REPORT 2014 - 09

VERMONT AGENCY OF TRANSPORTATION

Research & Development Section
Research Report

EVALUATION OF CONCRETE BRIDGE MIX DESIGNS FOR CONTROL OF CRACKING, PHASE I

Report 2014 – 09

November 2014

Evaluation Of Concrete Bridge Mix Designs For Control Of Cracking, Phase I

FINAL REPORT

Report 2014 – 09

November 2014

Reporting on SPR-RAC-710

STATE OF VERMONT
AGENCY OF TRANSPORTATION

RESEARCH & DEVELOPMENT SECTION

BRIAN R. SEARLES, SECRETARY OF TRANSPORTATION
CHRIS COLE, DIRECTOR OF POLICY, PLANNING AND INTERMODAL DEVELOPMENT
JOE SEGALE, P.E./PTP, PLANNING, POLICY & RESEARCH
WILLIAM E. AHEARN, P.E., RESEARCH & DEVELOPMENT

Prepared By:

Jason Tremblay, M.S., P.E., Research Engineer
Jim Wild, Concrete Engineer
George W. Colgrove III, Research Administrator

Reviewed By:

William E. Ahearn, P.E.,
Research Managing Engineer

Date: November 7, 2014

The information contained in this report was compiled for the use of the Vermont Agency of Transportation (VTrans). Conclusions and recommendations contained herein are based upon the research data obtained and the expertise of the researchers, and are not necessarily to be construed as Agency policy. This report does not constitute a standard, specification or regulation. VTrans assumes no liability for its contents or the use thereof.

Technical Report Documentation Page

<table>
<tr><td>1. Report No.
2014-09</td><td>2. Government Accession No.
- - -</td><td colspan="2">3. Recipient's Catalog No.
- - -</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
EVALUATION OF CONCRETE BRIDGE MIX DESIGNS FOR CONTROL OF CRACKING</td><td colspan="2">5. Report Date
November 2014</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Jason Tremblay, M.S., P.E., Research Engineer
Jim Wild, Concrete Engineer</td><td colspan="2">8. Performing Organization Report No.
2014-09</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Vermont Agency of Transportation
Materials and Research Section
1 National Life Drive
National Life Building
Montpelier, VT 05633-5001</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
RSCH016-710</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Federal Highway Administration
Division Office
Federal Building
Montpelier, VT 05602</td><td colspan="2">13. Type of Report and Period Covered
FINAL
(2009 – 2010)</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes</td></tr>
<tr><td colspan="4">16. Abstract
Cracking of concrete is a common problem with concrete structures such as bridge decks, pavements and bridge rail. The Agency of Transportation (VTrans) has recently invested in higher performing concrete mixes that are more impervious and has higher early strength. VTrans has also begun to standardize on bare decks on bridge rehabilitation projects. Higher strength concrete is more susceptible to cracking. With more decks being constructed with exposed concrete, the risks of chlorides and other corrosives penetrating to the reinforcing may lead to early deterioration. Additional moisture within the concrete may compound the deterioration during freeze-thaw periods. These stressors lead to decreased strength, which results in increased maintenance to ensure safety and durability, a reduction in the overall aesthetics of the structures and a decrease in public confidence and support. With closer attention made to the concrete mix by the addition of key admixtures, concrete may be able to perform as desired with fewer resulting problems.

With 22 different concrete mix designs produced and tested for various concrete properties, flexural and compressive strength, rapid chloride permeability and shrinkage, it is clear that there are seven candidate designs, given the measured data, which could outperform current VTrans standards. To ensure successful performance of new mix designs, further testing on each, with additional refining, a second phase of this project has been approved, with the same testing parameters, to refine the chosen mix designs further. The refining of designs will entail further optimization of aggregate gradations, as the industry has trended towards reporting benefits of this, lowering only cement content to achieve design strength within 10% at 28 days while other components remain unchanged in a mix, and include shrinkage control measures in most if not all mixes.</td></tr>
<tr><td colspan="2">17. Key Words
Concrete bridge deck, Concrete Mixes
Shrinkage cracking</td><td colspan="2">18. Distribution Statement
No Restrictions.</td></tr>
<tr><td>19. Security Classif. (of this report)
- - -</td><td>20. Security Classif. (of this page)
- - -</td><td>21. No. Pages</td><td>22. Price
- - -</td></tr>
</table>

Form DOT F1700.7 (8-72) **Reproduction of completed pages authorized**

TABLE OF CONTENTS

ABSTRACT

Cracking of concrete is a common problem with concrete structures such as bridge decks, pavements and bridge rail. The Agency of Transportation (VTrans) has recently invested in higher performing concrete mixes that are more impervious and has higher early strength. VTrans has also begun to standardize on bare decks on bridge rehabilitation projects. Higher strength concrete is more susceptible to cracking. With more decks being constructed with exposed concrete, the risks of chlorides and other corrosives penetrating to the reinforcing may lead to early deterioration. Additional moisture within the concrete may compound the deterioration during freeze-thaw periods. These stressors lead to decreased strength, which results in increased maintenance to ensure safety and durability, a reduction in the overall aesthetics of the structures and a decrease in public confidence and support. With closer attention made to the concrete mix by the addition of key admixtures, concrete may be able to perform as desired with fewer resulting problems.

With 22 different concrete mix designs produced and tested for various concrete properties, flexural and compressive strength, rapid chloride permeability and shrinkage, it is clear that there are seven candidate designs, given the measured data, which could outperform current VTrans standards. To ensure successful performance of new mix designs, further testing on each, with additional refining, a second phase of this project has been approved, with the same testing parameters, to refine the chosen mix designs further. The refining of designs will entail further optimization of aggregate gradations, as the industry has trended towards reporting benefits of this, lowering only cement content to achieve design strength within 10% at 28 days while other components remain unchanged in a mix, and include shrinkage control measures in most if not all mixes.

INTRODUCTION

Cracking of concrete bridge decks has been an ongoing problem throughout the State of Vermont. This problem is projected to be of increasing concern, as VTrans moves towards specifying bare concrete decks on bridge rehabilitation projects. Cracking in concrete allows for the penetration of chlorides and other corrosives resulting in deterioration of reinforcing. Additionally, moisture may also penetrate more readily resulting in accelerated damage from freeze thaw cycles in the form of scaling and spalling. These stressors lead to decreased strength, which results in increased maintenance to ensure safety and durability, a reduction in the overall aesthetics of the structures and a decrease in public confidence and support. The ability to greatly reduce or eliminate the majority of the concrete deck cracking is important to alleviate these concerns. The different materials that are incorporated into our standard concrete mixes need to be analyzed to decrease crack susceptibility.

Generally, concrete is comprised of four basic elements, Portland cement, a fine aggregate, a coarse aggregate and water. In many cases, pozzolans and admixtures are also incorporated into the mix, for specific characteristics such as air entrainment, alkali-silica reactivity (ASR) abatement and lower permeability. It should be noted that "high performance," or HP, mixes were introduced in the 1990's in an effort to stop Alkali- Silica-Reactivity distress in concrete, where a portion of the cement is substituted with mineral admixture and/or microsilica. Additional traits of HP mixes are their high strengths and projected durability characteristics. The State of Vermont allows several different options for the proportioning of high performance concrete compositions. Once thoroughly mixed, this matrix is poured into forms, around reinforcing, and then vibrated until properly consolidated. Sections that will be visible are usually finished to proper surface character, contour and elevation. Finally, the cast concrete cures for strength gain, improved durability and enhanced resistance to wear. Curing is essential for optimum performance and is typically accomplished through a wet curing process where the concrete is flooded, ponded or mist sprayed as well as some cover to retain water and reduce wicking of moisture to the surface. Ambient air temperature is another important parameter as higher temperatures increase the rate of strength gain and potential for premature drying of concrete leading to surface cracking.

While there are many causes for cracking in concrete, shrinkage cracking is most common. Generally, concrete is mixed with more water than is needed to hydrate the cement. As the cement begins to cure, water molecules are stored in numerous microscopic pores that develop throughout the initially soft concrete matrix. The water molecules are rapidly consumed during the beginning stages of the hydration process. As the water molecules are integrated into the crystalline matrix of the concrete, they leave the pores, creating a surface tension at the water/pore surface interface. This causes an inward directed force that tries to collapse the pore into itself, resulting with very slight contraction of the pore while the concrete is still soft. Once the concrete hardens, the contraction ceases. The cumulative effect of every pore contracting during the curing process is what causes the overall shrinkage to occur.

Shrinkage of the concrete in bridge superstructure elements is restrained by reinforcing thereby causing tensile strengths to develop within the hardened concrete. The location of shrinkage cracking can be controlled by the placement of construction joints. Such joints are not utilized along the length of bridge decks. Even when they are incorporated into the design for non-deck applications, cracking has often been observed between construction joints.

Objective

The objective of this research initiative was to examine a series of differing concrete mix designs to begin the process of selecting an optimum design for exposed concrete bridge decks as well as other concrete structures. The intension was to lower the amount of cracking that is present on bridge decks. Hardened concrete test specimens were produced from test batches using nine separate concrete mixes. These were tested using a prescribed methodology. Cracking was reduced either by using a single or a combination of shrinkage-control agents, aggregate proportioning, by reducing the amount of cementitious material or a blending of remedies. Lower cementitious materials could require a reduction of the total volume of mix water, based on the current water/cementitious ratios. Laboratory testing of this type is needed in order to provide a basis for support for moving forward with full-scale trials using one or more of the previously mentioned mix adjustment combination.

Mixes that were explored fall within three groups:

- <u>Group 1:</u> All high performance concrete (HPC) Class B mix designs
- <u>Group 2:</u> All HPC Class A mix designs
- <u>Group 3:</u> All HPC Class AA mix designs

The original work plan was to concentrate only on HPC A and B. Projects requiring a HPC Class AA overlay justified exploring shrinkage reducing strategies for this class of concrete as well. Providing an overlay mix free of cracks is important to keep water from intruding the horizontal interface layer to the old concrete and causing delamination by freeze thaw action.

Each of these groups included various recipes of mixes. Each group contained a control mix, which was the current standard mix used by VTrans in each HPC class. Some of the mixes utilized a shrinkage-reducing admixture or a shrinkage compensating cementitious admixture (or expansive cementitious admixture). The purpose of both of these was to find out how effective both of these are at reducing or eliminating the amount of shrinkage that would occur within the concrete during the curing process. In addition, some mixes incorporated various alterations to the typical mix designs, such as including more mid-range aggregate, ranging from 3/8” to 1/4” than in the control specimens. This was to provide a gradation with fewer gaps in order to reduce the overall needed paste content. Other mixes used a course aggregate gradation (3/4” for the HPC-A and HPC-B mixes.) Since it is suspected that silica fume contributes significantly to shrinkage in concrete, a few select mixes were designed without a silica fume addition. Six experimental mixes include an engineered aggregate gradation for HPC-B.

Engineered aggregates comprise of a blend of a select set of aggregate sizes and amounts to meet the Agency's specifications precisely. According to Table 704.01A in the 2011 Standard Specifications for Construction, the Agency defines how much of a particular size aggregate is allowed to pass through certain sieves, see Table 1 and Figure 1. The amount passing each sieve is expressed as a range of percentages. The Engineered gradation is the midpoint of each range. Another way to view this is what the gradation would be in perfect conditions with no tolerances.

Table 1 Fine Aggregate for Concrete

Sieve Designation	Percent by Weight Passing Square Mesh Sieves	Engineered Percentage
⅜ inch	100	100
No. 4	95 to 100	97.5
No. 16	50 to 80	65
No. 30	25 to 60	42.5
No. 50	10 to 30	20
No. 100	2 to 10	6

Table 704.01A – 2011 Standard Specifications for Construction

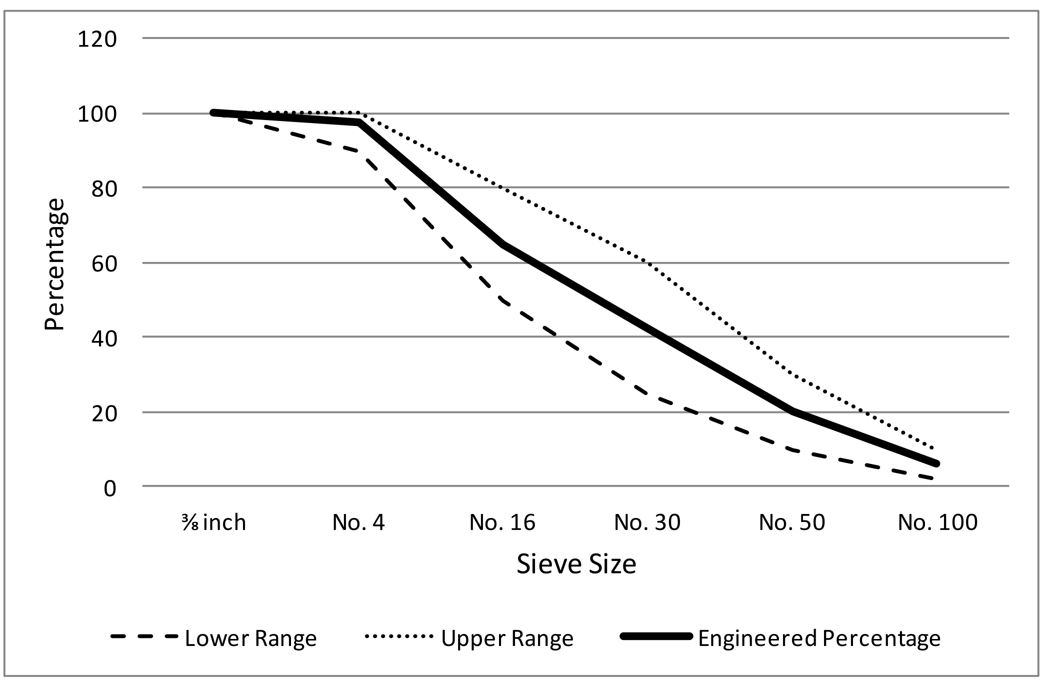


Figure 1 Showing acceptable gradation vs. Engineered Gradation

Testing was performed over time on prisms and cylinders produced from the specified mixes to determine essential material properties including the shrinkage susceptibility of each mix, permeability, compressive strength and Modulus of Elasticity. These tests are important, not only to determine if the experimental mixes improve upon material properties of concern, but also to make sure that other physical properties are not drastically impaired in the process. Technicians also made note of how each mix finished and consolidated based off the reference mix. A mix can be designed in the lab to optimize all the needed properties but if it cannot be placed and finished with acceptable effort then it will not be accepted by industry.

The analysis of the testing data was intended to pinpoint and detail the factors that contribute to decreasing the amount of shrinkage cracking in the concrete. Excessive cracking due to other factors (other than shrinkage), was examined for causations and contributing elements, such as excessive 28 day concrete strengths that lead to high moduli of elasticity and very rigid concrete that will crack sooner when put into a deflection situation.

The analysis of these experimental alternatives included other factors, such as cost, long-term durability, quality assurance, construction feasibility and probability of success.

At the conclusion of this project, it was apparent that further research was necessary. It was felt that more refinements could be made to the most promising mixes for additional optimization. It is anticipated that the mixes using an engineered aggregate will be used in a full-scale test on future concrete bridge deck placements for further testing and observations. It was expected that factors other than mix design would present themselves during the study, such as changing other admixtures, placement or construction practices or excessive 28-day strength.

EXPERIMENTAL METHODS AND DATA COLLECTION

Concrete Batching and Sample Preparation

All concrete batches were produced at the Materials and Research laboratory by the Structural Concrete Unit with the use of a small lab concrete mixer. Prior to full batch production, a ‘butter batch’ was mixed consisting of a scaled down version of the mix design in an effort to coat the mixer with paste so that none was lost from the full batch to create the most homogeneous final product possible. The butter batch, once completed, was discarded. In general, two batches of near identical formulation were produced on the same day, again in an effort to reduce potential variables. In addition to the batches that were incorporated into this study, supplemental test batches were made in order to focus on particular admixture dosages.

To eliminate as many variables as possible, the material sources were kept as consistent as possible between the different mixes. There were some variations, for example, the optimized gradation mixes that were used included some aggregates from other sources in order to get the grading needed. Most of the ¾" coarse aggregate was from the Frank W. Whitcomb source in Colchester, VT, while most of the fine aggregate was from the Nadeau source in Johnson, VT, collected from Carroll Concrete located on Grainger Road in Berlin VT. Cement for all batches came from Lafarge in St. Constant Quebec, and was collected from Carroll Concrete located on Route 12A in West Lebanon, NH. Consistent air entrainment and water reducing admixtures were also used throughout most of the study batches, with Darex II and ADVA 190, both from W.R. Grace, being used, respectively. For two batches, Micro-Air and Glenium 7500, both from BASF, were used. Four mixes contain shrinkage control measures, with two mixes incorporating a liquid admixture, W.R. Grace's Eclipse 4500 and two with type G expansive cement replacing a portion of standard cement, CompCon produced by ShrinkageComp Plus Inc.

During the study, the research team chose to include a ternary cement product called Tercem. This is a blended hydraulic cement product that "provides superior strength and durability" (*1*). The material provides better alkali reactivity prevention and provides better freeze-thaw protection. More local concrete suppliers have begun to replace standard portland cement with Tercem. The research team felt that the use of Tercem in the study would be advantageous in the mix comparisons. Two HPC B mixes were chosen for the evaluation.

Once each batch was mixed, air content, slump, W/C ratio, and unit weight measurements were taken, as prescribed below. In order to complete all the desired testing, three 4"x4"x11¼" prism forms, two 3"x3"x16" prism forms and ten 4"x8" cylinder forms were filled, comprising the test batch. All test specimens were placed in a fog room for curing.

Description of Admixtures

Air-entrainment – This admixture contains surfactants, which reduces the surface tension between the air and water interface within the cement paste. The entrapped air caused from mixing the concrete then stabilizes thereby creating very small and uniform air bubbles. Air entrainment protects the concrete from freezing, thawing and severe weathering (*2*).

Water Reducing – Where water aids in workability, it also allows for separation and sedimentation of the particles in a concrete mix. The reduction of water may aid in the uniformity of the mix; however, it can negatively affect the concrete's workability. Water-reducing or plasticizing admixtures allow for low viscous concrete flow, while keeping the water content low. Lowering the water to cement ratio will also aid in limiting shrinkage (*3*).

Shrinkage Reducing – Similar to air-entrainment admixtures, this admixture changes the surface tension between the water and pore wall interface. This reduces the inward directed force on the pore walls, thereby reducing the tendency of the pore to slightly collapse into itself. The resulting cumulative shrinkage will then be reduced (*4*).

Expansive Cement – During initial cure, there is an expansion within the concrete matrix. This expansion is contained within the form causing a compressive force on the concrete matrix including the pores. As hydration continues, the typical shrinkage mechanism continues, thereby reducing the compressive forces within the pores. Since, the concrete matrix does not go onto tension or the tensile forces are significantly reduced; cracking can be eliminated or reduced. (*5*)

Description of Test Batches

Table 2 displays the composition of the mixes, with amount of aggregate, cement, and admixtures included. The first column shows an identifying number for use as a key designator, to make referring to a specific mix easier throughout this document. Table A2 in the appendix lists specific notes that the production technicians had related to the mixes during and after batching.

In all, eleven high performance concrete (HPC) Class B mixes were produced, three Class A, and eight Class AA. Within each group, various proportions of coarse versus fine aggregate, cement percentages, and cement types were tested, along with four mixes having an expansive cement or shrinkage controlling admixture added. The first mix in each group (Key 1, 12, and 15, with the designation of "C") were proportioned to match standard VTrans concrete mix designs, and therefore will be considered the control designs for analysis purposes.

Table 2 Concrete mix design composition.

Key	Type	Coarse Aggregate (lb/yd3)	Fine Aggregate (lb/yd3)	Cement (lb/yd3)	Air Entrainer (oz/yd3)	Water Reducer (oz/cwt)	Shrinkage Control
C1	**HPC B**	1654	1385	610	2.5	4.7	
2	HPC B	1636	1454	551	3.4	8.0	
3	HPC B	1845	1175	610	4.8	7.0	
4	HPC B	1627/206	1283	563	5.3	10.3	
5	HPC B	1654	1385	610	7.5	5.0	314.0 ml admixture
6	HPC B	1654	1385	610	3.2	5.8	3.4 lb expansive cement
7	HPC B	1636	1454	551	2.9	10.0	
8	HPC B	1636	1454	612	4.3	5.7	
9	HPC B	1551	1620	564	2.9	5.1	
10	HPC B	1517	1558	611	3.1	5.3	
11	HPC B	1641	1297	611	1.5	4.6	
C12	**HPC A**	1654	1294	659	6.3	6.5	
13	HPC A	1654	1294	659	15.8	6.0	314.0 ml admixture
14	HPC A	1654	1294	659	6.7	6.7	3.7 lb expansive cement
C15	**HPC AA**	1350	1519	706	4.5	6.2	
16	HPC AA	1449	1503	610	4.0	8.0	
17	HPC AA	1449	1606	610	4.0	8.5	
18	HPC AA	1499	1557	610	4.2	8.3	
19	HPC AA	1499	1557	610	4.0	8.5	
20	HPC AA	1499	1557	610	4.4	8.2	
21	HPC AA	1561	1633	551	6.5	10.5	
22	HPC AA	1652	1319	610	4.3	8.5	

Of particular importance in Table 2 is the cement content. Within this project, a primary focus was to try to find a mix design that could be reliably used in the field that could contain a lower amount of cement than our standard mixes. In general, the lower amount of cement in concrete leads to a less total water volume, i.e. theoretically less shrinkage of the structure.

Concrete Testing

Four separate types of testing were performed on all prepared concrete samples. The first type consisted of fresh concrete tests that are performed at the time of batching, which include air content, slump, water to cement ratio, and the unit weight of the concrete. The second through fourth type included compression and flexural strength testing at various days and rapid chloride penetration testing at 56 days post casting. All tests are described in detail in the following sections.

General Concrete Tests

Air Content

Air content determination was performed in accordance with AASHTO T 152 "Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method" (*6*). The air content is found from identifying the change in volume of the concrete with a specified change in pressure.

Slump

Slump testing was performed in accordance with AASHTO T 119 "Standard Method of Test for Slump of Hydraulic Cement Concrete" (*7*). For this test, the freshly mixed concrete is compacted into a frustum of a cone shape. The mold is removed allowing the concrete fall freely. The distance between the original height of the mold and the new top of the concrete is measured and is considered the slump of the concrete.

Unit Weight

The unit weight of the concrete was determined in accordance with AASHTO T 121 "Standard Method of Test for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete" (*8*). A container of known volume is filled with fresh concrete and weighed on a calibrated scale. The recorded weight is divided by the known volume and the density of the concrete determined.

W/C Ratio

The water to cementitious content ratio is determined via a straightforward calculation of the total weight of water in the concrete divided by the total cementitious content of the concrete.

Compression Strength Test

Compressive strength is a vital component in determining the structural integrity of a concrete bridge deck and is defined as the capacity of a material to withstand axially directed pushing forces. Concrete deterioration may result in a lower compressive strength than originally designed.

Testing was performed in accordance with ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens" (*9*) and/or AASHTO T 22, "Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens" (*10*). Each cylinder is placed between two metal plates of a Tinius-Olsen machine. Computer commands are used to apply an increasing uniform axial compressive force on the specimen until failure.

Testing was done at 3, 7, 14, and 28 days post casting. For each test reported, two separate cylinders were tested and the average of the two taken to determine the compression strength of the batch at that day.

Flexural Strength Test

Flexural strength and modulus of rupture determination is an important aspect of concrete mix designs for concrete bridge decks, as the test attempts to simulate forces that are subjected to bridge decks. This testing was done to see if the modulus of rupture values would be affected by the concrete mix design variations. If values deviate significantly from assumed design values then that may affect durability of structural designs for bridges.

Flexural strength testing was done in accordance with AASHTO T 97 "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)" (*11*). The apparatus for this test consists of two point supports, one on either end of the bar, and two point forces, one each placed at one-third distances from the supports. The two point forces are acted upon by the Tinius-Olsen machine at once, creating an equal force on both. The stress applied needed to break the specimen is noted as the modulus of Rupture, R, in psi.

Testing was done on day 28 post casting. Two separate bars were tested and the average of the two taken to determine the modulus of rupture of the concrete mix design.

Shrinkage Test

Shrinkage tests were performed to determine the percent length change that could be expected from each of the mix designs, from factors other than applied forces or temperature differences. The main source of length changes would be from the chemical process that occurs within the concrete (hydration) during its curing period. Excessive length decreases could lead to considerable cracking during the curing process when the concrete is used on a bridge deck.

Shrinkage testing was done in accordance with AASHTO T 160 "Standard Method of Test for Length Change of Hardened Hydraulic Cement Mortar and Concrete" (*12*). Fresh concrete was placed into the molds and allowed to cure for approximately 24 hours. The bars were removed from the forms and wet cured in the fog room for 10 days to simulate the 10 wet cure days in the field for superstructures. They were then stored in the cement lab in which the humidity is above 50% and temperature kept around 72F. On the day of the readings, the bars were placed in buckets filled with lime-saturated water for 30 minutes in an effort to eliminate length changes due to temperature differences. The buckets filled with lime-saturated water were kept in the fog room. The fog room temperature is kept between 69.8 and 77°F. After the 30-minute period, the bars were removed and their length measured.

Length measurements were taken on day 2, 3, 7, 10, 14, 17, 21, 28, 42 and 56. Three separate bars were tested and the average of the three taken to determine the percent shrinkage of the concrete mix design.

Rapid Chloride Penetration Test

The determination of a concrete's ability to withstand the penetration of chloride ions is of utmost importance on a bridge deck. A concrete that more freely allows the passage of these ions into its surface, and ultimately to the reinforcing steel, will more readily deteriorate and exhibit a shorter lifespan.

Testing was performed in accordance with AASHTO T 277, "Standard Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration" (*13*). The basis of this method is a six-hour monitoring period of the amount of electrical current that passes through 2-inch thick slices of the concrete cylinders. A 60 V dc potential difference is maintained between two slices of the cylinder, one of which is submerged in a sodium chloride solution while the other in a sodium hydroxide solution. The ability of the specimen to resist chloride ion penetration is related to the total charge passed, in coulombs, between the samples. Samples are moist cured for 56 days prior to this testing. For each test, two separate cylinders were tested and the average of the two taken to determine (estimate) the chloride ion penetrability of the batch for that mix.

Results are reported as a qualitative rather than quantitative determination. According to the test method, the terms presented below in Table 3 should be used when assessing the potential for a concrete to pass chloride ions.

Table 3 Chloride ion penetrability based on charge passed.

Charge Passed (Coulombs)	Chloride Ion Penetrability
>4000	High
>2000 - 4000	Moderate
>1000 - 2000	Low
100 - 1000	Very Low
<100	Negligible

RESULTS AND ANALYSIS

Table 4 and Table 5 and show the results of all testing methods used, as described previously. All values represent the averaged values (minimum of two) within each mix design. Table 4 displays the air contents and slump measurements for each batch. VTrans' specifications say that slump values for these classes of concrete should be a maximum of 7 inches. Four mixes, 3, 7, 8 and 16 had a greater slump than the specification. Specifications also dictate that the concrete should have an air content of 7.0 ± 1.5. Five mixes, 4, 6, 17, 21 and 22 fell below this range. Historically slump had good correlation to w/c ratio, but admixture usage has effectively nullified the correlation.

Table 4 Concrete mix design general concrete measurements.

Key	Air Content	Slump (in)	W/C	Unit Weight (lb/yd^3)
C1	**6.1**	**5.8**	**0.47**	**141.4**
2	5.8	5.3	0.51	142.9
3	5.9	7.5	0.47	141.4
4	3.3	6.4	0.40	147.5
5	6.0	5.3	0.43	141.6
6	5.4	6.1	0.47	142.2
7	6.7	7.5	0.40	144.5
8	6.7	8.0	0.45	137.1
9	6.4	5.1	0.44	146.9
10	6.0	5.9	0.44	145.9
11	6.3	5.9	0.38	145.6
C12	**6.2**	**6.4**	**0.39**	**141.6**
13	6.4	6.5	0.40	141.7
14	6.4	4.0	0.40	141.3
C15	**7.4**	**5.9**	**0.44**	**139.0**
16	7.0	7.4	0.46	139.5
17	5.3	5.8	0.48	141.7
18	7.1	6.7	0.48	138.4
19	6.0	6.8	0.46	140.1
20	7.7	6.6	0.49	137.5
21	5.2	7.5	0.49	141.3
22	5.2	3.0	0.46	143.1

Table 5 lists all flexural and compressive strength and rapid chloride permeability (RCP) results. From Table 3, a RCP of between 100 and 1000 is considered very low. All test batches fell within this range, except one that registered just above 1000 (in the low category). This indicates that all mix designs produced can be considered at virtually no risk for normal chloride intrusion given an un-cracked, flaw-free structure.

Table 5 Concrete mix design strength and RCP measurements.

Key	Flexural Strength (psi)	RCP (Coulomb)	Compression Strength (psi)				28 Day Design Strength
			Day 3	Day 7	Day 14	Day 28	
C1	**902**	**608**	**3468**	**4574**	**5292**	**6218**	**3500**
2	993	472	3930	5133	6138	7013	
3	658	567	3705	4975	6088	6833	
4	980	409	3780	6028	7340	8290	
5	1025	599	3320	4358	5625	6303	
6	838	847	3288	4765	5325	6295	
7	1033	391	3780	5615	6645	7440	
8	890	1034	3608	3953	4590	5115	
9	1018	538	4053	5178	5992	6704	
10	977	502	4315	5904	6616	7474	
11	914	756	3794	4536	5021	5581	
C12	**1030**	**562**	**4325**	**5590**	**6548**	**7205**	**4000**
13	950	455	3730	5065	5915	6635	
14	870	650	3838	5370	6230	7043	
C15	**1068**	**642**	**5255**	**5858**	**6795**	**7643**	**4000**
16	1003	703	4995	5535	6618	7225	
17	1040	676	5345	5660	6260	6995	
18	813	738	4600	4962	5980	6738	
19	995	749	5165	5290	6125	6405	
20	723	733	4318	4798	5908	6905	
21	855	846	3678	4480	5595	6485	
22	1050	562	4968	5675	6738	7690	

Typically, for compression strength, VTrans requires a minimum of 3,500 psi (HPC-B) and 4,000 psi (HPC-A and AA) at 28 days. As can be seen in the table, all mixes substantially exceeded these values at day 28 and, in fact, all mixes passed this threshold by day 7. This means that no mixes designed will have trouble meeting the minimum thresholds. The mixes; however, show excessive strength, which can result in more brittle and crack-susceptible structures. For flexural strength, a typical minimum required for concrete is 600 psi. Every mix produced easily exceeded this value, and therefore flexural strength is not a concern for failure with these designs.

The extraordinary early strengths that are presented allow a contractor to work on the green-cured concrete. The specification provides that subsequent loading of concrete may occur at 85% of 28-day design strength provided cure is maintained. Every concrete tested met the criteria to allow loading of the concrete as it cured. The early stage loading may present a risk of increased cracking as a function of load transfer and creep.

Figure 2 shows the percent length change for 11 different days measurements, based on the original measured length. The data is shown in Appendix A. The figure shows the seven top promising mixes and the three control mixes. Gaps in the data represent days when measurements either could not be made or were performed incorrectly. Excessive shrinkage, especially early age shrinkage, is a major contributor to the development of cracks within concrete slabs or structures.

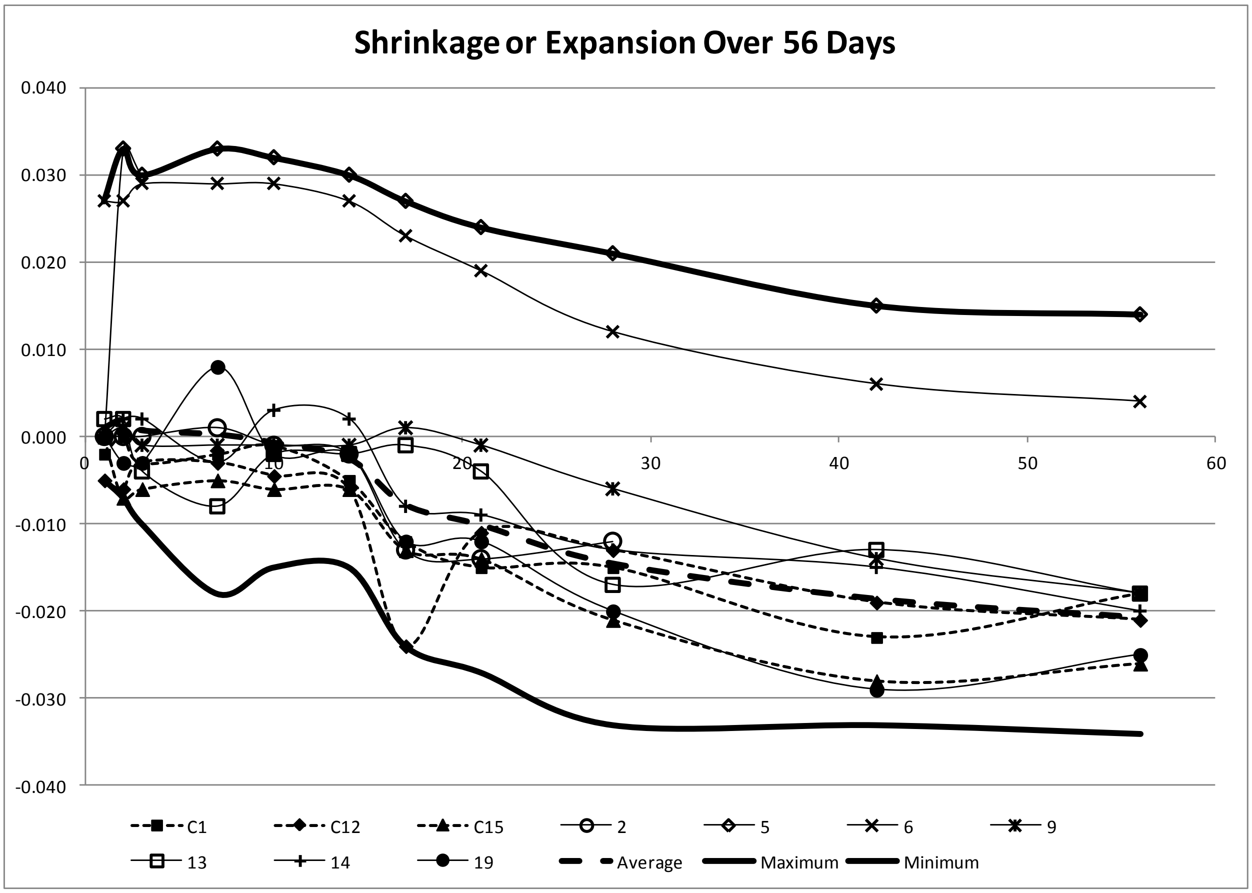


Figure 2 Shrinkage and Expansion of Control Mixes, Promising mixes as measured over 56 Days. (Top and bottom solid lines represent the extents with the bold dash line within the chart representing the average of all mixes.)

Of all mixes, only two displayed no shrinkage throughout the 56 days of measurements, mixes 5 and 6. These two HPC-B mixes had shrinkage control measures included. Mixes 13 and 14 were the two HPC-A that had the same shrinkage control measures, however they did not exhibit the same positive results as 5 and 6, although through day 17 they exhibited a greatly reduced shrinkage than the control mix in that group, number 12. This would indicate that the shrinkage control measures were doing an adequate job of controlling very early age shrinkage. It is possible that a larger dose of shrinkage control measures would be required in HPC-A concrete, as it requires more cement in the expansive zone.

For most of the mixes, however, there was a considerable amount of shrinkage. For example, using mix 16 as an example (the mix that had the most shrinkage as of day 56) at 0.034% length loss would equate to approximately 7/16ths of an inch on a 100 foot slab, which could result in severe cracking issues.

Numerous mixes exhibited greater shrinkage than their respective control mixes did. At various points during the measurements (looking primarily at days 14 and 56 as reference), HPC-B mixes 3, 4, 7, 8, 10, and 11 exceeded the shrinkage of control 1; and HPC-AA mixes 16, 18, 20, and 22 exceeded that of control 15.

When all of the above data and measurements are compiled, and mixes that exhibited some form of deficiency as compared to specifications or to control mixes, 12 of the 19 mixes can be eliminated from being considered an ‘optimized mix design’. This is not to say that they truly are deficient or non-workable, but rather they simply cannot be considered as a best alternative in this study. Table 6 below shows a summarized group of pertinent data from the remaining mixes.

Throughout all of the groups, the greatest impact on test results was the addition of shrinkage control measures within the HPC-B group, as seen in mixes 5 and 6 as compared to C1. The same shrinkage control measures were applied to HPC-A mixes (13 and 14 compared to C12), however they did not produce the same dramatic increase in performance. Mix 2 showed less shrinkage than C1 through most days; unfortunately, measurements are not available for the final two measurement days, so a comparison at day 56 cannot be made. For HPC-AA mixes, mix 19 performed the best as compared to C15; it performed better in shrinkage throughout the first two weeks, but was near identical over the final six weeks.

CONCLUSION AND RECOMMENDATIONS

With 22 different concrete mix designs produced and tested for various concrete properties, flexural and compressive strength, rapid chloride permeability and shrinkage, it is clear that there are seven candidate designs, given the measured data, which could outperform current VTrans standards, which were shown in Table 6. To ensure successful performance of new mix designs, further testing on each, with additional refining, should be undertaken.

Table 6 Summary of select concrete mix designs.

Key	Coarse Agg (lb/yd^3)	Fine Agg (lb/yd^3)	Cement (lb/yd^3)	Flex Strength (psi)	28-Day Compression (psi)	Day 14 Shrinkage	Day 56 Shrinkage
C1	1654	1385	610	902	6218	-0.005	-0.018
2	1636	1454	551	993	7013	-0.002	
5	1654	1385	610	1025	6303	0.030	0.014
6	1654	1385	610	838	6295	0.027	0.004
9	1551	1620	564	1018	6704	-0.001	-0.018
C12	1654	1294	659	1030	7205	-0.006	-0.021
13	1654	1294	659	950	6635	-0.002	-0.018
14	1654	1294	659	870	7043	0.002	-0.020
C15	1350	1519	706	1068	7643	-0.006	-0.026
19	1499	1557	610	995	6405	-0.002	-0.025

With the increasing high early strength concretes being placed to allow construction equipment on structures quicker, shrinkage control measures will become increasingly beneficial. It is clear that, at least to some extent, the measures used in this study had considerable impact on the length measurements of the bars during the short monitoring period. If the effect on length measurements on laboratory bars is noticeable, it makes sense that the length and volume changes on bridges and other structures could be impacted greatly with the use of shrinkage control measures.

High early strength gain could be seen within the results of this study. Design strengths at 28 days, according to Vermont Agency of Transportation specifications, are 3500 psi for Class B concrete and 4000 psi for Class A and AA. All 22 of the test mix designs passed these thresholds by seven days, and the majority had passed them by day three (eight of eleven for Class B, one of three for Class A, and seven of eight for Class AA). Typically, it can be expected to gain around 70% of the ultimate compressive strength of the concrete by day 7, 2450 and 2800 psi respectively; all designs in this study surpassed these levels by day 3. Further consideration of reduced cementitious material is essential.

Since completion of this project, there has been further development by other groups. One promising concept is with using lightweight fine aggregate by substituting a small portion of the normal weight sand with lightweight fine aggregate. Lightweight aggregate is capable of absorbing more water. This maintains a higher relative humidity within the concrete, thereby allows water to be released into the concrete matrix over a longer duration to aid in the hydration process. The result is a more complete hydration process of the cement and a reduction of concrete shrinkage. It is recommended that the addition of lightweight fine aggregate be incorporated into the phase II trial mix testing as another possible means to mitigate shrinkage.

IMPLEMENTATION STRATEGY

A second phase of this project has been approved, with the same testing parameters, to refine the chosen mix designs further. The refining of designs will entail further optimization of aggregate gradations, as the industry has trended towards reporting benefits of this, lowering only cement content to achieve design strength within 10% at 28 days while other components remain unchanged in a mix, and include shrinkage control measures in most if not all mixes. An additional aspect of the testing may be the production and measuring of a larger slab for length measurements, perhaps a one by one yard slab, to replicate what may occur in an actual structure better, versus the standard size of shrinkage bars. Ultimately, further testing would result in a design candidate to be used in a demonstration bridge or structure. Actual design of the mix for full-scale project assessment must be based on the location, materials and design demands for the project. Once the results of the second phase are compiled, they will be distributed and explained to pertinent sections of the Agency for future usage.

APPENDIX A - TABLES

Table A1 Concrete mix design length change measurements.

Key	Change in Length from Original by Day (%)										
	1	2	3	7	10	14	17	21	28	42	56
C1	**-0.002**	**0.000**	**-0.003**	**0.028**	**-0.001**	**-0.005**	**-0.012**	**-0.015**	**-0.015**	**-0.023**	**-0.018**
2	0.000	0.000	0.000	0.001	-0.001	-0.002	-0.013	-0.014	-0.012		
3	0.000	0.000	-0.002	-0.002	-0.011	-0.015	-0.012	-0.027	-0.033		-0.027
4	0.000	0.002	0.000	0.002	-0.002	-0.003	-0.012	-0.011	-0.015	-0.022	-0.025
5	0.000	0.033	0.030	0.033	0.032	0.030	0.027		0.021	0.015	0.014
6	0.027	0.027	0.029	0.029	0.029	0.027	0.023	0.019	0.012	0.006	0.004
7	0.000	0.002	-0.005	-0.018	-0.015		-0.014	-0.017	-0.025	-0.028	-0.031
8	0.000	-0.003	-0.003	-0.005	-0.004	-0.010	0.003	-0.004	-0.003	-0.006	-0.014
9	0.000	0.001	-0.001	-0.001	-0.001	-0.001	0.001	-0.001	-0.006	-0.014	-0.018
10	0.000	0.000	-0.001		0.000	-0.005	-0.005	-0.011	-0.016	-0.017	-0.023
11	0.000	0.000	0.001	0.000	-0.001	-0.013	-0.012	-0.013	-0.023	-0.018	-0.029
C12	**-0.005**	**-0.006**	**-0.003**	**-0.003**		**-0.006**	**-0.024**	**-0.011**	**-0.013**	**-0.019**	**-0.021**
13	0.002	0.002	-0.004	-0.008	-0.002	-0.002	-0.001	-0.004	-0.017	-0.013	-0.018
14	0.000	0.002	0.002	-0.003	0.003	0.002	-0.008	-0.009	-0.013	-0.015	-0.020
C15	**0.000**	**-0.007**		**-0.005**	**-0.006**	**-0.006**	**-0.013**	**-0.014**	**-0.021**	**-0.028**	**-0.026**
16	0.001	0.001	-0.002	-0.005	-0.008	-0.011	-0.018	-0.021	-0.026	-0.024	-0.034
17	0.000	0.001	0.002	0.003	0.002	0.001	-0.009	-0.010	-0.017	-0.022	-0.023
18	0.000	-0.006	-0.003	-0.004	-0.008	-0.011	-0.018	-0.021	-0.020	-0.032	-0.027
19	0.000	-0.003	-0.003	0.008	-0.002	-0.002	-0.012	-0.012	-0.020	-0.029	-0.025
20	0.000	-0.007		-0.010	-0.012	-0.015	-0.022	-0.026	-0.020	-0.033	-0.028
21	0.000		-0.010	-0.002	0.000	-0.002	-0.009	-0.014	-0.019	-0.024	-0.018
22	0.000		-0.002	-0.002	-0.002	-0.003	-0.011	-0.010	-0.018	-0.025	-0.027

Gaps in the data represent days when measurements either could not be made or were performed incorrectly.

Table A7 Concrete mix design list, including concrete type and general notes from technicians at time of batching.

Key	Type	Description
C1	**HPC B**	**Normal VTrans proportion**
2	HPC B	Finished well, workable
3	HPC B	Engineered but lacking correct 8-30 sieves, mixing worked ok
4	HPC B	Engineered 3/4 and 3/8, boney hard to work, not much paste
5	HPC B	With Eclipse 4500, shrinkage control admixture
6	HPC B	With CompCon, expansive cement, 61 lb cement replacement
7	HPC B	Used BASF Master Builders admixtures instead of WR Grace
8	HPC B	Engineered 1, Tercem
9	HPC B	Engineered 2, Tercem
10	HPC B	Engineered 3, Type II and Flyash
11	HPC B	Engineered 4, Type II and Flyash
C12	**HPC A**	**Normal VTrans proportion**
13	HPC A	With Eclipse 4500, shrinkage control admixture
14	HPC A	With CompCon, expansive cement, 66 lb cement replacement
C15	**HPC AA**	**Normal VTrans proportion**
16	HPC AA	Sand-agg. 0.50, Volumetric
17	HPC AA	Sand-agg. 0.52
18	HPC AA	Higher stone than sand
19	HPC AA	Sand-agg. 0.50, optimization program
20	HPC AA	Higher air and slump to match what may be found in the field, sand-agg 0.5
21	HPC AA	Sand-agg 0.51, on verge of segregating, water bleeding out, low cement
22	HPC AA	Sand-agg. 0.44, stony, hard to work
Air entrainment admixture with Darex II and water reducing admixture with ADVA 190 were used unless otherwise noted.		

APPENDIX B – PRODUCT LITERATURE

1. ADVA 190, High-range Water-reducing Admixture – Grace Concrete Products.
2. DAREX II AEA, Air-entrained Admixture – Grace Concrete Products.
3. ECLIPSE 4500, Shrinkage Reducing Admixture – Grace Concrete Products.
4. GLENIUM 7500, Full-range Water-reducing Admixture – Master Builders (BASF)
5. MICRO AIR, Air-entrained Admixture – Master Builders (BASF)
6. TERCEM 3000, Blended Hydraulic Cement – Lafarge NA

ADVA 190, HIGH-RANGE WATER-REDUCING ADMIXTURE – GRACE CONCRETE PRODUCTS.

ADVA® 190

High-range water-reducing admixture

ASTM C494 Type A and F, and ASTM C1017 Type I

Product Description

ADVA® 190 is a polycarboxlate-based high-range water-reducing admixture specifically formulated to meet the needs of the concrete industry. It is a low viscosity liquid, which has been formulated by the manufacturer for use as received. ADVA 190 is manufactured under closely controlled conditions to provide uniform, predictable performance and is formulated to comply with specifications for Chemical Admixtures for Concrete, ASTM Designation C494 as a Type A and F, and ASTM C1017 Type I admixture. ADVA 190 does not contain intentionally added calcium chloride. One gallon weighs approximately 8.8 lbs (1.1 kg/L).

Uses

ADVA 190 superplasticizer produces concrete with extremely workable characteristics referred to as high slump. It also allows concrete to be produced with very low water/cement ratios for high strength.

While ADVA 190 is ideal for use in any concrete where it is desired to minimize the water/cementitious ratio yet maintain workability, ADVA 190 is primarily intended for use in ready-mix concrete, but may also be used in other applications such as precast concrete and self-consolidating concrete.

Addition Rates

ADVA 190 superplasticizer addition rates can vary with type of application, but will normally range from 3 to 15 fl oz/100 lbs (195 to 980 mL/100 kg) of cementitious. In most instances, the addition of 3 to 6 fl oz/100 lbs (195 to 375 mL/100 kg) of cementitious will be sufficient. At a given water/cementitious ratio, the slump required for placement can be controlled by varying the addition rate. Should conditions require using more than the recommended addition rates, please consult your Grace representative.

ADVA 190 dosage requirements may also be affected by mix design, cementitious content and aggregate gradations. Please consult with your Grace Construction Products representative for more information and assistance.

Product Advantages

- Highly efficient, producing high slump concrete at very low dosages
- Provides a combination of slump life with near neutral set time
- Consistent air entrainment
- Consistent performance across cement chemistries
- Concrete finishes easily without stickiness, spotty set or tearing

Compatibility with Other Admixtures and Batch Sequencing

ADVA 190 is compatible with most Grace admixtures as long as they are added separately to the concrete mix. However, ADVA products are not recommended for use in concrete containing naphthalene-based admixtures including Daracem® 19 and Daracem 100, and melamine-based admixtures including Daracem ML 330 and Daracem 65. In general, it is recommended that ADVA 190 be added to the concrete mix near the end of the batch sequence for optimum performance. Different sequencing may be used if local testing shows better performance. Please see Grace Technical Bulletin TB-0110, *Admixture Dispenser Discharge Line Location and Sequencing for Concrete Batching Operations* for further recommendations. ADVA 190 should not come in contact with any other admixture before or during batching, even if diluted in mix water.

Pretesting of the concrete mix should be performed before use and as conditions and materials change in order to assure compatibility with other admixtures, and to optimize dosage rates, addition times in the batch sequencing and concrete performance. For concrete that requires air entrainment, the use of an ASTM C260 air-entraining agent (such as Daravair® or Darex® product lines) is recommended to provide suitable air void parameters for freeze-thaw resistance. Please consult your Grace representative for guidance.

Packaging & Handling

ADVA 190 is available in bulk, delivered by metered tank trucks, in 330 gal (1250 L) disposable totes, and in 55 gal (210 L) drums.

It will begin to freeze at approximately 32°F (0°C), but will return to full strength after thawing and thorough agitation. In storage, and for proper dispensing, ADVA 190 should be maintained at temperatures above 32°F (0°C).

Dispensing Equipment

A complete line of accurate, automatic dispensing equipment is available.

ADVA 190 ASTM C494 Type F High-Range Water Reducer Test Data

	US Units		Metric	
	Control	ADVA 190	Control	ADVA 190
Cement (pcy) (kg/m³)	517	517	307	307
Coarse aggregate (pcy) (kg/m³)	1944	1944	1153	1153
Fine aggregate (pcy) (kg/m³)	1144	1214	679	720
Water (pcy) (kg/m³)	235	204	396	344
w/cm	0.455	0.405	0.455	0.405
Slump (inches) (mm)	3.75	3.5	95	90
Plastic air (%)	5.5	5.4	5.5	5.4
Compressive strength				
1 day (psi) (MPa)	1860	2670	12.8	18.4
7 day (psi) (MPa)	4520	5530	31.2	38.1
28 day (psi) (MPa)	5440	6690	37.5	46.1
Initial set time (hr:min)	4:02	3:55	4:02	3:55
Length change 28 day (%)	-0.031	-0.028	-0.031	-0.028
Freeze-thaw resistance (RDME %)	92	98	92	98

www.graceconstruction.com

North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)

DC-60A Printed in U.S.A. 11/07

FA/LI/2M

GRACE

DARLEX II AEA, AIR-ENTRAINED ADMIXTURE – GRACE CONCRETE PRODUCTS

GRACE

Darex® AEA®
Air Entraining Admixture

Description
Darex® AEA® admixture is an aqueous solution of a complex mixture of organic acid salts. Darex AEA is specially formulated for use as an air-entraining admixture for concrete and is manufactured under rigid control which provides uniform, predictable performance. It is supplied ready-to-use and does not require premixing with water. One Litre weighs approximately 1.02kg ± 0.02kg.

Darex AEA meets the requirements of the following specifications for chemical admixtures for concrete: ASTM C260; AS1478 and AASHTO M154.

Applications
Darex AEA is used in ready-mix, block and concrete products plants. It is also used on the job with jobsite mixers, highway pavers ... wherever concrete is mixed and there is a need for purposeful air entrainment. Because Darex AEA imparts workability to the mix, it is particularly effective with slag, lightweight, or manufactured aggregates which tend to produce harsh concrete. It also makes possible the use of natural sand deficient in fines.

Air Entraining Action
Air is entrained by the development of a semi-microscopic bubble system — introduced into the mix by agitation and stabilised by Darex AEA — in the mortar phase of the concrete.

- **Workability is Improved**
  Millions of tiny air bubbles entrained with Darex AEA act as flexible ball bearings, lubricating and plasticising the concrete mix. This permits a reduction in mixing water with no loss in slump. Placeability is improved ... bleeding and segregation are minimised.
- **Durability is Increased**
  Darex AEA concrete is extremely durable, particularly when subjected to freezing

and thawing, It has resistance to frost and deicing salts, as well as to sulfate, sea and alkaline waters.

Compatibility wth Other Admixtures
Darex AEA is compatible in concrete with all known accelerating admixtures, water-reducing admixtures and water- reducing retarders. By combining the separate effects of air entrainment with the dispersion of a water-reducing admixture, the water requirement of concrete may be reduced with proportional increases in strength and improvement in durability. Each admixture should be added separately to the mix.

Addition Rates
There is no standard addition rate for Darex AEA. The amount to be used will depend upon the amount of air required under job conditions, usually in the range of 3 to 6%. Typical factors which might influence the amount of air-entrained are: temperature, cement, sand gradation, and use of extra fine materials such as fly ash. Typical Darex AEA addition rates range from 50 to 200 ml / 100kg of cementitious material. Higher addition rates can be used for various projects. Addition rates as high as 300 to 400 ml / 100kg of cementitious material can be considered.

The air-entraining efficiency of Darex AEA becomes even greater when used with water-reducing and set-retarding agents. This may allow a reduction of up to two-thirds in the amount of Darex AEA required for the specified air content.

It is Grace's recommendation that trials are conducted to determine the optimum addition range for your application.

Mix Water Reduction

Entrained air will increase the volume of the concrete making it necessary to adjust the mix proportions to maintain the cement factor and yield. This may be accomplished by a reduction in water requirement and aggregate content.

Dispensing Equipment

Please contact your local Grace representative for further information regarding the dispensing equipment for this product.

Packaging

Darex AEA is available in bulk, and 205L drums. Darex AEA contains no flammable ingredients. It freezes at about-1°C, but its air-entraining properties are completely restored by thawing and thorough agitation.

Health and Safety

See Darex AEA Material Safety Data Sheet or consult Grace Construction Products.

www.graceconstruction.com

Australia: Adelaide, Brisbane, Melbourne, Perth, Sydney - 1800 855 525
Hong Kong (852) 2675 7898 Indonesia (62-21) 893 4260 Japan (81-3) 5405 2991 Korea (82-32) 820 0800
China Mainland: Beijing (86-10) 6786 3488, Guangzhou (86-20) 3833 0775, Shanghai (86-21) 5467 4678, Whuan (86-27) 8792 5949 Malaysia (60-3) 9074 6133 New Zealand: Auckland (64-9) 579 1320, Christchurch (64-3) 327 2173, Wellington (64-4) 238 2048 Philippines (63-49) 549 7373
Singapore (65) 6265 3033 Taiwan (886-3) 461 5461 Thailand (66-2) 709 4470
Vietnam: Hanoi (84-320) 3555 135, Ho Chi Minh City (84-8) 3710 6168

GRACE

ECLIPSE 4500, SHRINKAGE REDUCING ADMIXTURE – GRACE CONCRETE PRODUCTS

Grace Concrete Products

ECLIPSE® 4500

Shrinkage reducing admixture

Product Description

Eclipse® 4500 is a liquid admixture for concrete that dramatically reduces drying shrinkage and the potential for drying shrinkage-induced cracking and curling. Rather than functioning as an expansive agent, Eclipse 4500 acts by reducing the surface tension of pore water. Eclipse 4500 is specifically formulated for use in air-entrained concrete exposed to freezing and thawing conditions. Eclipse 4500 is a clear liquid admixture that weighs approximately 7.7 lbs/gal (0.92 kg/L).

Uses

Eclipse 4500 may be used in any concrete but provides the most value when used in concrete located in freeze-thaw environments where the potential for cracking due to drying shrinkage is prevalent and undesirable. Typical applications include, but are not limited to bridge decks, parking garages, marine structures and containment structures. Eclipse 4500 can be used in ready mix, precast, and prestress concrete, in addition to mortar, grout and wet mix shotcrete.

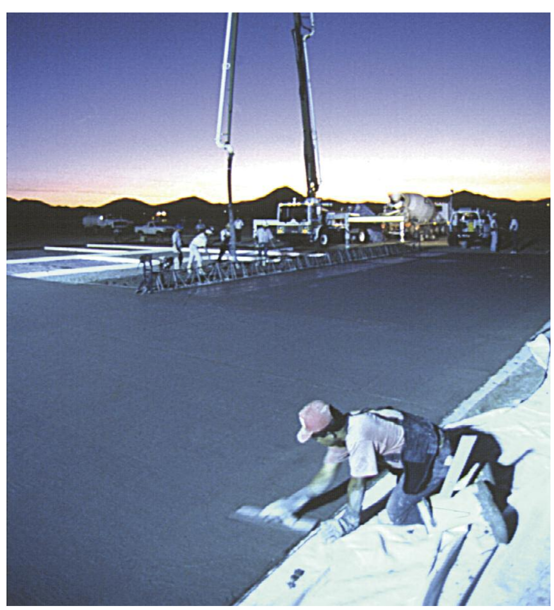
Performance

Impact on plastic and hardened concrete properties—
Figure 1 illustrates ASTM C157 drying shrinkage reduction up to 90 days (after 7 day curing) for concrete mixtures containing 0.75 gal/yd^3 (3.7 L/m^3) and 1.5 gal/yd^3 (7.4 L/m^3) of Eclipse 4500. This data depicts typical Eclipse 4500 test results for a well proportioned concrete mixture. However, pre-job drying shrinkage testing it is recommended to determine actual drying shrinkage characteristics for a specific mix design and set of materials.

Eclipse 4500 impacts workability (slump) similarly to an equal volume of water; therefore, Eclipse 4500 should replace an equal volume of water. Eclipse 4500 may have a slight retarding effect on a concrete mix, typically less than one hour. It is recommended that Eclipse 4500 be used with near neutral setting polycarboxylate-based admixtures (including the MIRA® and ADVA® product lines). Eclipse 4500 may also cause a decrease (typically less than 10%) in early and later age compressive strengths. Eclipse 4500 is a non chloride containing, non-corrosive admixture that will not initiate or contribute to the corrosion of reinforcing steel.

Product Advantages

- Reduces drying shrinkage up to 80% at 28 days and 50% at 1 year and beyond
- Enables normal performance of air-entraining admixtures
- Reduces the potential of cracking due to drying shrinkage in full or partially restrained concrete
- Reduces curling
- Improves durability, which reduces maintenance and repair costs



Air management guidelines

Concrete containing Eclipse 4500 typically requires slightly higher AEA dosages to achieve similar plastic air content compared to an identical concrete mixture not containing Eclipse 4500.

The following guidelines are recommended for concrete containing Eclipse 4500 and subject to freezing and thawing conditions. These guidelines were developed and validated through extensive laboratory and field testing. Note that minimum plastic concrete air contents represent plastic air **at the point of placement.**

- Minimum compressive strength at 28 days of 4,500 psi (31 MPa)
- Maximum water-cementitious materials ratio of 0.45
- Minimum fresh concrete air content in accordance with the maximum aggregate size

Maximum Aggregate Size	Minimum Plastic Concrete Air Content
⅜ in. (9.5 mm)	7.5%
½ in. (12.5 mm)	7%
¾ in. (19 mm) or greater	6%

Addition Rates

Typical Eclipse 4500 dosage rates are 0.5 to 1.5 gal/yd³ (2.5 to 7.5 L/m³). However, dosage rates ranging from 0.2 to 2.0 gal/yd³ (1.0 to 10 L/m³) can be utilized to meet specific drying shrinkage requirements. Dosage rates as low as 0.2 gal/yd³ (1.0 L/m³) have been successfully used in concrete mixes which are just outside drying shrinkage specifications. It is recommended that trial mixtures be evaluated for shrinkage reduction in accordance with ASTM C157 prior to construction.

Compatibility with Other Admixtures and Batch Sequencing

Eclipse 4500 is compatible with the complete line of Grace Admixtures. In mixtures containing mid- or high-range water reducers, it is recommended that Eclipse 4500 be used with polycarboxylate-based MIRA mid-range water reducers and ADVA high-range water reducers. Eclipse 4500 is fully compatible with ASTM C260 air entrainers including Daravair® and Darex® and with calcium nitrite-based products including DCI® and DCI S. In general, Eclipse 4500 may be added to the concrete batch sequencing at any time, however, preferably after the dry materials and most of the water. Different sequencing may be used if local testing shows better performance. Please see Grace Technical Bulletin TB-0110, *Admixture Dispenser Discharge Line Location and Sequencing for Concrete Batching Operations* for further recommendations. Eclipse 4500 should not come in contact with any other admixture before or during the batching process, even if diluted in mix water. Pretesting of the concrete mix should be performed before use, and as conditions and materials change in order to assure compatibility, and to optimize dosage rates, addition times in the batch sequencing and concrete performance. Please consult your Grace representative for specific guidance.

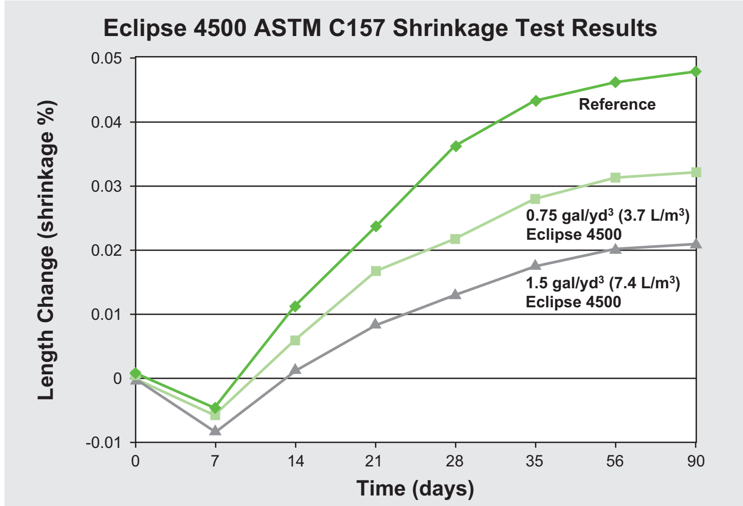


Figure 1

Packaging & Handling

Eclipse 4500 is available in bulk quantities by Grace metered systems, in 275 gal (1,040 L) totes, or in 55 gal (208 L) drums.

Dispensing Equipment

A complete line of automatic dispensing equipment is available through W.R. Grace & Co.–Conn.

Flammability

Eclipse 4500 has a flash point of 216°F (102°C). This is substantially above the upper limit of 140°F (60°C) for classification as a flammable material and above the limit of 200°F (93°C) for classification as a combustible material by DOT requirements. Nonetheless, this product must be treated with care and protected from excessive heat, open flame or sparks. For more information, consult the MSDS.

www.graceconstruction.com

North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)

EC-20D Printed in U.S.A. 7/11 FA/PDF

GRACE

GLENIUM 7500, FULL-RANGE WATER-REDUCING ADMIXTURE – MASTER BUILDERS (BASF)

BASF

The Chemical Company

3/4	03 30 00 03 40 00 03 70 00 04 05 16	**Product Data** Cast-in-Place Concrete Precast Concrete Mass Concrete Masonry Grouting

GLENIUM® 7500

Full-Range Water-Reducing Admixture

Description

GLENIUM® 7500 full-range water-reducing admixture is based on the next generation of polycarboxylate technology found in all of the GLENIUM 7000 series products. This technology combines state-of-the-art molecular engineering with a precise understanding of regional cements to provide specific and exceptional value to all phases of the concrete construction process.

GLENIUM 7500 admixture is very effective in producing concrete mixtures with different levels of workability including applications that require self-consolidating concrete (SCC). The use of GLENIUM 7500 admixture results in faster setting characteristics as well as improved early age compressive strength. GLENIUM 7500 admixture meets ASTM C 494/C 494M compliance requirements for Type A, water-reducing, and Type F, high-range water-reducing, admixtures.

Applications

Recommended for use in:

- Concrete with varying water reduction requirements (5-40%)
- Concrete where control of workability and setting time is critical
- Concrete where high flowability, increased stability, high early and ultimate strengths, and improved durability are needed
- Production of Rheodynamic® Self-Consolidating Concrete (SCC) mixtures
- 4x4™ Concrete for fast-track construction
- Pervious Concrete mixtures

Features

- Dosage flexibility for normal, mid-range and high-range applications
- Excellent early strength development
- Controls setting characteristics
- Optimizes slump retention/setting relationship
- Consistent air entrainment

Benefits

- Faster turnover of forms due to accelerated early strength development
- Reduces finishing labor costs due to optimized set times
- Use in fast track construction
- Minimizes the need for slump adjustments at the jobsite
- Less jobsite QC support required
- Fewer rejected loads
- Optimizes concrete mixture costs

Performance Characteristics

Concrete produced with GLENIUM 7500 admixture achieves significantly higher early age strength than first generation polycarboxylate high-range water-reducing admixtures. GLENIUM 7500 admixture also strikes the perfect balance between workability retention and setting characteristics in order to provide efficiency in placing and finishing concrete. The dosage flexibility of GLENIUM 7500 allows it to be used as a normal, mid-range, and high-range water reducer.

Guidelines for Use

Dosage: GLENIUM 7500 admixture has a recommended dosage range of 2-15 fl oz/cwt (130-975 mL/100 kg) of cementitious materials. For most mid to high-range applications, dosages in the range of 5-8 fl oz/cwt (325-520 mL/100 kg) will provide excellent performance. For high performance and Rheodynamic Self-Consolidating Concrete mixtures, dosages of up to 12 fl oz/cwt (780 mL/100 kg) of cementitious materials can be utilized. Because of variations in concrete materials, jobsite conditions and/or applications, dosages outside of the recommended range may be required. In such cases, contact your local BASF Construction Chemicals representative.

Mixing: GLENIUM 7500 admixture can be added with the initial batch water or as a delayed addition. However, optimum water reduction is generally obtained with a delayed addition.

Master Builders

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: GLENIUM 7500 admixture will neither initiate nor promote corrosion of reinforcing steel embedded in concrete, prestressing steel or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of GLENIUM 7500 admixture.

Compatibility: GLENIUM 7500 admixture is compatible with most admixtures used in the production of quality concrete, including normal, mid-range and high-range water-reducing admixtures, air-entrainers, accelerators, retarders, extended set control admixtures, corrosion inhibitors, and shrinkage reducers.

Do not use GLENIUM 7500 admixture with admixtures containing beta-naphthalene sulfonate. Erratic behaviors in slump, workability retention and pumpability may be experienced.

Storage and Handling

Storage Temperature: GLENIUM 7500 admixture must be stored at temperatures above 40 °F (5 °C). If GLENIUM 7500 admixture freezes, thaw and reconstitute by mechanical agitation.

Shelf Life: GLENIUM 7500 admixture has a minimum shelf life of 9 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your local sales representative regarding suitability for use and dosage recommendations if the shelf life of GLENIUM 7500 admixture has been exceeded.

Packaging

GLENIUM 7500 admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: GLENIUM 7500 admixture.

Additional Information

For additional information on GLENIUM 7500 admixture or on its use in developing concrete mixtures with special performance characteristics, contact your BASF Construction Chemicals representative.

The Admixture Systems business of BASF's Construction Chemicals division is a leading provider of innovative admixtures for specialty concrete used in the ready-mixed, precast, manufactured concrete products, underground construction and paving markets throughout the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

BASF Corporation
Admixture Systems
www.masterbuilders.com
United States 23700 Chagrin Boulevard, Cleveland, Ohio 44122-5544 ● Tel: 800 628-9990 ● Fax: 216 839-8821
Canada 1800 Clark Boulevard, Brampton, Ontario L6T 4M7 ● Tel: 800 387-5862 ● Fax: 905 792-0651

Certified to NSF/ANSI 61

MICRO AIR, AIR-ENTRAINED ADMIXTURE – MASTER BUILDERS (BASF)

Description

Micro Air air-entraining admixture provides concrete with extra protection by creating air bubbles that are ultrastable, small and closely spaced – a characteristic especially useful in the types of concrete known for their difficulty to entrain and maintain the air content desired.

Even when used at a lower dosage than standard air-entraining admixtures, Micro Air admixture meets the requirements of ASTM C 260, AASHTO M 154, and CRD-C 13.

Applications

Recommended for use in:

- Concrete exposed to cyclic freezing and thawing
- Production of high-quality normal or lightweight concrete (heavyweight concrete normally does not contain entrained air)

MICRO AIR®

Air-Entraining Admixture

Features

- Ready-to-use in the proper concentration for rapid, accurate dispensing
- Greatly improved stability of air-entrainment
- Ultra stable air bubbles

Benefits

- Increased resistance to damage from cyclic freezing and thawing
- Increased resistance to scaling from deicing salts
- Improved plasticity and workability
- Improved air-void system in hardened concrete
- Improved ability to entrain and retain air in low-slump concrete, concrete containing high-carbon content fly ash, concrete using large amounts of fine materials, concrete using high-alkali cements, high-temperature concrete, and concrete with extended mixing times
- Reduced permeability – increased watertightness
- Reduced segregation and bleeding

Performance Characteristics

Concrete durability research has established that the best protection for concrete from the adverse effects of freezing and thawing cycles and deicing salts results from: proper air content in the hardened concrete, a suitable air-void system in terms of bubble size and spacing and adequate concrete strength, assuming the use of sound aggregates and proper mixing, transporting, placing, consolidation, finishing and curing techniques. Micro Air admixture can be used to obtain adequate freezing and thawing durability in a properly proportioned concrete mixture, if standard industry practices are followed.

Air Content Determination: The total air content of normal weight concrete should be measured in strict accordance with ASTM C 231, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method” or ASTM C 173/C 173M, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.”

The air content of lightweight concrete should only be determined using the Volumetric Method. The air content should be verified by calculating the gravimetric air content in accordance with ASTM C 138/C 138M, “Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.” If the total air content, as measured by the Pressure Method or Volumetric Method and as verified by the Gravimetric Method, deviates by more than 1-1/2%, the cause should be determined and corrected through equipment calibration or by whatever process is deemed necessary.

Guidelines for Use

Dosage: There is no standard dosage for Micro Air admixture. The exact quantity of air-entraining admixture needed for a given air content of concrete varies because of differences in concrete making materials and ambient conditions. Typical factors that might influence the amount of air entrained include: temperature, cementitious materials, sand gradation, sand-aggregate ratio, mixture proportions, slump, means of conveying and placement, consolidation and finishing technique.

The amount of Micro Air admixture used will depend upon the amount of entrained air required under actual job conditions. In a trial mixture, use 1/8 to 1-1/2 fl oz/cwt (8-98 mL/100 kg) of cement. In mixtures containing water-reducing or set-control admixtures, the amount of Micro Air admixture needed is somewhat less than the amount required in plain concrete. Due to possible changes in the factors that can affect the dosage of Micro Air admixture, frequent air content checks should be made during the course of the work. Adjustments to the dosage should be based on the amount of entrained air required in the mixture at the point of placement. If an unusually high or low dosage of Micro Air admixture is required to obtain the desired air content, consult your BASF Construction Chemicals representative. In such cases, it may be necessary to determine that, in addition to a proper air content in the fresh concrete, a suitable air-void system is achieved in the hardened concrete.

Dispensing and Mixing: Add Micro Air admixture to the concrete mixture using a dispenser designed for air-entraining admixtures; or add manually using a suitable measuring device that ensures accuracy within plus or minus 3% of the required amount. For optimum, consistent performance, the air-entraining admixture should be dispensed on damp, fine aggregate or with the initial batch water. If the concrete mixture contains lightweight aggregate, field evaluations should be conducted to determine the best method to dispense the air-entraining admixture.

Precaution

In a 2005 publication from the Portland Cement Association (PCA R&D Serial No. 2789), it was reported that problematic air-void clustering that can potentially lead to above normal decreases in strength was found to coincide with late additions of water to air-entrained concretes. Late additions of water include the conventional practice of holding back water during batching for addition at the jobsite. Therefore, caution should be exercised with delayed additions to air-entrained concrete. Furthermore, an air content check should be performed after any post-batching addition to an air-entrained concrete mixture.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: Micro Air admixture will neither initiate nor promote corrosion of reinforcing and prestressing steel embedded in concrete, or of galvanized steel floor and roof systems. No calcium chloride or other chloride-based ingredients are used in the manufacture of this admixture.

Compatibility: Micro Air admixture may be used in combination with any BASF Construction Chemicals admixture, unless stated otherwise on the data sheet for the other product. When used in conjunction with other admixtures, each admixture must be dispensed separately into the mixture.

Storage and Handling

Storage Temperature: Micro Air admixture should be stored and dispensed at 35 °F (2 °C) or higher. Although freezing does not harm this product, precautions should be taken to protect it from freezing. If it freezes, thaw and reconstitute by mild mechanical agitation. ***Do not use pressurized air for agitation.***

Shelf Life: Micro Air admixture has a minimum shelf life of 18 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your BASF Construction Chemicals representative regarding suitability for use and dosage recommendations if the shelf life of Micro Air admixture has been exceeded.

Safety: Micro Air admixture is a caustic solution. Chemical goggles and gloves are recommended when transferring or handling this material. (See MSDS and/or product label for complete information.)

Packaging

Micro Air admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: Micro Air admixture.

Additional Information

For suggested specification information or for additional product data on Micro Air admixture, contact your BASF Construction Chemicals representative.

The Admixture Systems business of BASF Construction Chemicals is a leading provider of innovative admixtures for specialty concrete used in the ready mix, precast, manufactured concrete products, underground construction and paving markets throughout the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

Certified to NSF/ANSI 61

BASF Construction Chemicals, LLC
Admixture Systems
www.masterbuilders.com
United States 23700 Chagrin Boulevard, Cleveland, Ohio 44122-5544 ● Tel: 800 628-9990 ● Fax: 216 839-8821
Canada 1800 Clark Boulevard, Brampton, Ontario L6T 4M7 ● Tel: 800 387-5862 ● Fax: 905 792-0651

TERCEM 3000, BLENDED HYDRAULIC CEMENT – LAFARGE NA

LAFARGE

Tercem 3000®
Blended Hydraulic Cement

Provides flexibility in concrete proportioning to assist in achieving:

Higher Ultimate Strength

Improved Durability

Reduced Permeability

Improved Rheology

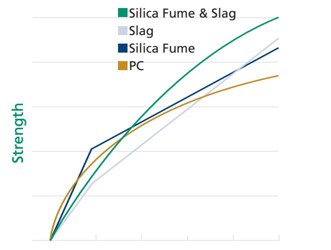
Better Finishability

Reduced Impact on the Environment

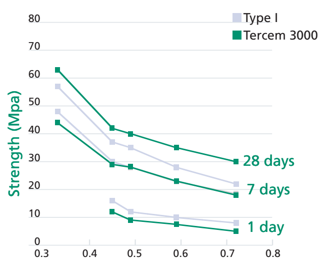
LAFARGE

Tercem 3000®
Blended Hydraulic Cement

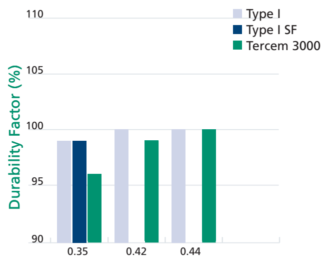
Performance Benefits for the Concrete Industry



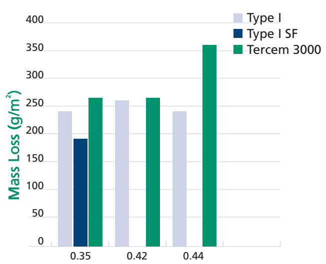
Tercem 3000
REACTIVITY



Tercem 3000
STRENGTH PERFORMANCE



Resistance to Freezing and Thawing
ASTM C 666 - 300 F/T CYCLES



Deicer Salt Scaling Resistance
ASTM C 672 - 50 CYCLES

Lafarge Tercem 3000 is a high-performance ternary hydraulic cement that provides superior strength and excellent durability. It is manufactured with portland cement, granulated blast furnace slag, and silica fume. It is an ideal product for high performance concrete applications. Tercem 3000 is also well suited for walls, foundations, beams, columns, water retention structures, precast and prestressed products, roads and bridges, and industrial floors. In addition, Tercem 3000 can provide outstanding results in roller compacted concrete.

Tercem 3000 has been used since 1998 to produce quality concrete meeting stringent design requirements for strength and durability. The materials in Tercem 3000 work synergistically to produce concrete that has superior strength, increased resistance to alkali aggregate reaction, increased resistance to sulfate attack, and reduced permeability. Tercem 3000 shows good freeze-thaw resistance when tested in accordance with ASTM C-666 and good deicer salt scaling resistance when tested in accordance with ASTM C 672. Tercem 3000 meets the requirements of the Bureau de Normalisation du Quebec 2621-900 for deicer scaling resistance. As with all concrete, for good freeze-thaw resistance and good deicer scaling resistance, a properly designed mixture that is finished and cured in accordance with ACI and CSA specifications and standards is essential.

Tercem 3000 contains post-industrial materials and can be used for projects where sustainable construction practices are required. Tercem 3000 can help a project achieve LEED credits.

Tercem 3000 meets the applicable requirements of CSA A3000 "Cementitious Material Compendium," ASTM C 595 "Blended Hydraulic Cement," A3001 "Blended Hydraulic Cement" and ASTM C 1157 "Standard Performance Specification for Hydraulic Cement."

In all applications where Tercem 3000 is used, all applicable project specifications, local standards, CSA standards, and ACI standards should be followed.

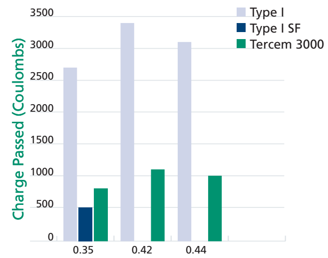
Benefits of Tercem 3000® Blended Hydraulic Cement

- Superior 28 day strength
- Lower permeability
- Reduced bleeding
- Increased resistance to ASR
- Increased resistance to sulfate attack
- Improved durability
- Only one silo required
- Better finishability

Graphical data presented represents results generated in Lafarge's laboratories. Individual results may vary and should be confirmed if specific properties are desired.

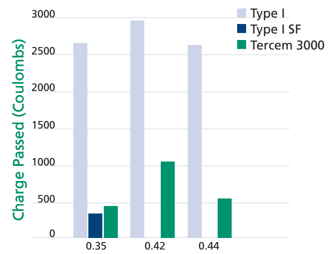
Product claims are based on proper use in accordance with recognized industry standards. Contact your Lafarge North America representative for assistance.

Lafarge Blended Cements provide a significant contribution to sustainable construction. The use of these materials in concrete production consumes less energy and offers improved efficiency and building performance. These materials can also be used to help achieve LEED (Leadership in Energy and Environmental Design) points in the USGBC's (U.S. Green Building Council) and CaGBC's (Canada Green Building Council) LEED programs.



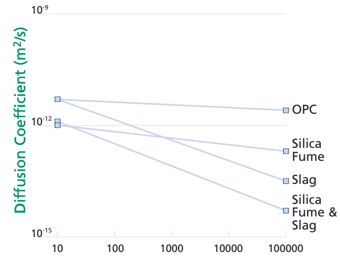
Chloride Permeability Nominal W/CM

ASTM C 1202 - 28 DAYS



Chloride Permeability Nominal W/CM

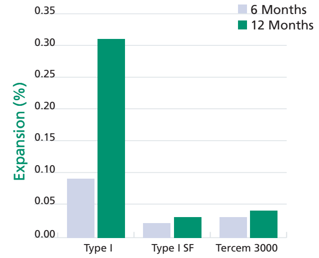
ASTM C 1202 - 56 DAYS



Ternary Blends Age (Days)

CHLORIDE DIFFUSION

Dr. M.D.A. Thomas, University of New Brunswick, NB, Canada, April 2003



Sulphate Resistance

ASTM C 1012

Product Data

Tercem 3000®
Blended Hydraulic Cement

Properties of "Fresh Concrete"

Water requirements – Tercem 3000 contains silica fume, which is a very fine material that generally requires the careful selection of admixtures to control water demand and slump loss to maximize the performance of the mixture. A properly designed mixture containing Tercem 3000 should have excellent slump retention even at low water to cement ratios.

Air Content – When changing any mixture ingredients, the air-entraining dosage should be checked and adjusted if necessary.

Segregation and Bleeding – Concrete containing this cement may have reduced bleed water, or bleed water may not be present at all. This product helps reduce segregation.

Heat of Hydration – Care should be taken when using this - or any other - cementitious product in mass concrete to insure the temperature gradients do not exceed those recommended by industry standards or by specification limits.

Setting Time – Setting time of Tercem 3000 is generally equivalent to GU or T-I/II cement.

Finishability – Finishability of concrete containing Tercem 3000 is similar to portland only mixtures. However, finishability is improved when compared to binary mixtures incorporating portland cement and silica fume.

Pumping – Pumpability of concrete containing this cement is generally equivalent or better than concrete containing straight portland cement.

Proportioning – Use of this cement does not require special proportions. Proportions should be selected according to ACI 211 and final mixtures should conform with applicable provisions of CSA 23.1. Trial batches should be done before using this cement in order to define the proportions required for strength and durability.

Curing – Proper curing of all concrete is essential. Special attention to curing is necessary when using Tercem 3000 due to the reduction of bleed water and should begin immediately after finishing. Surface cracking will occur if the concrete is allowed to dry prematurely.

Properties of "Hardened Concrete"

Strength – Proper use of this cement enhances compressive and flexural strengths when compared to concrete containing straight portland cement.

Permeability – In a properly designed mixture, concrete containing Tercem 3000 will dramatically decrease permeability compared to concrete containing portland cement.

Alkali-silica Reactivity (alkali aggregate reaction) – Test data shows that Tercem 3000 increases the resistance to alkali silica reaction. The ability to mitigate ASR should be confirmed using actual project materials.

Resistance to Sulfate Attack – Tercem 3000 can be used as part of a system to improve the resistance of concrete to sulfate attack. The ability to mitigate sulfate attack should be confirmed using actual project materials.

Freeze-Thaw Resistance – Tercem 3000 shows good freeze-thaw resistance when tested in accordance with ASTM C-666 for freeze-thaw resistance. As with all concrete, for good freeze-thaw resistance, a properly designed mixture that is finished and cured inaccordance with ACI and CSA specifications and standards is essential.

Deicer Scaling – Tercem 3000 meets all the specification limits of BNQ 2621-900 and, when tested in accordance with ASTM C-672, shows good deicer scaling resistance. As with all concrete, for good scaling resistance, a properly designed mixture that is finished and cured in accordance with ACI and CSA specifications and standards is essential.

General Statement

Tercem 3000 is a hydraulic cement containing a blend of silica fume, granulated blast furnace slag and portland cement. This cement is generally used in high performance applications, where enhanced strength and/or durability properties are required. To achieve these and other special properties, particular care is needed when proportioning, batching, placing, finishing and curing concrete containing this product.

Precautions

Direct contact with wet cement should be avoided. If contact occurs, the skin should be washed with water as soon as possible. Exposure can cause serious, potentially irreversible tissue destruction in the form of chemical (caustic) burns.
If cement gets into the eyes, immediately rinse thoroughly with water and seek medical attention. For more information, reference the applicable Lafarge Material Safety Data Sheet (MSDS). The MSDS should be consulted prior to use of this product and is available upon request and online at www.lafarge-na.com.

Company Profile

Lafarge in North America is part of the Lafarge Group. The world leader in building materials, active on five continents, the Lafarge Group holds top-ranking positions in cement, aggregates, concrete and gypsum.

By focusing on the development and improvement of building materials, Lafarge puts the customer at the core of its strategy and offers the construction industry and the general public innovative solutions that will bring more safety, comfort and beauty to our everyday lives.

Please contact your Lafarge Office for specific product information, availability and ordering.

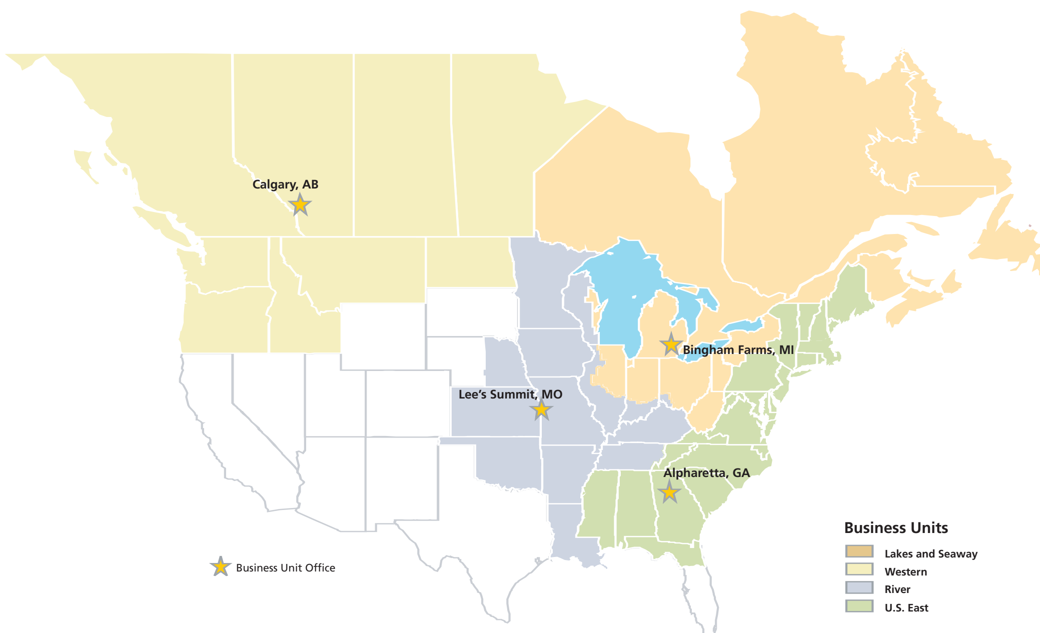
Lakes and Seaway Business Unit
Bingham Farms, Michigan
Phone: 248-594-1991

U.S. East Business Unit
Alpharetta, Georgia
Phone: 678-746-2000

River Business Unit
Lee's Summit, Missouri
Phone: 816-251-2100

Western Business Unit
Calgary, Alberta
Phone: 403-271-9110

Lafarge North America Cement Operating Areas



Limited Warranty

Lafarge warrants that Lafarge Tercem 3000® meets the applicable requirements of ASTM C 1157, ASTM C 595 and CSA A3001. Lafarge makes no other warranty, whether of merchantability or fitness for a particular purpose with respect to Lafarge Tercem 3000®. Having no control over its use, Lafarge will not guarantee finished work in which Lafarge Tercem 3000 is used.

PBT3E 1/07

LAFARGE NORTH AMERICA

CEMENT

Lafarge North America Inc.
12950 Worldgate Drive, Suite 500
Herndon, VA 20170

Lafarge Canada Inc.
606 Cathcart Street
Montréal, Québec H3B 1L7

www.lafarge-na.com

Printed on recycled paper

REFERENCES

1. Lafarge North America Inc., "Tercem 3000 Blended Hydraulic Cement – PBT3E", Herndon, VA, January, 2007.

2. W. R. Grace and Company, "Grace Concrete Products – DAREX II AEA Air-entraining admixture – AIR-3H", Cambridge, Ma., November 2011.

3. Hewlett, Peter C., "Lea's Chemistry of Cement and Concrete – Fourth Edition.," Oxford UK, Elsevier Butterworth-Heinemann, 1998.

4. W. R. Grace and Company, "Grace Concrete Products – ECLIPSE 4500 Shrinkage Reduction Admixture – EC-20D", Cambridge, Ma., July 2011.

5. ShrinkageComp Plus, Inc, "CompCon – An Introduction," http://www.shrinkagecomp.com/Products.html, Vancleave, MS., March 23, 2014.

6. AASHTO T-152, "Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

7. AASHTO T-119, "Standard Method of Test for Slump of Hydraulic Cement Concrete", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

8. AASHTO T-121, "Standard Method of Test for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

9. ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", ASTM International, West Conshohocken, PA, www.astm.org.

10. AASHTO T-22, "Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

11. AASHTO T-97, "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

12. AASHTO T-160, "Standard Method of Test for Length Change of Hardened Hydraulic Cement Mortar and Concrete", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.

13. AASHTO T-277, "Standard Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Pentration", *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th Edition 2007.