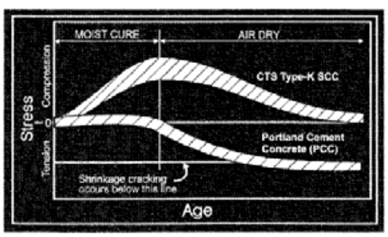


Figure 1

Significant volume changes do not occur as the concrete is typically restrained by the reinforcing steel and the subbase friction. The design and placement techniques for concrete produced with CTS Type-K are similar to regular Portland cement concrete; however, concrete can be installed in placements as large as 25,000 sq. ft. without joints. Super flat floor profiles may be obtained through the use of laser screeds and proper finishing techniques.

While CTS Type-K can eliminate shrinkage cracks -- the most common type of concrete crack -- concrete may crack from other causes such as structural overloading, settlement, and plastic shrinkage.

Applications: CTS Type-K can be used in any application where regular Portland cement concrete is used including:

<u>Bridge Decks and Parking Structures</u>: CTS Type-K's ability to minimize shrinkage cracks and reduce porosity provides long term protection against seepage of salts and other corrosive materials from penetrating bridge decks & parking garage decks, thus reducing the corrosion of the reinforcing steel and improving the life of the structures.

<u>Reinforced Slabs and Slabs on Grade</u>: By using CTS Type-K, larger concrete slab placements may be made and within those larger placements joints can be eliminated. Slab placements should be as square as possible without exceeding a 3:1 length to width ratio. Additional reinforcement may allow for placements with increased length to width ratios. Warping and curling of slabs can be significantly reduced when CTS Type-K is used.

Concrete with a slump of 4 1/2-in to 6 1/2-in is normally used for slabs. Due to the absence of bleed water, finishing on CTS Type-K concrete slabs may begin earlier than finishing on similar Portland cement concrete slabs

CTS Type-K

Containment Vessels: Due to the nature of the CTS Type-K cement, jointing and the resulting water stops can be reduced and, in many cases, eliminated to provide a containment vessel or structure with fewer potential leaks. CTS Type-K concrete's reduced bleed water provides a denser wall and slab section that decreases the permeability and lessens the possibilities of seepage.

Post-Tensioned Structural Concrete: Using CTS Type-K cement will reduce support column movement and shear wall stresses in post tensioned structures, allowing a reduction in reinforcing steel. Due to the internal compressive forces with CTS Type-K concrete, there is no need to post-tension a slab on grade at an early age to induce internal compression. This developed compression can be utilized in reducing the stressing steel required in normal concrete.

Toppings: In both bonded and unbonded toppings, the use of the CTS Type-K cement offers the same advantages as the ones described for the full depth CTS Type-K slabs such as fewer joints and a more durable wearing surface.

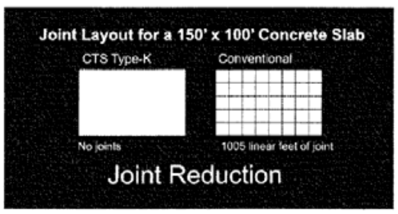
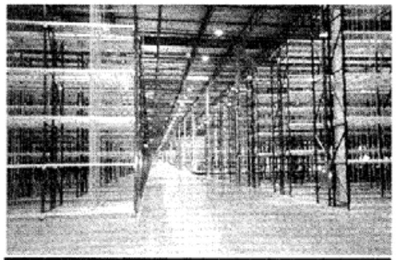


Figure 2

Additional Uses:

- Waste Water Treatment Plants
- Hazardous Waste Containment
- Swimming Pools
- Non-Shrink Grout
- Soil & Rock Anchoring
- Roof Decks
- Precast Concrete
- Cast-in-Place Concrete

4. TECHNICAL INFORMATION: The following industry test procedures and standards apply to CTS Type-K cement:
ASTM C-845 Standard Specification for Expansive Hydraulic Cement.
ASTM C-806 Test Method for Restrained Expansion of Expansive Cement Mortar.
ASTM C-878 Test Method for Restrained Expansion of Shrinkage-Compensating Concrete.



Concrete floors designed with joint spacing of 150-ft provide building owners with a very low life cycle cost floor solution.

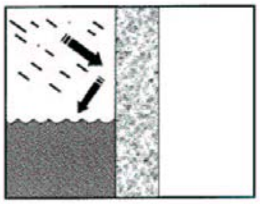
5. AVAILABILITY: CTS Type-K cement is available throughout the United States. The cement is packaged in 94-lb sacks and may also be purchased in bulk. For more information about CTS Type-K cement contact the CTS Cement Manufacturing Corp. headquarters at:

11065 Knott Avenue, Suite A
Cypress, CA 90630
Phone: (714)379-8260
Fax: (714)379-8270
Web: www.ctscement.com

Price Information: Significant cost advantages can be realized through the reduced life cycle cost of CTS Type-K concrete. Prices will vary depending on specific job conditions. Contact CTS for price quotes.

6. WARRANTY: CTS Cement Manufacturing Corporation warrants its material to be of good quality, and, at its sole option, within one year from date of sale, will replace defective materials or refund the purchase price thereof and such replacement or refund shall be the limit of CTS's responsibility. Except for the foregoing, all warranties, express or implied including merchantability and fitness for a particular purpose are excluded. CTS shall not be liable for any consequential, incidental, or special damages arising directly or indirectly from the use of the material.

8.3.3 Caltite



EVERDURE CALTITE

Waterproofing and Corrosion-resisting admixture

Cementaid Systems distributed by Glacier Northwest, Inc.

Applications

EVERDURE CALTITE is a heavy-duty waterproofing, corrosion and crack resisting ingredient (HPI) that is ideal for the following applications:

1. Heavy-duty integral waterproofing and dampproofing ingredient for structural concrete where there are severe damp conditions or water under pressure.

2. Protection of concrete against sulfate or acid bearing soil waters, and seawater wetting and drying.

3. To minimize deterioration of concrete floors and toppings subjected to acid and chemical attack.

Best places to use:

- Basements, tunnels, lift wells, podium decks and concrete roofs to replace membrane and coating systems.
- Joint-free industrial floors or floors exposed to chemical attack.
- Foundations/substructures where soil waters may contain sulfates or acids.
- Concrete in a marine or aggressive environment.

Specifications

All concrete (specify sections) shall be waterproofed/protected by the addition of Cementaid EVERDURE CALTITE at the rate of 30 liters per cubic meter (6 gal/cy). Superplasticizer shall be added at the recommended rate. The water content shall be reduced to preserve the specified slump and achieve a w/c ratio not greater than 0.42. The cement content of EVERDURE CALTITE concrete shall not be less than 350 kg per cubic meter (590 lb./cy).

Note:

- ***Flatwork Curing Requirement:*** Use Confilm evaporation retardant and an approved curing compound.
- ***Control Joints and penetrations:*** Apply Volclay expanding joint strip according to drawings.
- ***Projections through prepared openings:*** Fill void space with approved non-shrink grout containing Caltite recommended rate.
- ***Monitoring of Caltite System installation:*** Monitoring team provided by Caltite supplier.
- ***Performance Warranty:*** 10-years, provided by Caltite Supplier on all approved Caltite installations.

Benefits

- More than 40 years proven waterproofing/corrosionproofing field performance.
- Effective and permanent protection throughout the concrete.
- Eliminates requirement for membrane and coating products.
- Water absorption as measured by British Standard 1881: pt. 122: 1983 is consistently less than 1% in field concrete.
- Water permeability found to be reduced by approximately 10 times.
- Water vapor transmission resistance 603 MN. s/g for a 300 mm section.
- Reduces drying shrinkage by up to 50%.
- Exceptionally low chloride penetration rates.
- High resistivity due to non-sorptive nature of EVERDURE CALTITE concrete.
- Excellent freeze-thaw, salt-scaling and acid resistance.
- No detrimental effect on strength or other properties of concrete.

Dosage

Concrete:
30 liters of EVERDURE CALTITE per cubic meter of concrete plus Superplasticizer as recommended by Glacier Northwest technical staff.

Topping or Render: (PERFORMANCE WARRANTY EXCLUDED)
4.5 liters of EVERDURE CALTITE per 50 kg of cement.
0.5 liters Superplasticizer pr 50 kg. of cement .

Mix Adjustment:
The quantity of added water will need to reduced by approximately 1 liter for every liter of EVERDURE CALTITE and approx. 10 liters for every liter of Superplasticizer to retain the same workability.

Contact Glacier Northwest: (206) 764-3119

YOU CAN RELY ON

CEMENTAID

How EVERDURE CALTITE works:

Developed in 1958 after 9 years research into Integral waterproofers. EVERDURE CALTITE is the essential extra ingredient in concrete, in addition to cement, aggregate and water, which profoundly reduces capillary absorption, wick action and permeability under pressure to negligible levels, as well as providing maximum durability over the long term. Thus EVERDURE CALTITE completely eliminates the need for membranes or other temporary methods of waterproofing.

• EVERDURE CALTITE concrete requires a minimum cement content of 350 kg per cubic metre (or 595 lb per cubic yard) and a maximum W/C of 0.45 to provide a concrete of reasonably low porosity.

• The EVERDURE CALTITE SYSTEM uses two special ingredients to achieve truly effective water-tightness and corrosion-free life:-

SUPERPLASTET, a highly effective, slump-retaining superplasticiser, greatly reduces the batching water requirements, thus limiting the volume of the capillary network in the concrete. SUPERPLASTET also improves the workability to assist placing and proper compaction.

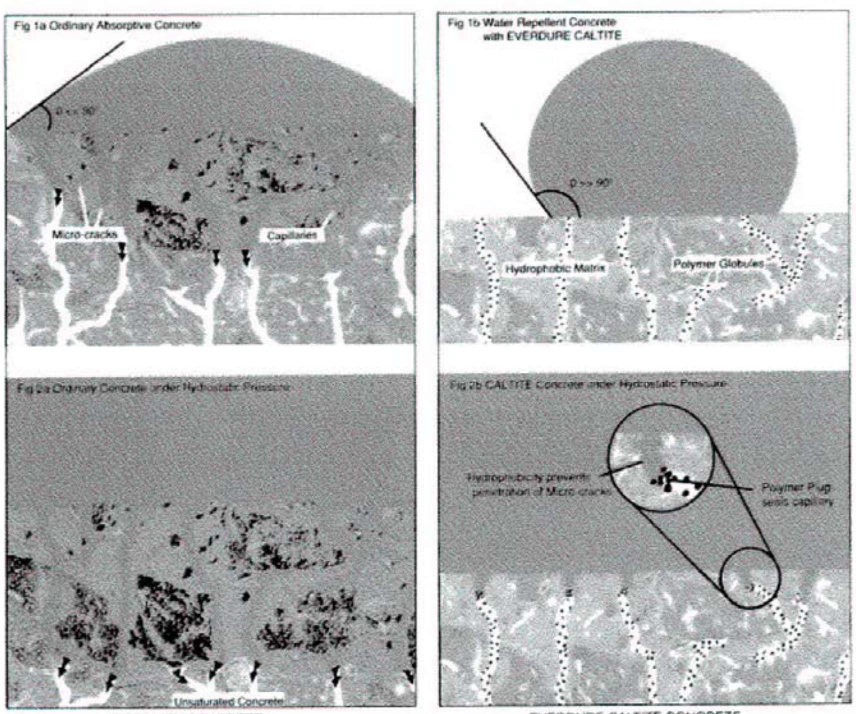
CALTITE is a unique reactive Hydrophobic Pore-blocking Ingredient which is dosed at the rate of 30 litres per cubic metre of concrete. CALTITE has two distinct waterproofing actions:

i) The first is a reaction of the hydrophobic component with the cement, fundamentally changing the surface tension. It produces a concrete which is inherently water-repellent and non-absorptive throughout its entire mass (see Figure Ib compared with Figure 1a).

ii) In the second action, discrete polymer globules moving with the bleed water, collect in the capillaries. When the hardened concrete is subjected to water under pressure, these globules are forced together to form a physical "plug" blocking the capillaries and preventing water entry (see Figure 2b).

• The EVERDURE CALTITE SYSTEM also includes service by representatives of Cementaid during each Caltite concrete pour, both at the batching plant and on site to help ensure correct dosage and to monitor concrete quality.

While the EVERDURE CALTITE SYSTEM is easy to use and relatively insensitive to abuse, we recommend good concrete practice in accordance with the relevant standards for the best results. Refer to the Technical Specification for details.



ORDINARY CONCRETE

EVERDURE CALTITE CONCRETE

YOU CAN RELY ON

CEMENTAID

Properties of EVERDURE CALTITE

Compressive Strength:

Independent studies confirm that EVERDURE CALTITE has no detrimental effect on compressive strength (Table 1). The Technical Manager of Ready Mixed Concrete wrote that "both as a result of laboratory tests and extensive work tests, this company is satisfied that when EVERDURE CALTITE is used in our concrete, its properties in terms of denseness and compressive strength are enhanced."

Note: As EVERDURE CALTITE concrete is highly water repellent, it is sensitive to early moisture loss from small test specimens prior to water curing. Unlike ordinary or pozzolanic concretes which are absorbent, EVERDURE CALTITE will not readily reabsorb lost water and the strength of the test specimen may be affected.

This is obviously not a problem in field concretes where the relative volume of concrete is far greater and full water curing is unlikely. Indeed cores from field concretes show superior performance.

Table 1: Compressive strength of concrete with and without the EVERDURE CALTITE SYSTEM (EDC).

Testing Authority	Mix	Cement kg/m3	Free w/c	Compressive Strength 7 days	28 days
Royal Melbourne Institute of Technology	Control	310	0.49	22.0	32.7
	EDC	310	0.49	21.7	33.1
University of Toronto	Control	360	0.45	28.2	34.0
	EDC	360	0.45	24.7	34.0
Fugro Middle East	Control	370	0.45	-	52.0
	EDC	370	0.45		52.5
Messrs Sandberg	Control	490	0.44	42.0	58.0
	EDC	490	0.45	46.0	56.5
University of Liverpool	Control	400	0.33	-	81.0
	EDC	400	0.33	-	83.0

Tensile Strength:

The EVERDUR ECALTITE SYSTEM enhances tensile strength when compared with reference concretes. Queen's University found that while compressive strength was comparable with the control, the EVERDURE CALTITE concrete had a 23% higher pull-off tensile strength. Unisearch found EVERDURE CALTITE concrete to have an 8% increase in tensile strength relative to the control.

Shrinkage:

EVERDURE CALTITE significantly reduces the drying shrinkage of concrete by as much as 50 percent. This appears due to both the slower rate of drying and the change in surface tension within the cement paste.

Absorption:

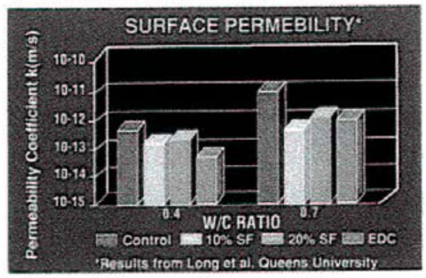
Absorption is a major component contributing to water and moisture movement when there is a humidity differential across a concrete section such as in basements, tunnels, pools and roofs.

Independent comparative studies of products have shown EVERDURE CALTITE to be superior to all other waterproofers, pozzolanic materials, etc.

Compliance testing of EVERDURE CALTITE concretes confirm that the absorption is consistently less than 1.0% in typical field concretes compared with 4-6% for ordinary concrete. (BS1881 : Part 122: 1983).

Permeability:

EVERDURE CALTITE has been found to reduce permeability by a factor of ten compared with an unmodified concrete. Queen's University, Belfast, conducted tests on concretes with water / cementitious ratios of 0.4 and 0.7. Concretes containing no additive silica fume at 10% and 20% replacement and EVERDURE CALTITE were compared. The results, given in Figure 3, showed that EVERDURE CALTIT gave a full ten fold reduction in permeability for both concrete qualities. The EVERDURE CALTITE concrete had significantly lower permeability than the silica fume concretes at the lower water/cementitious ratio.



Water Vapour Transmission:

Imperial College (London) conducted tests on water vapour transmission with liquid water on one face and 0% relative humidity on the other. The water vapour transmission resistance was 100.5 MN.s/g for 50mm thick section equivalent to 603 MN.s/g for a 300mm section. This compares favourably with membrane products.

Water Quality:

The EVERDURE CALTITE SYSTEM has been tested to determine its effect on the properties of potable water. As a result, EVERDURE CALTITE concrete is approved for use for potable water storage by various public utilities authorities.

Long-term Effectiveness:

EVERDURE CALTITE has been used in structural concrete for more than 30 years. Cores taken from EVERDURE CALTITE structures up to 25 years old confirm the long-term effectiveness of its ingredients on watertightness. Ultrasonic pulse velocity and compressive strength tests confirm that there has been no detrimental effect on mechanical properties.

The excellent durability of EVERDURE CALTITE is due to the hydrophobic component becoming substantive with the concrete matrix.

Note: The excellent long-term performance of EVERDURE CALTITE is unique to this ingredient. Ordinary "waterproofers" and attempted copies of EVERDURE CALTITE have been found to be chemically unstable or liable to physical displacement within the cement paste.

8.3.4 Hycrete

The "Solution" For Concrete Protection

Hycrete TECHNOLOGIES, LLC

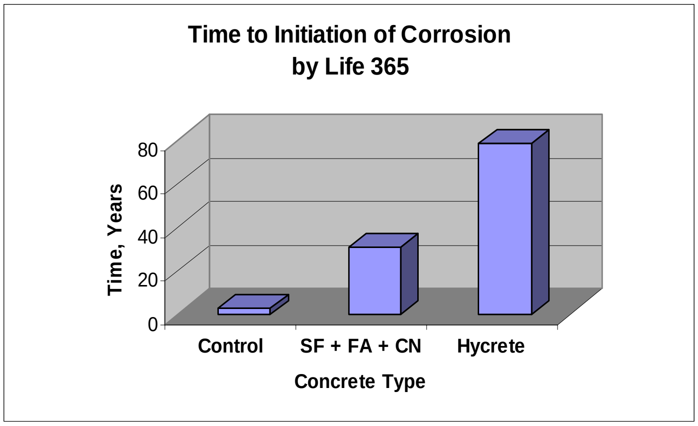
Hycrete Corrosion Inhibitor and Hydrophobic Testing Summary

www.hycrete.com

250 Newark Avenue, Suite 300
Jersey City, NJ 07302
(201) 386-8110

Long Life

Testing by the University of Massachusetts shows that bridges built with Hycrete can last more than 75 years before any corrosion would occur to the plain steel reinforcing bars. This performance surpasses combinations of silica fume, fly ash, and calcium nitrite.

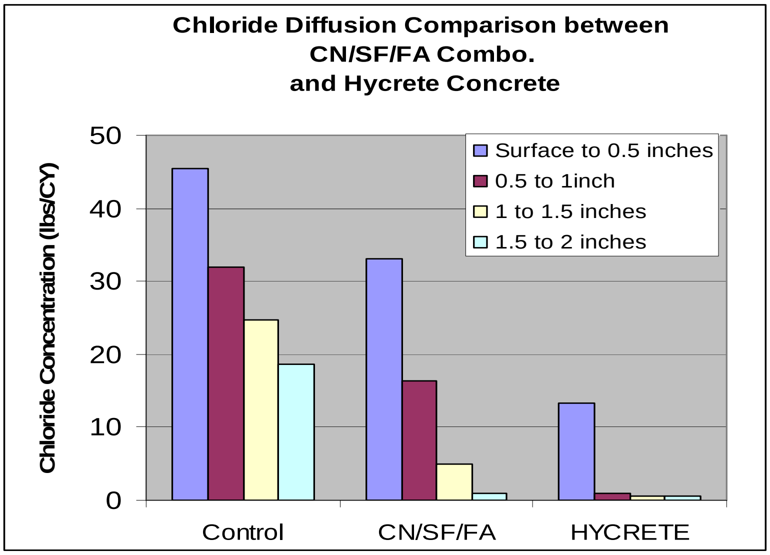


Chloride Diffusion Reduction:

UMass/ New England Transportation Consortium. Concrete mixes: w/c 0.40, Admixture: CN (1 gal/cy), Silica Fume (6%), Fly Ash (15%), Hycrete (2 gpy) Double-ASTM G-109 blocks, Salt Ponding Regime 12 weeks of 4 day ponding, then 12 weeks of continuous ponding.

Diffusion Coefficients, **m^2/sec**

Control	1.7E-11
CN+SF+FA	2.1E-12
Hycrete	4.2E-13



Compressive Strength In slag mixes Hycrete concrete is typically strength neutral. In fly ash or straight cement mixes, compressive strengths are often reduced by 5-15% versus control mixes of similar design. The type of aggregate can also affect the strength. Standard mix adjustments (water cement ratio reduction) are used to design Hycrete concrete that exceed project strength requirements.

NY / NJ Port Authority Testing: HPC mix with Fly ash:

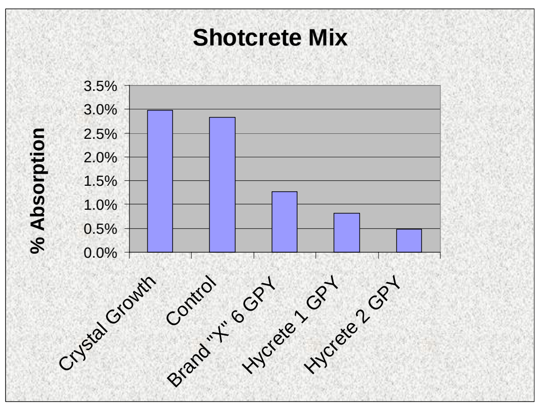
	CONTROL	HYCRETE	% difference
Air Content	5.5%	5.9%	
Slump	3.5	6	
1 DAY psi	1630	1520	7%
7 Day psi	3850	3210	17%
28 Day psi	5190	4940	5%

Absorption Testing (BSI 1881): This rugged test is used to test for hydrophobic concrete. Low w/c concrete typically tests in the 2%-4% absorption range with BSI 1881 Part 122 testing. Hydrophobic concrete is typically benchmarked at less than 1% absorption. Hycrete performs at the 0.4% to 0.9% range.

Northern California Independent Lab Testing

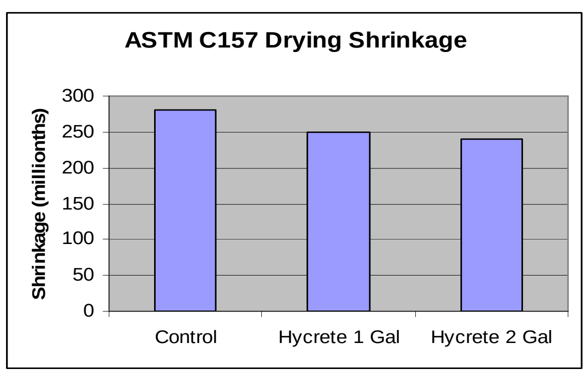
70/30 Shotcrete Mix
.38 W/C Water Reducer and Superplasticizer

Rebound = **Excellent**
Odor = **Neutral**
Consolidation = **Excellent**
Stand up = **Excellent**
Set Time = **Neutral**
Absorption = **Superior**



Drying shrinkage ASTM C157

Shrinkage reduction (10% to15%.) versus control of Cement + Fly ash, 0.40 w/c.
Nelson Testing, Chicago, IL



8.3.5 DegaDeck

degussa.

creating essentials

DEGADECK® BRIDGE DECK OVERLAY SYSTEM

Reactive methacrylate polymer overlay

PRODUCT DATA

7 071800 **Traffic Coatings**

Description

Degadeck® Bridge Deck Overlay System is a rapid curing methacrylate reactive resin formulated as an overlay and traffic wearing surface for concrete structures. The system is composed of the following:

DEGADECK® PRIMER is a reactive methacrylate resin used to prime properly prepared concrete.

DEGADECK® BODYCOAT FILLER component is a blend of specially graded fillers used with Degadeck® Bodycoat Resin Component and Powder Hardener to form the slurry layer of the overlay system.

DEGADECK® BODYCOAT RESIN component is a flexible methacrylate reactive resin used with Degadeck® Bodycoat Filler Component to form the slurry layer.

DEGADECK® TOPCOAT is a methacrylate reactive resin used as a wearing coarse to accept both pedestrian and vehicular traffic.

POWDER HARDENER is 50% dibenzoyl peroxide (BPO) in granulated powder form to initiate the cure of the Degadeck® resins.

DYNAGRIP #8 AGGREGATE is a specially graded, angular, hard-wearing stone or synthetic aggregate that is broadcast into the Degadeck® Bodycoat slurry and serves as the wearing course for vehicular traffic.

Features	Benefits
• Fast curing (1 hour)	On highway and bridge projects, allows fast return of traffic flow, contributing directly to worker and driver safety
• Extremely durable	Extends the service life of the bridge deck
• Can be used at temperatures ranging from 14 to 104° F (-10 to 40° C)	Extended application season
• Aggregate broadcast	Provides skid-resistant surface
• Weighs less than 3 lb/ft²	Reduces deadload on bridge structures
• Economical	Alternative to costly overlay systems or deck replacement.
• Waterproof	Prevents chloride ion contamination, freeze/thaw damage and salt scaling
• Compatible with other Degadeck® methacrylate systems	Provides complete systems approach to concrete protection
• High strength	Excellent bonding capabilities to a variety of concrete substrates
• UV resistance	Exposure to sunlight does not affect product performance

Yield

Degadeck® Primer:
100 ft²/gallon, depending on porosity of substrate.

Degadeck® Bodycoat slurry:
20 ft²/unit at 3/16" (187 mils)

Degadeck® Bodycoat Unit:
1.5 gallon (5.7 L) Degadeck® Bodycoat Liquid
1-30 lb (13.6 kg) bag Degadeck® Bodycoat Filler

Degadeck® Topcoat:
Approximately 80 ft²/gallon

Dynagrip #8 Aggregate:
1.5 lbs/ft²

Powder Hardener:
See Mixing charts for the appropriate products

Packaging

Degadeck® Primer:
38 lb (17.3 kg) pails, equals 4.7 gallons (17.8 L)
396 lb (180 kg) steel drums, equals 47.5 gallons (179.8 L)

Degadeck® Bodycoat Resin Component:
440 lb (200 kg) drum, equals 52.3 gallons (198 L)

Degadeck® Bodycoat Filler Component:
30 lb (13.6 kg) bag

Degadeck® Topcoat:
38 lb (17.3 kg) pails, equals 4.7 gallons (17.8 L)
440 lb (200 kg) drum, equals 55 gallons (208 L)

Dynagrip #8 Aggregate:
50 lb bags

Powder Hardener:
2.5 lb bottle
50 lb box

Protection and Repair

www.DegussaBuildingSystems.com

Technical Data

Composition

Degadeck® Bridge Overlay System is a reactive methacrylate system.

Compliances

- Degadeck® Bridge Overlay Sytem is classified under DOT regulations as Resin Solution, UN 1866, Class 3, PG II.

Typical Properties

DEGADECK® BODYCOAT

PROPERTY	VALUE	
	RESIN	FILLER
Appearance	Liquid	Grey powder
Specific gravity, g/cm³ (DIN 51757)	0.98	—
Approximate bulk density, lb/ft³ (kg/m³)	—	78.5 (1.26)
Viscosity, cP MPa·sec (ASTM D 2393)	700 – 1,100	—
Flash point, ° F (° C) (DIN 51755)	48 (9)	—

DEGADECK® TOPCOAT

PROPERTY	VALUE
Appearance	Liquid
Specific gravity, g/cm³ at 68° F (20° C), (DIN 51757)	0.97
Viscosity*, at 73° F (23° C), sp 2/12 rpm, MPa·sec	80 – 150
Flash point, (DIN 51755) ° F (° C)	48 (9)

* DIN 53018 Brookfield DVII

Test Data

DEGADECK® BODYCOAT

PROPERTY	RESULTS		TEST METHODS
	NEAT	FILLED 2.45:1	
Compressive strength, psi (MPa)	—	2,400 – 3,000 (16.5 – 20.7)	ASTM D 695
Tensile strength, psi (MPa)	500 (3.5)	1,290 – 1,380 (8.9 – 9.7)	ASTM D 638
Elongation at break, %	50	13	ASTM D 638
Flexural strength, psi (MPa)	—	1,500 – 1,700 (10.3 – 11.7)	ASTM C 790
Coefficient of thermal expansion, /° F (/° C)	—	4.4×10^{5} (7.9×10^{5})	VDE 0304/1
Hardness, Shore D	56	—	ASTM D 2240
Water absorption, %/24 hrs	< 0.1	0.5	ASTM D 570

DEGADECK® TOPCOAT

PROPERTY	RESULTS	TEST METHODS
Tensile strength, psi (MPa)	2,150 (14.8)	ASTM D 638
Elongation at break, %	35	ASTM D 638
Hardness, Shore D	62	ASTM D 2240
Water absorption, %/24 hrs	< 0.1	ASTM D 570

Color

Clear

Shelf Life

All components:
1 year when properly stored

Storage

Store in original, unopened containers. The containers must not be exposed to direct sunlight. Maximum storage temperature is 86° F (30° C).

Where to use

APPLICATION

- Bridge decks
- Civil engineering applications

LOCATION

- Exterior
- Horizontal

SUBSTRATE

- Concrete

How to Apply

Surface Preparation

1. The concrete surface must be clean, dry and free of oil, contaminants, laitance, and debris, and fully cured for 28 days.

2. Patch or repair deck delaminations, spalls and cracks with Degadeck® Polymer Concrete and allow to cure.

3. Mechanically prepare the surface to expose coarse aggregate and remove all loose materials. Meet the requirements of ICRI Guideline No. 03732 Standard CSP 5. To ensure proper surface preparation, perform "direct tension" testing (in accordance with ACI 503 Appendix A) every 4,500 ft^2 (414 m^2).

Mixing

DEGADECK® PRIMER

1. Mix enough material for a 5 to 10 minute application, with a slow-speed drill and jiffy style mixing blade.

2. Mix 1 gallon (or multiples of one gallon – maximum 5 gallons) with Powder Hardener per mixing chart below. Mix thoroughly for 30 – 60 seconds, and apply immediately.

DEGADECK® PRIMER (1 GALLON)

TEMPERATURE	POWDER HARDENER	
° F (° C)	VOLUME OUNCES	WEIGHT %
40 (4)	11	6
50 (10)	9	5
60 (16)	7	4
70 (21)	5	3
80 (27)	3	2
90 (32)	2	1

NOTE: For temperatures below 35° F (2° C), please consult with Degussa Technical Support and the Cold Temperature Mixing Chart.

DEGADECK® BODYCOAT

1. Degadeck® Bodycoat can be mixed in 5 gallon pails with a mixing blade or in concrete drum mixers. Measure out no more than 1.5 gallons of Degadeck® Bodycoat Resin Component per 30 lb (one bag) of Degadeck® Bodycoat Filler Component.

2. Add Degadeck® Bodycoat Resin Component to container followed by Degadeck® Bodycoat Filler Component and mix to obtain a slurry consistency. Then add the appropriate amount of Powder Hardener (see chart below) and mix thoroughly for 30 – 60 seconds.

DEGADECK® BODYCOAT RESIN COMPONENT (1.5 GALLONS)

TEMPERATURE	POWDER HARDENER	
° F (° C)	VOLUME OUNCES	WEIGHT %
40 (4)	16	4.8
50 (10)	13	3.9
60 (16)	10	3.0
70 (21)	7	2.1
80 (27)	5	1.5
90 (32)	3	0.9

NOTE: For temperatures below 35° F (2° C), please consult with Degussa Technical Support and the Cold Temperature Mixing Chart.

DEGADECK® TOPCOAT

1. Mix 1 gallon (or multiples of one gallon – maximum 5 gallons) with appropriate amount of Powder Hardener per mixing chart below. Mix thoroughly for 30 – 60 seconds, using a slow-speed drill and jiffy-style mixing blade.

DEGADECK® TOPCOAT (1 GALLON)

TEMPERATURE	POWDER HARDENER	
° F (° C)	VOLUME OUNCES	WEIGHT %
40 (4)	11	6
50 (10)	9	5
60 (16)	7	4
70 (21)	5	3
80 (27)	3	2
90 (32)	2	1

NOTE: For temperatures below 35° F (2° C), please consult with Degussa Technical Support and the Cold Temperature Mixing Chart.

Priming

1. Immediately after mixing Degadeck® Primer, pour onto the concrete surface and distribute with heavy nap, solvent-grade roller, brush or squeegee at approximately 100 ft^2/gallon leaving a uniform glaze on the surface.

2. Avoid puddling. Re-prime any areas indicating high surface absorption of the primer.

3. Allow to cure, approximately 1 hour.

4. OPTIONAL: If primer is to be left over night, light broadcast 30 mesh sand into the wet, uncured primer at a rate of up to 4 lbs/100 ft^2.

Application

Apply the Degadeck® Bodycoat slurry immediately after mixing by pouring directly onto the primed and cured deck surface, and distribute by means of steel gauge rake to desired thickness, normally 3/16", at the rate of approximately 20 ft^2 per unit.

WEARING COURSE AGGREGATE

Broadcast to rejection, approximately 1.5 lbs/ft^2, Dynagrip #8 or specified wearing course aggregate into the fresh, uncured Degadeck® Bodycoat. Aggregate should be thrown into the air and allowed to "rain" down into s l u rry to avoid rippling. Allow to cure, approximately one hour. Completely remove excess aggregate.

TOPCOAT

Degadeck® Topcoat is applied to the freshly swept wearing course using heavy nap (3/4") rollers at a rate of 80 ft^2/gallon.

Clean Up

Clean tools as needed with MMA, acetone, ethyl acetate or similar solvents.

For Best Performance

- Application substrate temperature must be between 14 and 104° F (-10 and 40° C).
- Curing problems may occur if material is applied at a lower than recommended thickness.
- Make certain the most current versions of product data sheet and MSDS are being used; call Customer Service (1-800-433-9517) to verify the most current versions.
- Proper application is the responsibility of the user. Field visits by Degussa personnel are for the purpose of making technical recommendations only and not for supervising or providing quality control on the job site.

DEGADECK® TOPCOAT

Warning

Degadeck® Topcoat contains methyl methacrylate; 2-ethylhexyl acrylate; acrylic polymer; and methacrylic acid ester.

Risks

FLAMMABLE LIQUID AND VAPOR. May cause skin and eye irritation. Ingestion may cause irritation. Inhalation of vapors may cause irritation and intoxication with headaches, dizziness and nausea. Repeated exposure may cause injury to the kidneys and liver. Repeated or prolonged overexposure may cause central nervous system damage. May cause dermatitis and allergic responses. Repeated or prolonged contact with skin may cause sensitization.

Precautions

KEEP AWAY FROM HEAT, FLAME AND SOURCES OF IGNITION. Heat, aging, or contamination may lead to violent rupture of sealed containers. Vapors are heavier than air. Keep container closed. Check periodically for warm or bulging containers. Use only with adequate ventilation. DO NOT get in eyes, on skin or on clothing. Wash thoroughly after handling. DO NOT breathe vapors. DO NOT take internally. Use impervious gloves, eye protection and if the TLV is exceeded or used in a poorly ventilated area, use NIOSH approved respiratory protection in accordance with applicable Federal, state and local regulations. Empty container may contain hazardous residues. All label warnings must be observed until container is commercially cleaned or reconditioned.

First Aid

In case of eye contact, flush thoroughly with water for at least 15 minutes. SEEK IMMEDIATE MEDICAL ATTENTION. In case of skin contact, wash affected areas with soap and water. If irritation persists, SEEK MEDICAL ATTENTION. Remove and wash contaminated clothing. If inhalation effects occur, remove to fresh air. If discomfort persists or any breathing difficulty occurs, or if swallowed, SEEK IMMEDIATE MEDICAL ATTENTION.

Refer to Material Safety Data Sheet (MSDS) for further information.

VOC Content

< 100 g/L or 0.83 lbs/gallon, less water and exempt solvents.

POWDER HARDENER

Danger - Organic Peroxide

Powder Hardener contains dibenzoyl peroxide; and dicyclohexyl phthalate.

Risks

May cause skin, eye and respiratory irritation. May cause dermatitis and allergic responses. Repeated or prolonged contact with skin may cause sensitization. May cause dermatitis and allergic responses. Ingestion may cause irritation.

Precautions

KEEP AWAY FROM HEAT, FLAME AND SOURCES OF IGNITION. Use only with adequate ventilation. Avoid contact with skin, eyes and clothing. Keep container closed when not in use. Wash thoroughly after handling. DO NOT take internally. Prevent inhalation of dust. Use impervious gloves, eye protection and if the TLV is exceeded or used in a poorly ventilated area, use NIOSH/MSHA approved respiratory protection in accordance with applicable Federal, state and local regulations. Empty container may contain hazardous residues. All label warnings must be observed until container is commercially cleaned or reconditioned.

First Aid

In case of eye contact, flush thoroughly with water for at least 15 minutes. In case of skin contact, wash affected areas with soap and water. If irritation persists, SEEK MEDICAL ATTENTION. Remove and wash contaminated clothing. If inhalation causes physical discomfort, remove to fresh air. If discomfort persists or any breathing difficulty occurs or if swallowed, SEEK IMMEDIATE MEDICAL ATTENTION.

Refer to Material Safety Data Sheet (MSDS) for further information.

VOC Content

0 g/L or 0 lbs/gallon, less water and exempt solvents when components are mixed and applied per manufacturer's instructions.

For medical emergencies only, call ChemTrec (1-800-424-9300).

Degussa Building Systems

889 Valley Park Drive
Shakopee, MN, 55379

www.DegussaBuildingSystems.com

Customer Service 800-433-9517
Technical Service 800-243-6739

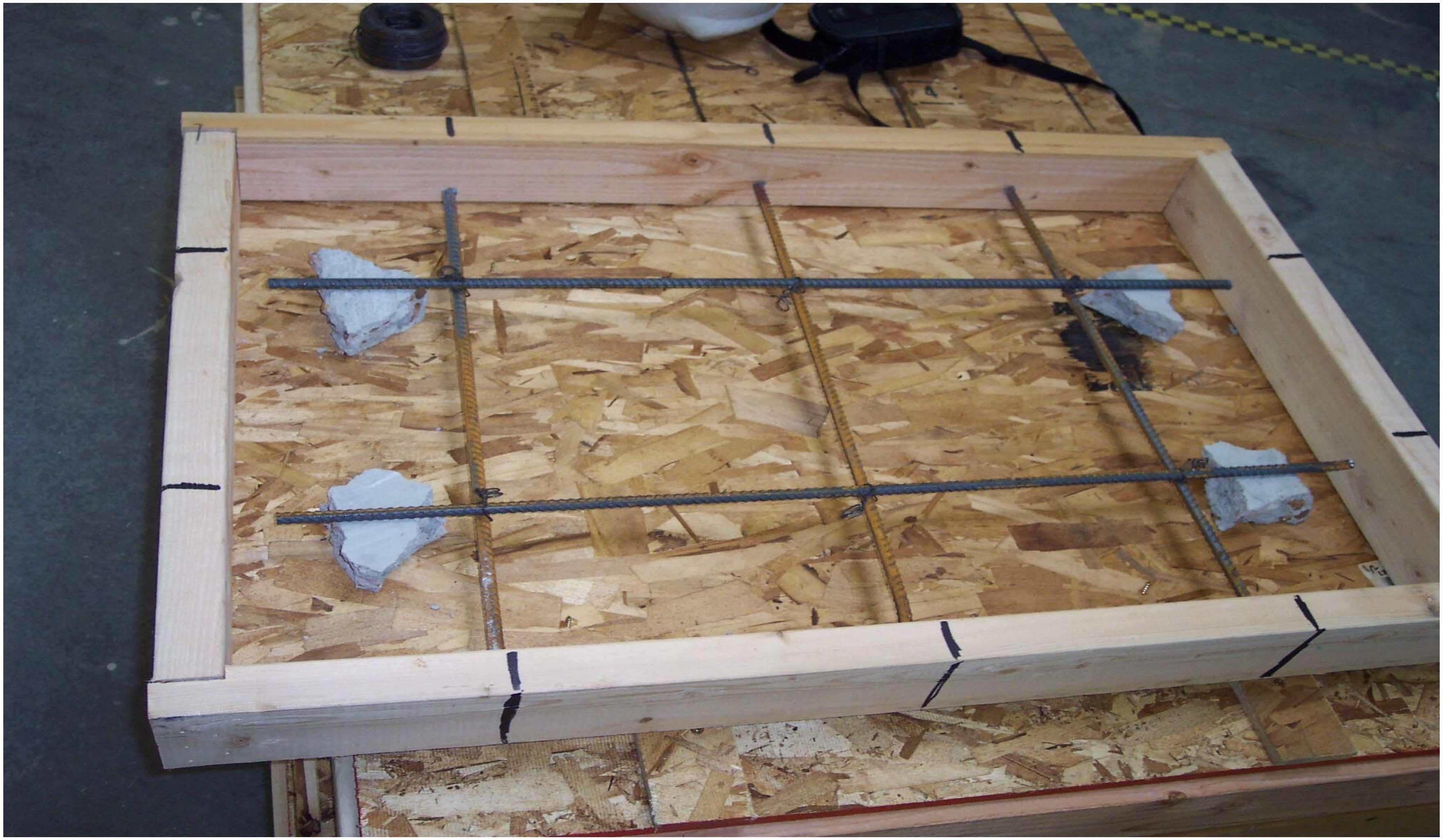
Form No. 1031120 8/05 (Replaces 1/02)
Printed on recycled paper including 10% post-consumer fiber.

8.4 Definitions and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AM	Asphaltic Membrane
ASTM	American Society for Testing and Materials
ASR	Alkali - Silica Reactivity
CDOT	Colorado Department of Transportation
COV	Coefficient of Variation
HMA	Hot Mix Asphaltic (concrete)
HMWM	High Molecular Weight Metacrylate
RCP	Rapid Chloride Permeability, (ASTM C1202 test)
Type K	Expansive Hydraulic Cement, ASTM C845
VOW	Velocity of Wear

8.5 Photographs of Laboratory Testing

Restraining Reinforcement for Type K Cement Pane



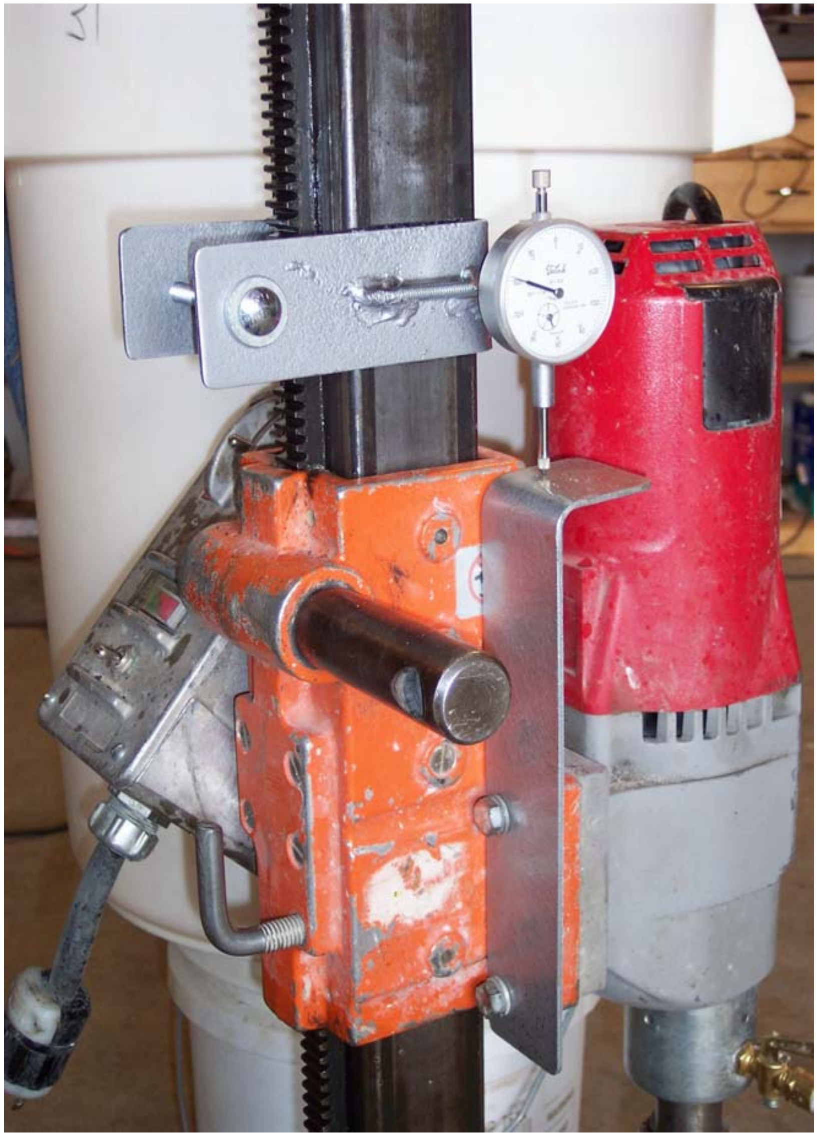
Test panels at the beginning of 14-day curing period.

Application of CDOT-Approved Liquid Curing Compound to Most Panels

Sandblasting off the Liquid Curing compound at 14-days

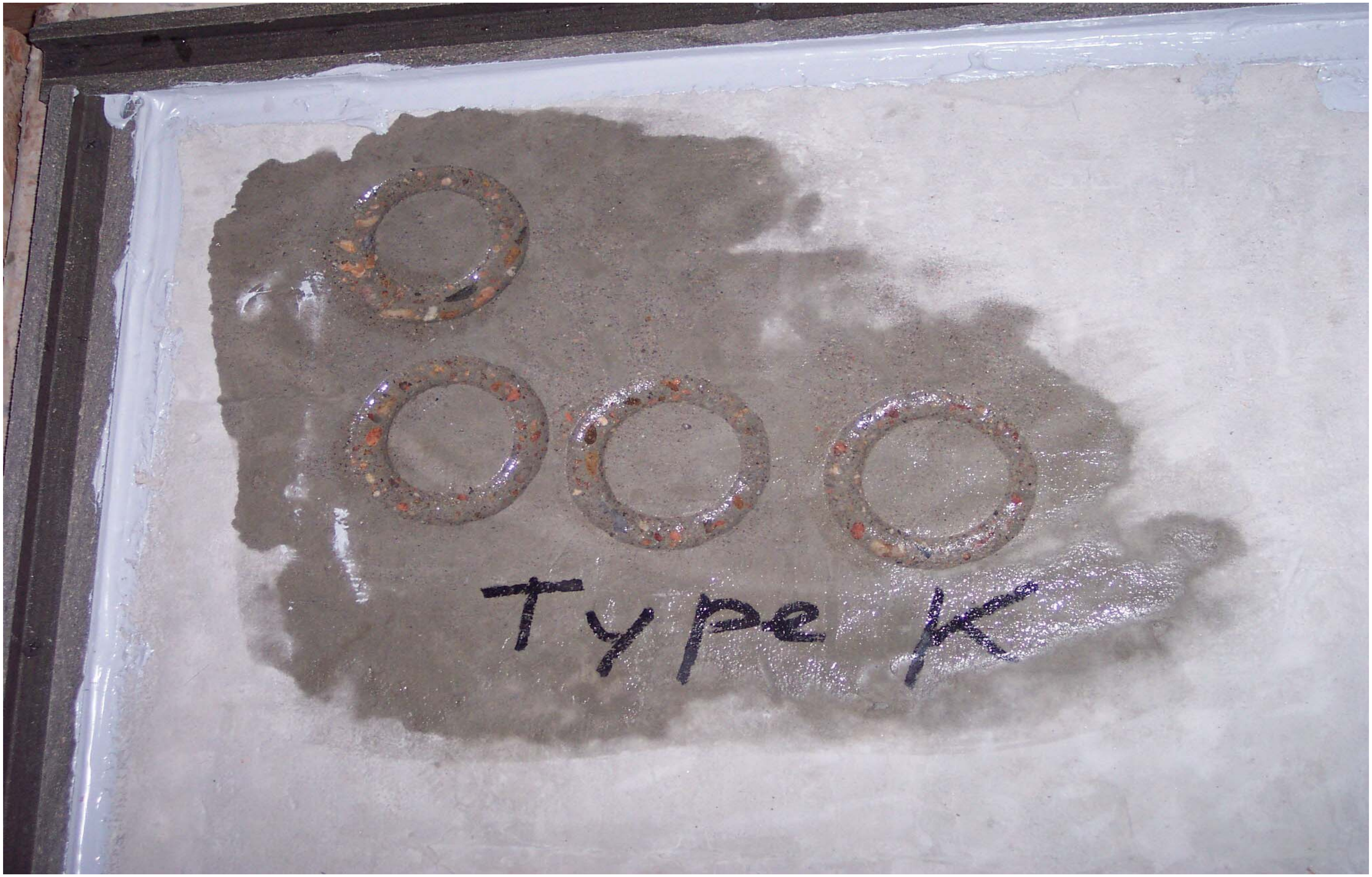
C779 Surface Abrasion Testing

Close-up of Dial Gage Attachment to Coring Machine



Close-up of custom designed abrasion attachment

Close-up of Completed Abrasion Wear Surfaces



Drilling Method for Penetrated Chloride Ion Content

Sampling of the Drilling Dust

Modified C1202 Test Cell, with custom-made rubber gaskets