ing installation. No generally accepted test method was available for reference of a pH test method; therefore the DSP contains an imbedded method.

The aggregate characteristics in the repair material are described in accordance with the sections of ASTM C 33 using the material retained on a 0.1-mm (170- mesh) sieve considered as aggregate. The grading is to be documented as this indicates some limitations for depth of placement as well as provide an indicator of adulteration or extension following installation. Even more important in the DSP is the reporting of deleterious or unstable aggregates in the product.

Section 3, Material Properties

Section 3, called "Material Properties" typically recommends different tests for mortar and concrete materials. The test method used for the reported result must also be reported, as some results may be determined by specified alternate methods. Plastic properties are reported first and include:

- Density and Yield (ASTM C 185 [for mortar] or C 138 [for concrete and extended mortar])
- Density and yield are useful for determining the coverage of the material when applied as well as providing a baseline check for proper mixing, since the material density will change as the ratio of powder to mixing liquid changes or air is entrapped from over mixing.
- Setting Time (ASTM C 266 or C 191) at both the minimum and maximum stated application temperatures (the mortar fraction should be sieved from concrete materials for setting time)
- Setting time is a useful indicator of the working time of the material once mixed. There is no industry standard for cementitious materials for working time. It has been suggested to replace ASTM C266 and/or C191 with ASTM C 807, which is quite similar to the C191 but uses a different sized needle to perhaps better test aggregate containing mortars. Additionally, ASTM C403 is being considered as a method for setting time based on a plot of penetration resistance using a series of standard needles for extended mortars and concretes. Alternatively, merely referencing that portion of ASTM C 403 describing the procedure for sieving of coarse aggregate could clarify the existing document on this point.
- Air Content (ASTM C 185 [mortar] or C 231 [concrete]) Air content is a useful indicator of the resistance to deterioration from freezing and thawing cycles. A proposed clarification to the revision of the DSP is to require the mixing liquid quantity to be used in the air content calculations in situations where the liquid is not water.

The hardened properties are also reported in Section 3 of the Protocol. A different demolding and curing regimen is specified based upon the speed of hardening and polymer modification. Different hardened property tests are typically specified for mortar and concrete mixtures and include direct and splitting tensile, flexural, compressive strengths, modulus of elasticity, bond strength, length change, coefficient of thermal expansion, resistance to freezing and thawing, deicer scaling resistance, compressive creep, rapid chloride ion permeability, chloride permeability, sulfate resistance, chemical resistance, and cracking resistance. A listing of these tests with some minimal detail is shown in Table 1 below, however the user of the DSP is cautioned to obtain the full document from ICRI before attempting to use or produce data according to the DSP.

Table 1 DSP Hardened Properties Tests

	Test Method for Mortar	Test Method for Concrete
Compressive Strength	ASTM C 109	ASTM C39
Flexural Strength	ASTM C 348	ASTM C 78
Splitting Tensile Strength	ASTM C 496 50x100 mm cylinders	ASTM C 496 75x150 mm cylinders
Direct Tensile Strength	CRD C 164 50x100 mm specimen	CRD C 164 75x150 mm specimen
Modulus of Elasticity	ASTM C 469 75 x 150 mm specimen	ASTM C 469 75 x 150 mm specimen
Bond Strength	ICRI 210.3 (Former 03739) or ASTM C1583 on CSP 3 28-34 MPa concrete substrate	ICRI 210.3 (Former 03739) or ASTM C1583 on CSP 3 28-34 MPa concrete substrate
Length Change	ASTM C 157 75 x 75 x 275 mm bar* @ 3, 7, 14, 30, 60, & ultimate per ASTM C 596	ASTM C 157 75 x 75 x 275 mm bar* @ 3, 7, 14, 30, 60, & ultimate per ASTM C 596
Coefficient of Thermal Expansion	CRD C 39 w/ C157 bars* 60-5^{o} C cycle @ 50% RH & >95% RH	CRD C 39 w/ C157 bars* 60-5^{o} C cycle @ 50% RH & >95% RH
Freezing and Thawing Resistance	ASTM C666A on 25mm overlay applied to F/T durable substrate	ASTM C666A on 25mm overlay applied to F/T durable substrate
Scaling Resistance	ASTM C 672 start @ 28D	ASTM C 672 start @ 28D
Compressive Creep	ASTM C 512	ASTM C 512
Rapid Chloride Permeability	ASTM C 1202 @ 28 D	ASTM C 1202 @ 28 D
Chloride Ponding	AASHTO T 259 or ASTM C1543	AASHTO T 259 or ASTM C1543
Sulfate Resistance	ASTM C 1012	ASTM C 1012
Chemical Resistance	ASTM D 1308 w/ C157 bars*	ASTM D 1308 w/ C157 bars*
Cracking Resistance	ASTM C1581	ASTM C1581

* Use specimens from ASTM C 157 length change

This document continues to evolve. Several changes are being discussed to further clarify the testing for hardened properties in the DSP. ICRI has changed their document numbering system since the publication of the DSP, which will be corrected editorially in the next edition. ASTM has adopted a test method for bond strength and for chloride ponding which will be referenced in addition to the ICRI method. Clarification is also needed on the length of testing of length change specimens, such as requiring reporting of values up to 1 year in duration. Freezing and thawing resistance using the composite beams described in the DSP should include a description of the location of the driving unit and pickup unit for the forced resonance equipment and impactor and accelerometer for the impact resonance equipment used for ASTM C 666 so that the test is conducted to establish the durability of both the repair material and the bond of the repair material to the specified substrate. In the chemical resistance test method, a statement is needed describing that the selection of the chemicals' and duration of exposure of the testing is situational depending on the repair material exposure environment.

Section 4, Packaging and Storage

Section 4 called "Packaging and Storage" requires labelling of the packages in accordance with the "Product Marking" section of either ASTM C 928 or C 1107. The package label must contain the volume yield of the product as cubic meters (or cubic feet) per package, the shelf life listed as a "use-by" date, and the minimum and maximum storage temperatures and conditions. It is currently unclear in the existing DSP if all tests are required to be run on freshly mixed material at the maximum working time, and/or at the extreme application temperatures as required by C 1107 or outside the ranges of C 928. As a practical matter, due to the time required for casting, the quantity of materials needed, and the expense of testing products for the entire DSP, the next version of the DSP will likely only recommend that tests specifically listed or required at these extreme conditions should be run to avoid confusion on this point.

Section 5, How to Use the Material

The last section, "How to Use the Material" includes reporting the aggregate extension requirements (if any). Concrete surface preparation is to be reported in accordance with the ICRI 320.2 (former 03732) Concrete Surface Profile. The type and amount of mixing liquid, instructions for material application and temperatures, finishing guidelines, curing regimen, application thickness, and cleanup recommendations are also to be listed in this section. Coordinating specific equipment requirements and terminology with the developmental "Pictorial Atlas of Concrete Repair Equipment" is intended to also be included in the next version of the DSP.

THE FUTURE OF PROTOCOLS

Protocols are a new type of document to the concrete repair industry that can help resolve several of the obstacles that exist regarding the development of specifications:

- "one size fits all" for a type of material (certainly not the best case for concrete repair)
- the acceptance that minimum performance limits represent the true level of performance needed for a material, rather than the lowest common denominator that was agreeable among the industry specification developers (frequently material suppliers)
- the commoditization of a material type which limits further development of technology to address the application need (i.e., once a specification has been developed, the products complying tend to compete upon price with limited further investment in product differentiation)

Several other protocol type documents are currently under development within the repair industry, including one for elastomeric coatings, penetrating sealers, and corrosion mitigation techniques for existing concrete structures, another SDC initiative (6).

CONCLUSIONS

The Data Sheet Protocol provides useful information to the material purchaser, applicator and specifier. Advantages of the Protocol approach to material property characterization are that standardization organizations can more easily reach consensus, specifiers can select the important material properties and performance based on their experience, and the properties can be verified due to the transparency of the test methods. As with any standardized document, periodic revision, improvement, clarification, and reapproval are both required as well as needed. Hopefully this article has helped to explain both the existing document and the planned changes for the next edition of the document.

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1) REMR-CS-2 "The Condition of Corps of Engineers Civil Works Concrete Structures," by James E. McDonald and Roy L. Campbell, Sr. [ADA157992] U.S. Army Engineer Research and Development Center (USAERDC), ATTN: CEERD-PA-Z, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

2) Issue #4 ConRepNet Nov. 2004, BUILDING RESEARCH ESTABLISHMENT LTD Bucknalls Lane, 9XX GARSTON,WATFORD,HERTS, WD25, UNITED KINGDOM http://projects.bre.co.uk/conrepnet/pages/default.htm

3) Vision 2020, ACI Strategic Development Council, 38800 Country Club Drive, Farmington Hills, Michigan 48331, 2004 (http://www.concretesdc.org/_pdfs/Vision2020-Version1.0_%20May2006.pdf)

4) Guideline 320.3 (formerly 03740) International Concrete Repair Institute, 10600 West Higgins Road, Suite 607, Rosemont, IL 60018, 2004http://www.icri.org/COMMITTEES/03740DataSheetProtocol_11082004_linenumberedDraft.pdf

5) Guideline 364.3 R-09 Guide for Cementitious Repair Material Data Sheet, ACI International, 38800 Country Club Drive, Farmington Hills, Michigan 48331, 2009 http://www.concrete.org/COMMITTEES/GetDocument.asp?DocID=48900

6) Performance of Concrete Reinforcing Steel Corrosion Prevention and Mitigation Technologies, ACI Foundation, ACI International, 38800 Country Club Drive, Farmington Hills, Michigan 48331, 2010, http://www.concrete.org/foundation/10.29.2009%20Release.htm

The following list shows the standards used in the DSP and where they may located, however the DSP may only reference portions of some documents or require modifications to the standards published for different purposes than concrete repair materials.

- ASTM E 11 “Standard Specification for Wire Cloth and Sieves for Testing Purposes”, Vol. 14.02
- ASTM C 33, “Standard Specification for Concrete Aggregates,” Vol. 4.02
- ASTM C 114, “Standard Test Methods for Chemical Analysis of Hydraulic Cement,” Vol. 4.01
- ASTM C 150, “Standard Specification for Portland Cement,” Vol. 4.01
- ASTM C 1218/C 1218M “Standard Test Method for Water-Soluble Chloride in Mortar and Concrete” Vol. 4.02
- ASTM C 1152/C 1152M “Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete” Vol. 4.02
- ACI 222 “Corrosion of Metals in Concrete, Manual of Concrete Practice”, ACI International

- ASTM C 117 “Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing” Vol. 4.02
- ASTM C 185, “Standard Test Method for Air Content of Hydraulic Cement Mortar,” Vol. 4.01
- ASTM C 138, “Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete,” Vol. 4.02
- ASTM C 266, “Standard Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles,” Vol. 4.01
- ASTM C 191, “Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle,” Vol. 4.01
- ASTM C 807, “Standard Test Method for Time of Setting of Hydraulic Cement Mortar by Modified Vicat Needle, Vol. 4.01
- ASTM C 403, “Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance”, Vol. 4.02
- ASTM C 231, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method,” Vol. 4.02
- ASTM C642 “Standard Test Method for Density, Absorption, and Voids in Hardened Concrete”, Vol. 4.02
- ASTM C 109, “Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens),” Vol. 4.01
- ASTM C 39, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens,” Vol. 4.02
- ASTM C 348, “Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars,” Vol. 4.01
- ASTM C 78, “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading),” Vol. 4.02
- ASTM C 496, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens,” Vol. 4.02
- CRD C 164, “Standard Test Method for Direct Tensile Strength of Cylindrical Concrete or Mortar Specimens,” Handbook for Concrete and Cement, United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS
- ASTM C 469, “Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression” Vol. 4.02
- ACI 503R, “Use of Epoxy Compounds With Concrete,” Manual of Concrete Practice, ACI International
- ICRI Guideline No. 310.2 (former 03732) “Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays”, International Concrete Repair Institute 1997
- ASTM C 157, “Standard Test Method for Length Change of Hardened Hydraulic-Cement, Mortar, and Concrete,” Vol. 4.02
- ASTM C 511, “Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes,” Vol. 4.01
- ASTM C 1439, “Standard Test Methods for Polymer-Modified Mortar and Concrete,” Vol. 4.02
- ASTM C 596, “Standard Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement,” Vol. 4.01
- CRD C 39-81, “Test Method for Coefficient of Linear Thermal Expansion of Concrete,” Handbook for
- Concrete and Cement, http://www.wes.army.mil/SL/MTC/handbook/handbook.htm

- ASTM C666, “Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing,” Vol. 4.02
- ASTM C 672, “Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals,” Vol. 4.02
- ASTM C 512, “Standard Test Method for Creep of Concrete in Compression,” Vol. 4.02
- ASTM C 1202, “Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration,” Vol. 4.02
- AASHTO T 259, “Resistance of Concrete to Chloride Ion Penetration,” Standard Specifications for Transportation Materials and Methods of Sampling and Testing
- ASTM C1543 “Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding” Vol. 4.02
- ASTM C 1012, “Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution,”
- ASTM D 1308, “Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes,”
- ASTM C1581 “Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage” Vol. 4.02
- ASTM C928, “Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs,” Vol. 4.02
- ASTM C 1107, “Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink),” Vol. 4.02
- ICRI Guideline No. 310.1 (former 03730) “Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion” International Concrete Repair Institute 2008
- Material Safety Data Sheet (MSDS), Federal Register, Volume 48, Number 228, Occupational Safety and Health Administration, 1983, U.S. Department of Labor, Washington, D.C

Sustainability by Using Zero Wash-out Admixture for Large Underwater Concreting Project in India

By Surendra Manjrekar and Ishita Manjrekar

Synopsis: This paper maps the development of Anti-washout admixtures for the first time on the Indian subcontinent. Anti washout admixture was required to be used for the construction of a weir for the SriSalem Dam across the Krishna River in Andhra Pradesh, India. The project required 30000 cubic meters of concreting to be done under water without the erection of a cofferdam and the project cost was estimated to be about $5.6 million. The consultants were SNC Lavelin, Canada and the contractors were Patel Engineering, India. Since there were no manufacturers of anti washout admixture in India, this was a significant development from Sunanda Speciality Coatings Pvt. Ltd.'s lab involving over 100 trials that culminated in about 90000 liters of the admixture being used in the project.

Keywords: **under water concreting, anti-washout admixture, admixture, mix design**

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INTRODUCTION

In mega hydro power structures and for mass underwater concreting projects like construction of weirs, concreting for dams, erection of caissons, concrete placed under water is inherently susceptible to cement washout, laitance, segregation, cold joints, and water entrapment. Consequently, concrete placed under water is required to remain cohesive. A high degree of cohesiveness improves homogeneity and strength of the underwater concrete by minimizing cement washout. The required degree of concrete cohesion, however, depends on many variables such as the thickness and configuration of placements, flow distance, required in-place strength, and exposure to flowing water during placement. At the same time, it must possess some unique workability characteristics. The essential workability requirements are that the concrete must flow easily, retain adequate cohesion against washout and segregation, and possess self-consolidating characteristics (because it is impractical to consolidate concrete under water by using mechanical vibration).

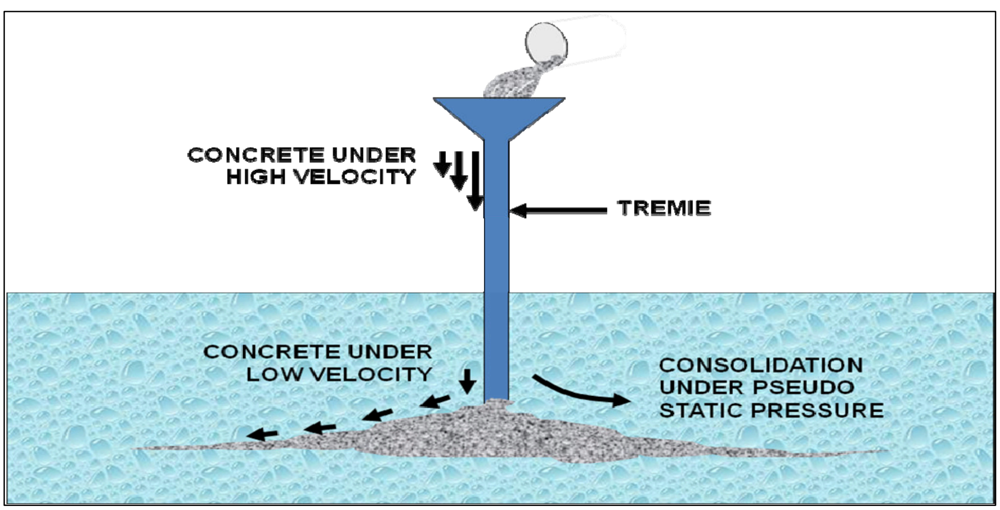

Figure 1. Kinetic States of concrete as it is placed underwater.

Concrete placed underwater typically undergoes a wide range of kinetic states i.e. concrete falls through a tremie pipe at a high velocity, it mixes and flows out of the tremie pipe at slower speeds and finally consolidates under pseudo static conditions.

Underwater concrete must be able to easily flow out of the tremie pipe, completely fill the placement area and consolidate under its own weight. It is reported[1] that the workability of underwater concrete should be higher than 175mm slump which helps in self consolidation under its own buoyant weight. The workability of underwater concrete includes additional requirements such as self-leveling and high anti-washout characteristics.

Research indicates that in-place concrete quality is closely related to the way concrete flows underwater[4]. Investigations reveal that concrete generally flows underwater in one of the following two patterns: Pattern 1: Bulged flow; Pattern 2: Layered flow

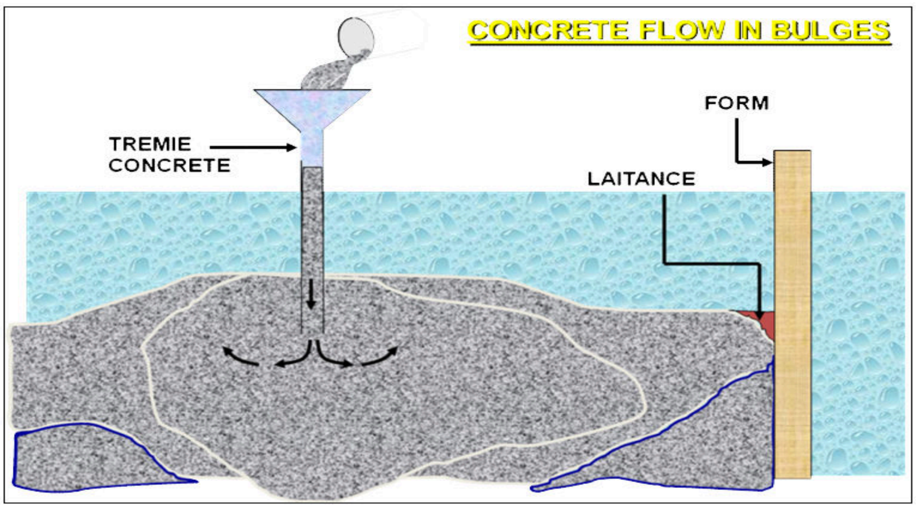

Figure 2. Bulged Flow

When concrete is highly flowable and cohesive it tends to flow in a “bulged flow pattern” where newly placed concrete pushes previously placed concrete sideways forming a successive series of bulges. It has been found that bulged flow pattern tends to develop concrete with a relatively flat, smooth top surface and good in place quality.

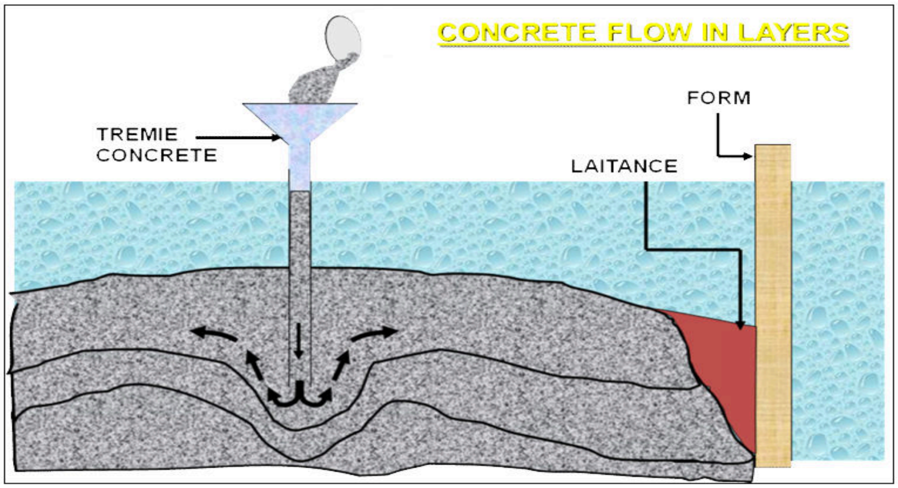

Figure 3: Layered Flow

On the other hand less flowable concrete flows in a "layered pattern" where newly placed concrete flows upwards around the placement pipe and over the top of the previously placed concrete. Apparently this layered flow pattern exposes more concrete surfaces to water and is usually associated with steeply sloped and rugged top surface with large quantity of laitance; hence it was understood and established that the mixture proportions of underwater concrete had to be a compromise between its flowability and cohesion. Without the use of admixtures, these two inversely related properties could not be attained because higher flowability leads to less cohesive concrete and vice versa

WEIR PROJECT AT SRISALEM, HYDERABAD-INDIA

M/s Patel Engineering Ltd, Mumbai are the pioneers in heavy civil engineering construction since the 1950's, especially in hydro power structures were awarded the job as turnkey contractors for the construction of a weir project at Sri Salem, Hyderabad

PROJECT DETAILS:

Project Title	: Weir Project at Srisalem, Dam, Srisalem.
Clients	: Andra Pradesh Power Generation Company (APGENCO)
Clients Consultants	: SNC Lavelin Limited, Canada
Contractors	: Patel Engineering Limited, Hyderabad
Concreting for Weir	: 30,000 cu.m. (39,244 c.y.)
Dredging quantity	: 40,000 cu.m. (52, c.y.)325
Estimated Project Cost	: Rs. 25 Crores (approx $5.6 million)

MIX DESIGN DETAILS OF UNDERWATER:

Desired Strength: M20 grade of concrete
Slump requirements: 170 mm – 230 mm with admixtures
Anti-washout admixture specified for tremie concrete.
The effectiveness of anti-washout admixtures shall be measured in accordance with the **United States Corps of Engineers** specification CRD-C61—"Test method for determining the resistance of freshly mixed concrete to washing out in water" issued on December 1st 1989.
The maximum washout shall not exceed 8% cumulative mass loss.