

CRB

CONCRETE REPAIR BULLETIN

July/August 2022
Vol. 35, No. 4



SHOTCRETE



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Shields Million Dollar Artwork in
World Trade Center Subway Station



"CHORUS," a marble mosaic by multimedia artist Ann Hamilton, New York City

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The WTC Cortland Street subway station in New York City is located on the World Trade Center grounds. The station's reopening is viewed as a major milestone in recovery for the neighborhood impacted by events of that tragic day.

A white, monochromatic marble mosaic by multimedia artist Ann Hamilton was designed with the adjacent World Trade Center Transportation Hub in mind. Commissioned by Metropolitan Transit Authority Arts & Design, "CHORUS" spans a total of 4,350 square feet across the walls of both platforms and comprises small marble tesserae forming a white-on-white surface of text from the 1776 Declaration of Independence and the 1948 United Nations Universal Declaration of Human Rights. The piece has been valued at more than \$1 million.

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ON THE COVER: Shotcrete image courtesy of the American Shotcrete Association—see their article by Charles Hanskat on page 30.

CRB

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FEATURES

14 Compatible Shotcrete Specifications and Repair Materials

by William Clements and Kevin Robertson

20 Structural Modifications of Draft Tubes Using Overhead Wet-Mix Steel Fiber Reinforced Shotcrete

by Lihe Zhang, Shaun M. Radomski, Dudley R. Morgan, and David Graham

30 Shotcrete for Repair—Not Your Father's Gunitite

by Charles Hanskat, American Shotcrete Association

DEPARTMENTS

2	President's Message	37	Association News
4	TAC Talk	40	Chapter News
6	Certification Update	45	Chapter Chair Letter
12	ICRI Supporting Members	46	Product Innovation
36	Concrete Repair Calendar	47	New ICRI Members
36	Industry News	48	Index of Advertisers

NOTE FROM THE EDITOR



Summer is well underway and Fall is rapidly approaching. I hope everyone is having a safe and productive Summer. ICRI Chapters have had a busy summer of chapter meetings, demo days, and golf outings. ICRI Education and Certification programs are up and running throughout the country.

This issue of the *Concrete Repair Bulletin* highlights shotcrete and includes articles on the use of shotcrete for repairs; an article on Compatible Shotcrete Specifications and Repair Material; and a case study on Modifying Draft Tubes with Wet-Mix Steel Fiber Reinforced Concrete.

ICRI is looking for Fall Convention presenters. The 2022 ICRI Fall Convention is November 7-9 at the InterContinental Buckhead Atlanta, and the theme is *Fire, Impact, Blast: Repairs after Extraordinary Events*.

We continue to look for CRB authors and articles. Topics and article guidelines are available on the Resources tab on the ICRI website.

Please make sure you let Dale Regnier know your chapter's upcoming events and remember to check the ICRI website for the schedule of upcoming events.

I hope you all continue to have a safe and productive 2022!

Jerry Phenney
RAM Construction Services
Editor, *Concrete Repair Bulletin*

PRESIDENT'S MESSAGE



JOHN MCDUGALL

In today's 24-hour news cycle, be it online through the myriad of social media feeds, TV and the talking heads, or more traditional print media sources, it is all too easy to be overwhelmed with the onslaught of bad news. While there are certainly newsworthy stories that need to be told, and lessons to be learned from those stories, I trust you don't turn to ICRI for those concerns. I fully intend to celebrate the wins and share the good news within our industry. And there is much to celebrate.

At the conclusion of our 2022 Spring Convention in Baltimore we celebrated a number of remarkable people at the Tuesday recognition luncheon. These individuals have shaped and will continue to influence our industry. We announced our 2022 40under40 award winners and introduced the latest class of ICRI Fellows. We also recognized our former Technical Director Ken Lozen who retired after 34 years of dedication to the advancement of our industry and our institute.

The certification team, led by ICRI Certifications Committee Chair Tom Donnelly and ICRI Program Director Dale Regnier, have seen significant activity in both the Concrete Slab Moisture Testing Technician (CSMT) and Concrete Surface Repair Technician (CSRT) programs. Since mid-2021—even with continued headwinds from the pandemic—the team has certified 39 new CSRT technicians through live and virtual performance exams. In addition, CSMT Faculty Lead Peter Craig and the team have conducted 9 CSMT programs with 89 newly certified CSMT technicians. These programs continue to grow with many more classes in the pipeline.

Our leadership, both internationally and in chapters, have participated in the support of ACI 562 code adoption. I have personally participated in adoption efforts in North Carolina, South Carolina, and Massachusetts, offering testimony at various hearings. We have also seen code progress or adoption in North Carolina, South Carolina, Virginia, Massachusetts, Ohio, Hawaii, Florida, and significant traction at the International Existing Building Code (IEBC) level for the next code update. This code adoption will make our industry

better, safer, and create a competitive balance where low quality work is no longer acceptable just because it's cheap.

We all see the pressure on our supply chain partners and the challenges in finding, developing, and keeping talented team members. ICRI is here to help. With our new webinar series, technical documents, presentations, education, certification programs, and the hundreds of chapter meetings each year, there are countless opportunities to connect with project partners and improve the skills of your team. For information on these offerings, visit the ICRI website—www.icri.org.

Looking ahead, we are working to develop a full ICRI association app that will not only encompass ICRI convention information, it will also provide timely information on a range of ICRI programs. With this app, we want to help chapters feature and promote their educational, technical, and social activities on a common calendar for easy review. In addition, we want to provide an easy-to-use platform to access ICRI technical information in the field, on the go.

ICRI has also just signed an agreement with a developer to build our first-ever technical, field-based app focused on concrete repair. There will be more news about this in the months to come. For now, it's another important example of ICRI focusing on the future and working to support our industry.

Last but certainly not least, we have also begun ramping up the focus on the Fall Convention in Atlanta, November 7-9. We're excited to see what the Georgia Chapter has in store for us! Mark your calendar now and look for registration details in the coming weeks.

We have a lot of wins to celebrate and more to look forward to. For now, I wish you all a safe and prosperous summer!

John McDougall, CCSRT
2022 ICRI President



ICRI Mission: ICRI provides education, certification, networking, and leadership to improve the quality of repair, restoration, and protection/preservation of concrete and other material systems.

Our Vision: ICRI will be the center for repair leadership supporting a profession built on science and craftsmanship, making the built world safer and longer lasting.

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MARK NELSON

ICRI TAC Goal for 2022—Create ICRI Technical Committee Sell Sheets

The third of our four ICRI Technical Activities Committee (TAC) goals for 2022 is to create Committee Sell Sheets for each individual ICRI technical committee. By the end of this year, each technical committee will have their own pamphlet describing the committee purpose as well as detailing their current activities within that specific committee.

The purpose of creating sell sheets is to eventually distribute them at local ICRI chapter meetings. These handouts will provide notice of the opportunity for local ICRI chapter members to join our international ICRI technical committees. The individual sell sheets will provide specific details on how to join a particular committee while also informing the readers about the benefits of committee membership.

Thank you to ICRI TAC members Scott Distefano (Sika) and Jeff Ohler (Euclid Chemical) for leading the task group. The sell sheet program is also a joint effort with the ICRI Marketing Committee. Thanks to Ed Kluckowski (Freyssinet) as well as the entire ICRI Marketing Committee in supporting us with this important goal.

ICRI Technical Committee Chairs

Mark Kennedy has stepped down as the Committee 320 committee chair. I would like to thank Mark for his work leading this committee over the past few years. I would also like to welcome new 320 Committee Chair Joshua Lloyd

(SGS/TEC) and new 320 Committee Vice-Chair Dave Wingard (Quikrete). This important committee is in great hands with these new leaders.

Following is a list of the ICRI Technical Committee Chairs. If you want to become more active in ICRI and the repair industry, please feel free to contact them directly to learn more about their committees.

- **Liying Jiang**, *Structural Technologies*
Committee 110—Guide Specifications
- **Paul Farrell**, *Carolina Restoration & Waterproofing*
Committee 120—Environmental Health and Safety
- **Marthe Brock**, *Master Builders Solutions USA*
Committee 130—Contracts, Warranties, and Agreements
- **Vincent LaPointe**, *SIMCO Technologies*
Committee 160—Life Cycle and Sustainability
- **Charles Mitchell and David Rodler**, *SK&A*
Committee 210—Evaluation
- **Peter Haveron**, *Texas Concrete Restoration*
Committee 310—Surface Preparation
- **Joshua Lloyd**, *SGS-TEC Services, Inc.*
Committee 320—Concrete Repair Materials and Methods
- **Tarek Alkhrdaji**, *Structural Technologies*
Committee 330—Strengthening and Stabilization
- **Jason Coleman**, *Wiss, Janney, Elstner Associates, Inc.*
Committee 410—Masonry
- **Jorge Costa**, *Durability, Inc.*
Committee 510—Corrosion
- **Eric Muench**, *Sika Corporation*
Committee 710—Coatings and Waterproofing

Mark Nelson is chair of the ICRI Technical Activities Committee (TAC).



Volunteer

Why Volunteer?

The success of the International Concrete Repair Institute and its work in the industry depends on a strong, active volunteer force. As a member of ICRI, you are invited to participate in the meetings and projects of any ICRI administrative or technical committee. All are volunteer-led and depend on your expert contributions.


ICRI's volunteer program strives to create an environment that is friendly and welcoming. As an ICRI volunteer, you work closely with volunteer leaders and ICRI staff—active parts of each committee—and available to assist you to answer questions about how ICRI operates, and to help you be the most effective volunteer possible.

Follow Your Interests

Check out the administrative and technical committees of ICRI, attend their meetings and learn what each is working on. Then decide where your area(s) of interest fit best. The ICRI staff is here to answer your questions and help align you with your interests. You are welcome to attend any meeting of any committee on the administrative or technical committee list. You attend—you can decide if you want to join.

Length of Commitment

Most volunteer commitments are ongoing; leadership positions are a 3-year commitment. Committees usually meet monthly for 1-1.5 hours. In addition, committees often require tasks to be completed outside of the meetings on the volunteer's own time. Visit www.icri.org for more information.



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CERTIFICATIONUPDATE

CSRT Live Performance Exams Are Back!

With COVID-19 cases trending downward, ICRI has brought back the scheduling of Live Performance Exams (LPE) for its Concrete Surface Repair Technician (CSRT) Certification program.

ICRI's North Texas Chapter hosted its second CSRT LPE in December 2021, thanks to the generous support of ICRI Company Member RTC Restoration & Glass, Carrollton, Texas. RTC did an outstanding job setting up the testing area in their warehouse, **and** provided the participants, volunteers, and judges with a home-cooked barbeque dinner at the conclusion of the exams. Congratulations to new CSRTs: Stephen Grelle, PE, Wiss, Janney, Elstner; Carlos Carillo and Francisco Zepeda, RTC Restoration and Glass, Inc.; and Anthony Ferrante, Quikrete Companies. Thank you to the event judges Jonathan O'Connor, Terracon, and Mark LeMay, JQ Engineering. Plus, thank you to the guys at RTC for their great work hosting this event!



Layout of the testing area including all four stations and the necessary equipment

The North Texas Chapter and RTC have already committed to host their third CSRT Live Performance Exam on December 7, 2022, at the RTC facility in Carrollton, Texas. Registration is currently open and you can begin the process by signing up to take the five-module Educational portion of the CSRT program at icri.org.

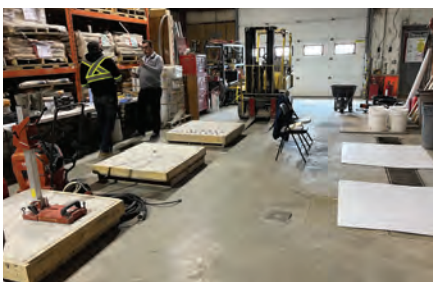
Vector Construction in Decatur, Illinois, hosted a CSRT Live Performance Exam for 11 of its employees on March 5, 2022. Vector did a exceptional job setting up its shop for the event that was judged by ICRI Technical Director Dave Fuller and Mark LeMay, JQ Engineering. Congratulations to new CSRTs Nick Elliott, Michael Kerman, Andrew Nailer, Wes Rice, Seth Scott, Arth Brown III, Cody Bush, Adam Toby, and Chris Sieczkowski.



Performing the slump flow test using the inverted cone option

Continuing the trend, Vector Construction's Edmonton, Alberta, Canada, office hosted a CSRT Live Performance Exam for 13 of its employees on May 5-6. Working with Chance Edwards at Vector, ICRI Program Director Dale Regnier and SME Mark LeMay found a well-organized setup and volunteers at Vector's shop in Edmonton. Congratulations to new CSRTs Chance Edwards, Justin Street, Mark Mallari, Markus Krauss, Robert DeCruyenaere, Kyle Finlay, Morgan Lloyd, Crisandro Pulongbarit, Tyler Doyle, Tyler Manuel, Brent Brooksher, Jacob Duffin, and Ken Selman.

(Continued on page 8...)



Setup of testing area at Vector's shop in Decatur, IL



ICRI Technical Director Dave Fuller (L), judging the preparation of a concrete cylinder



Performing the Direct Tensile Pull-Off Test



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Upcoming 2022 Program Locations:

- Sacramento, CA—July 20–21
- Chicago, IL Area—August 3–4
- Denver, CO—August 22–23
- Dallas/Ft. Worth, TX Area—October 25–26

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- ✓ Take this course by itself or get certified through the certification course

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- ✓ Qualifies you to perform pre- and post-placement inspections and testing
- ✓ Includes the five online training modules in the education course, an online knowledge exam, and performance exam on ASTM test methods (video recorded or live)

Upcoming Live Performance Exam Locations:

- Raleigh, NC—August 18, 2022
- Denver, CO—August 24, 2022
- Dallas, TX—December 7, 2022

(Live Performance Exams require an additional fee)



Learn more at www.icri.org

Questions? Contact Program Director Dale Regnier at daler@icri.org

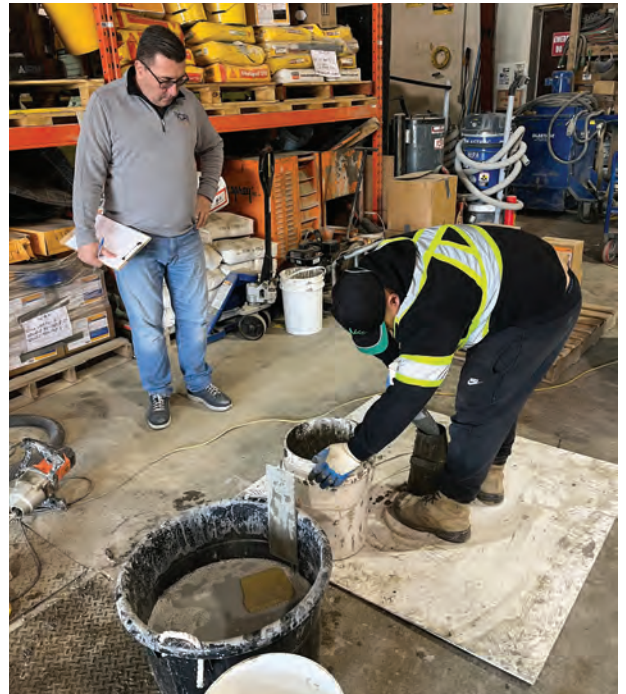
(...continued from page 6)

In addition to the December 7 CSRT Live Performance Exam in Dallas, additional Live Performance Exams are scheduled by the ICRI Carolinas Chapter on August 18, 2022, at Baker Restoration, 517 Mercury Street, Raleigh, NC, and by the Rocky Mountain Chapter on August 24, 2022, at National Waterproofing Supply Company, 11929 East 51st Avenue, Denver, CO. Registration information can be found on the ICRI website.

If your company or chapter wishes to schedule a CSRT Live Performance Exam, please contact ICRI Program Director Dale Regnier, daler@icri.org, and provide him with contact information for the point person who would be in charge of coordinating the event, the proposed exam location, and potential date(s).



Exam area setup at Vector shop in Edmonton



ICRI Program Director Dale Regnier, judging the preparation of a slump flow test



Group shot of the new Certified CSRTs at Vector Construction, Edmonton, Alberta, Canada



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Compatible Shotcrete Specifications and Repair Materials

by William Clements and Kevin Robertson

Concrete repair projects can often be completed using a variety of repair materials and methods. In some cases, the specific requirements of a project may dictate the required material or method. Shotcrete is used as a repair method to replace other methods, such as form-and-pour or form-and-pump to reduce labor costs and accelerate the construction schedule. Shotcrete is often also required in some circumstances where access to the repair area is limited, both in terms of location and time available (Fig. 1). Upon determining a repair method, a repair material must then be selected that is compatible with the concrete substrate, durable in the expected exposure conditions, and meets the structural requirements detailed by the design professional responsible for designing the repair. Ideally these important criteria would be evaluated by the design professional and incorporated into the project specification to address the specific requirements of the project based on the expected service life of the repair. Because all specifications are not created equal and, in some cases, shotcrete is still a new repair method for some design professionals, it is simpler for some or all of these important repair criteria to be missed or overlooked.

The service life of any repair also depends on the successful bond of the repair material to the substrate, the ability for the repair material to resist the exposure conditions in the field, and the ability for the repair material to resist cracking while in service. Even if the repair material exhibits excellent durability properties, if cracks develop either in the repair material or around the perimeter of the repair area, they can act as direct lines to the reinforcing steel for aggressive agents such as water and chlorides. Therefore, when considering these factors, the repair material must be as compatible as possible with the substrate to reduce the potential for cracking.¹

SPECIFICATIONS

As with most specifications in the construction industry, concrete repair specifications typically use either a prescription specification or performance specification. Prescription specifications either reference the actual repair product(s) by name or the constituents and/or characteristics of the repair material. In contrast, a performance specification outlines the performance requirements of the re-



Fig. 1: Remote dam repair using dry-mix shotcrete and a cofferdam (Côté, Ferland, and Robertson 2014)

pair material in accordance with applicable standards. In general, there is currently a trend towards performance specifications, but in North America both ACI 318 and CSA A23.1/A23.2 still use a hybrid method of both prescription and performance when classifying concrete.² There are cases where contractors prefer to submit an equal alternative to prescribed products based on experience, or the contractor is looking to propose the shotcrete method in lieu of form-and-pour or form-and-pump. It can be simpler for a contractor to submit a shotcrete material for a performance specification, as the contractor and manufacturer simply need to display compliance with the project specification through the appropriate submittals to obtain approval. This process does become much more difficult, however, when the project specification presents a product or certain performance criteria that do not match the typical test methods applicable to shotcrete. ACI 506-E “Specification for Shotcrete” addresses the commonly tested performance characteristics such as compressive strength, flexural strength, and air content, noting that any hardened test samples must be produced from sprayed test panels. Although it is common to see specifications or technical data sheets from manufacturers for shotcrete

Property	Repair Mortar Test Method	Repair Mortar Specimen Type	Shotcrete Method	Shotcrete Specimen Type
Compressive Strength	ASTM C-109	Cast Cube (2"x2")	ASTM C-1604	Core (3" Ø)
Flexural Strength	ASTM C-348	Cast Beam (1.5" x 1.5" x 6.5")	ASTM C-78	Sawed Beam (6" x 6" x 21")
Splitting Tensile Strength	ASTM C-496	Cast Cylinder (4" x 8")	ASTM C-496 (Modified)	Core (3" Ø)
Slant Shear Bond Strength	ASTM C-882	Cast Cylinder (3" x 6" - 30°)	ASTM C-1583 (Pull-Off Bond Strength)	Tensile Bond of Core (3" Ø)

Fig. 2: Test methods for repair mortars compared to the corresponding method for shotcrete.

materials, indicating results for test methods which are applicable to repair mortars and not for shotcrete. For example, the compressive strength of shotcrete should always be evaluated in accordance with ASTM C-1604, but it is typical for manufacturers to present data in accordance with ASTM C-109. ASTM C-109 involves manually consolidating shotcrete into cube molds, as opposed to being shot, and is therefore not representative of the in-place shotcrete. An example of commonly specified test methods in a shotcrete repair specification, compared to the corresponding applicable test method for shotcrete is presented in Figure 2.

A common misconception when it comes to current shotcrete specifications for repair projects is the consideration of equivalency of "Low Velocity Mortar Spray" or "Low Pressure Mortar Spray" to high velocity dry-mix or wet-mix shotcrete. As noted in Fig. 2, the adapted ASTM test methods for compressive strength, flexural strength, and other test methods differentiate shotcrete from mortar. Low velocity spraying involves pumping at a lower pressure than conventional wet-mix shotcrete and is therefore shot at a much lower velocity. The main difference between both methods is the velocity at which the material is shot into place. While shotcrete has been characterized to travel at speeds of 45-75 mph (72-120 km/h) which is required in order to achieve proper compaction, low velocity mortar spray is in essence a method of placing a material that is typically hand-troweled into place.³ Low velocity mortar spraying simply lacks the velocity required to encapsulate reinforcing steel and even wire mesh in most cases. In some of North America's construction markets, the shotcrete method has been given a bad reputation because the specifications have been written around low velocity mortar spraying, which were considered to be accepted as shotcrete. Both methods have their place in the repair industry depending on the type of repairs to be completed. When designing repairs that utilize wire mesh or reinforcing steel, high velocity shotcrete must be used in order

to have the ability to properly encapsulate the steel and not create any voids behind the steel.

The method of application changes the mix design of dry-mix shotcrete materials compared to wet-mix shotcrete materials, as wet-mix shotcrete materials must be pumped prior to spraying. Wet-mix shotcrete commonly contains an air-entraining admixture to either provide durability in freeze-thaw environments, or to improve the pumpability of the material using the "high initial air content concept."⁴ Using a high initial air content ranging from 10-20%, the "high initial air content concept" has been proven to increase the slump and pumpability of shotcrete during pumping, and to produce an air content of 3-5% in-place after shooting. It has been shown that compressive strength can be reduced by an average of 5.5% for every 1% of air content above normal levels, which makes it clear that as-batched wet-mix shotcrete is not representative of the in-place material considering the compaction and elimination of air voids that takes place during the shooting process.⁵ In the case of dry-mix shotcrete where water is added at or close to the nozzle, the shotcrete mixture will possess an increased water demand when mixed in a mechanical mixer compared to being sprayed. The increased water demand and the use of an air-entraining admixture will also have a significant effect on the compressive strength and mechanical properties of dry-mix shotcrete materials when they are mixed mechanically. Therefore, any test results presented for the mechanical and durability properties of a shotcrete repair material should be from as-shot samples.

ADAPTING TEST METHODS TO THE SHOTCRETE PROCESS

The ICRI technical data sheet protocol established in ICRI Guideline No. 320.3R provides a thorough list of both mechanical and durability parameters that should be provided on the technical data sheet of any repair material. Although the guideline details which ASTM standard test

method should be followed for mortars and which methods should be followed for concrete, some adaptations are required when applying the protocol to a shotcrete material. Considering most of the test methods described in ICRI Guideline No. 320.3R and noted in Fig. 2 reoccur in concrete repair specifications from



Fig. 3: Conventional square shotcrete test panels used for obtaining cores

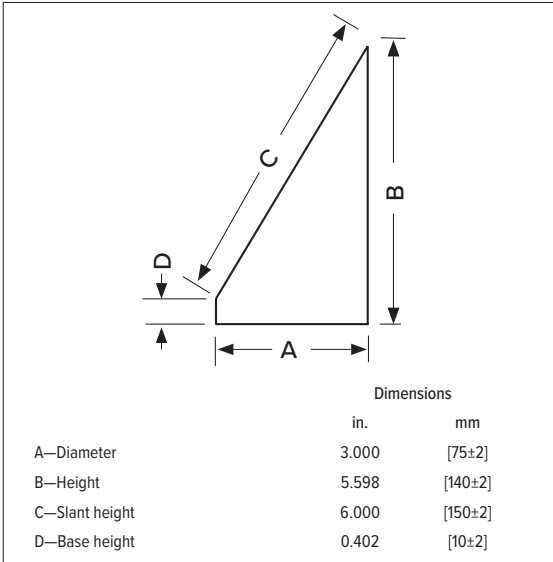


Fig. 4: Schematic of slant shear dummy section (ASTM C 882)



Fig. 5: Inclined precast mould for slant shear bond strength testing (ASTM C 882)

the industry, KING enlisted Laval University to execute a testing program for the required parameters using a silica-fume enhanced dry-mix shotcrete (KING MS-D1). The samples tested were obtained from coring or sawing conventional test panels (Fig. 3), spraying shotcrete onto precast concrete sections or by spraying oversized test samples for durability testing and then sawing the edges around the perimeter of the samples in order to remove sections of rebound and overspray.

The Slant Shear Bond Strength test (ASTM C-882) was originally developed to test the bond strength of epoxy between two cast mortar sections. The concrete repair industry has since adopted a modified version of the test, wherein the concrete repair material is poured onto the hardened mortar dummy (Fig. 4) and then the composite cylinder is tested in compression.

The resulting load on the cylinder is divided by the area of the ellipse, resulting in a shear bond strength along the 30° plane of the bonding surface. To modify the test method to the shotcrete process, a precast concrete section was poured using the appropriate angle (Fig. 5), and then the shotcrete was sprayed onto the precast section. Cores were taken perpendicular to top surface of the composite sample, to model the shotcrete being cast onto the mortar dummy as per the standard (Fig. 6).

Following the completion of the test program, it is apparent that most test methods for concrete materials can be adapted to the shotcrete process, although in some cases it is not simple to do so. The results of the testing program are presented in Fig. 7, and when compared to typical requirements for concrete, dry-mix shotcrete is an excellent concrete repair material. Notably the bond strength exhibited by the ASTM C-882 test samples were very high, and two of the five cores tested at 28 days failed with multiple vertical cracks as opposed to failing along the bond line.

DEVELOPING COMPATIBLE DRY-MIX SHOTCRETE

Almost all reinforced concrete structures will require some type of repair during their expected service life, and the type and extent of repairs are a function of the structure’s age, exposure conditions, original design, construction methods and building materials used. Where possible, it is best to replace any concrete that is removed from the structure, with a material that has physical properties like the substrate such as compressive strength, modulus of elasticity, and coefficient of thermal expansion. This helps reduce the risk of de-bonding by ensuring that any physical movement, either due to loading or temperature changes in the substrate, are mirrored in the repair material. These properties do not, however, predict the inevitable volume change that a shotcrete repair material will undergo once in-place. This volume change is a complex combination of chemical/autogenous shrinkage of the cement paste, drying shrinkage from moisture loss, and tensile creep (relaxation). Once the tensile forces of shrinkage exceed the tensile strength of the material, cracking can occur within the material itself, and once the tensile forces of shrinkage exceed the bond strength of the repair material to the substrate, cracking can occur at the perimeter of the repair.

Even though shotcrete is very similar once shot to cast-in-place concrete, the shotcrete mix design must be tailored to the process to



Fig. 6: Composite core for slant shear bond strength testing (ASTM C 882)



Fig. 8: Shotcrete being sprayed into inclined AASHTO T 344 rings

Property	Test Method	Sample Type	Result (28 Days)
Flexural Strength	ASTM C-78	Sawed Beam (6"x 6" x 21")	1,088 psi (7.5 MPa)
Splitting Tensile Strength	ASTM C-496	Core (3" Ø)	645 psi (4.45 MPa)
Direct Tensile Strength	CRD-C-164	Core (3" Ø)	500 psi (3.45 MPa)
Modulus of Elasticity	ASTM C-469	Core (3" Ø)	4.2 x 10 ⁶ psi (29.0 GPa)
Pull-Off Bond Strength	ASTM C-1583	Tensile Bond of Core (3" Ø)	420 psi (2.9 MPa)
Slant Shear Bond Strength	ASTM C-882	Core (3" Ø-30° Incline)	3,335 psi (23.0 MPa)
Length Change	ASTM C-157	Sawed Beam (3"x 3" x 11 1/4")	50% RH: -0.0494% 100% RH: +0.0122%
Coefficient of Thermal Expansion	CRD-C-39	Core (3" Ø)	6.5 x 10 ⁻⁶ /°F (11.7 x 10 ⁻⁶ /°C)
Freeze-Thaw	ASTM C-666	Sawed Beam (3"x 3" x 11 1/4")	100% Durability Factor
Salt Scaling	ASTM C-672	Sawed Beam 72 in ² surface	0.04 lb/ft ² (0.2 kg/m ²)
Chloride Ion Penetrability	ASTM C-1202	Core (4" Ø)	500 Coulombs

Fig. 7: Adapted test methods for shotcrete using ICRI Guideline No. 320.3R

Mix No.	Cement Content (%)	Coarse Aggregate (%)	Silica Fume (%)	Fly Ash (%)	Polymer-BWC (%)	Age of Cracking AASHTO T 344 (DAYS)
1	21	15	0	0	0	25
2	18.9	15	2.1	0	0	9
3	19.4	15	1.6	0	0	6.5
4	14.4	15	1.6	5	0	6
5	19.4	15	1.6	0	2.0	7
6 (HC-D1)	*	*	*	*	*	40

Fig. 9: Age of cracking for different dry-mix shotcrete formulas. Note: The remainder of the formula consisted of sand. *Proprietary mix design

facilitate pumping, optimize build-up while spraying and to reduce rebound. The use of silica fume in shotcrete can greatly reduce rebound, increase build-up thickness, increase compressive strength, and reduce permeability.⁶ Conversely, silica fume also increases drying shrinkage in shotcrete, which can increase the risk of cracking—especially if proper wet curing techniques are not used on-site after shooting. To reduce shrinkage and improve compatibility, it would be beneficial to remove silica fume from the dry-mix shotcrete formulation, but the loss of productivity and efficiency due to excessive rebound in the field would generally not be acceptable. Some potential techniques for reducing shrinkage in shotcrete materials include the use of coarse aggregate, reducing the cementitious content, replacing cement with fly ash, and using polymer. To evaluate the effectiveness of these techniques, it is required to use a test method that captures all of the parameters noted previously as the shotcrete undergoes volume change.


Currently the best test method for predicting the risk of cracking in a repair material is the AASHTO T 344 standard test method (ring test), which has recently been adapted to the shotcrete process at Laval University.⁷ The method

involves spraying shotcrete into a steel ring mould, which is mounted in an inclined overhead position to allow rebound to escape the mould (Fig. 8).

Following moist curing, the shotcrete ring is placed in a controlled environment at 50% (±5%) relative humidity and a temperature of 70 ± 2°F (21 ± 1°C). The stress developed in the shotcrete ring is monitored using a data acquisition system, wherein cracking potential is then calculated as a function of the average stress developed and the age at which cracking occurs. Using a wet curing period of 3 days followed by drying, several mix designs along with a proprietary mix design developed by KING (HC-D1) were compared using the ring test to evaluate cracking potential.⁸ The formula used and the age of cracking for each mix design is presented in Fig. 9.

Mix No. 1 indicates that the removal of silica fume greatly reduces the age of cracking, while the addition of either fly ash or polymer had no effect on the age of cracking based on the results presented for Mix No. 4 and Mix No. 5. The performance of KING HC-D1 indicates a dry-mix shotcrete formulation with very low cracking potential, even when compared to the mix design without silica fume.

CONCLUSIONS

The shotcrete process can be used to achieve compatible concrete repairs, offering a long service life. The combination of specifying the correct physical properties (test methods), and using the right shotcrete material, help guarantee success in the field. The mechanical and durability properties of shotcrete should always be determined using samples that are shot and not cast, by adapting any applicable standards to the shotcrete process. The development of a highly compatible dry-mix shotcrete with a very low cracking potential shows promise, and testing of the other key properties as described in this article are currently underway. 

REFERENCES

1. McDonald, J.E.; Vaysburd, A.M.; Emmons, P.H.; Poston, R.W.; and Kesner, K.E. *Selecting Durable Repair Materials: Performance Criteria—Summary*. Concrete International, 2002, V. 24, No. 1, pp. 37-44.
2. Tanesi, J., Da Silva, M.G., Gomes, V. & Camarini G. (2010) *From prescription to performance: international trends on concrete specifications and the Brazilian perspective*. V.3, No. 4, 420-431.
3. Hanskat, C. *Pneumatically Applied Concrete: A Confusion of Terminology*. Shotcrete Magazine, 2016, pp. 22-25.
4. Jolin, M., and Ginouse, N. (2012) *Recent Research in Wet-Mix Shotcrete at Laval University*. 3 Congresso Brasileiro de Tênis E Estruturas Subterâneas, São Paulo, Brazil, p. 19.
5. Neville, A. (2011). *Properties of Concrete* (5th ed.). Halow, Essex, England: Pearson Education Limited.
6. Wolseifer, J. and Morgan, D.R. (1993) *Silica Fume in Shotcrete*. Concrete International, V. 15, No. 4, 34-39.
7. Girard, S.; Jolin, M.; Bissonnette, B.; and Lemay, J-D. (2017) *Measuring the Cracking Potential of Shotcrete*. Concrete International, V. 39, No. 8, 44-48.
8. Menu, B.; Pépin Beaudet, A.; Jolin, M.; Bissonnette, B.; Molez, L. (2018) *Évaluation quantitative de la sensibilité à la fissuration du béton projeté au moyen de l'essai de retrait restreint annulaire*.

ACI Committee 318. (2014). *Building Code Requirements for Structural Concrete (ACI 318-14)*. Farmington Hills, MI, USA: American Concrete Institute.

ASTM C-78. (2018). *Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)*. West Conshohocken, PA, USA: ASTM International.

CSA A23.1/A23.2 (2014). *Concrete Materials and Methods of Construction/Test Methods and Standard Practices for Concrete*. Toronto, ON, CAN: CSA Group.

ACI Committee 506-E. (2013). *Specification for Shotcrete (ACI 506.2-13)*. Farmington Hills, MI, USA: American Concrete Institute.

ASTM C-1604. (2012). *Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete*. West Conshohocken, PA, USA: ASTM International.

ASTM C-109. (2016). *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)*. West Conshohocken, PA, USA: ASTM International.

ASTM C-157. (2017). *Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete*. West Conshohocken, PA, USA: ASTM International.

ASTM C-348. (2018). *Standard Test Method for Flexural Strength of Hydraulic Cement Mortars*. West Conshohocken, PA, USA: ASTM International.

ASTM C-469. (2014). *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*. West Conshohocken, PA, USA: ASTM International.

ASTM C-496. (2017). *Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens*. West Conshohocken, PA, USA: ASTM International.

ASTM C-666. (2015). *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*. West Conshohocken, PA, USA: ASTM International.

ASTM C-672. (2012). *Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals*. West Conshohocken, PA, USA: ASTM International.

ASTM C-1202. (2018). *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*. West Conshohocken, PA, USA: ASTM International.

ASTM C-1583. (2013). *Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)*. West Conshohocken, PA, USA: ASTM International.

CRD C-39. (1981). *Test Method for Coefficient of Linear Thermal Expansion of Concrete*. Washington, DC, USA: U.S. Army Corps of Engineers.

CRD C-164. (1992). *Standard Test Method for Direct Tensile Strength of Cylindrical Concrete or Mortar Specimens*. Washington, DC, USA: U.S. Army Corps of Engineers.

ICRI Technical Activities Committee. (2003). ICRI Guideline No. 320.3R: *Guideline for Inorganic Repair Material Data Sheet Protocol*. St. Paul, MN, USA: International Concrete Repair Institute.

ASTM C-882. (2013). *Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear*. West Conshohocken, PA, USA: ASTM International.

AASHTO T 344. (2008). *Standard Method for Estimating the Cracking Tendency of Concrete*. Washington, DC, USA: American Association of State and Highway Transportation Officials.



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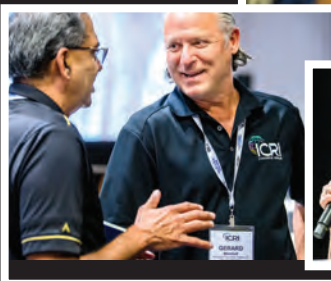
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Structural Modifications of Draft Tubes Using Overhead Wet-Mix Steel Fiber Reinforced Shotcrete

by Lihe (John) Zhang, Shaun M. Radomski, Dudley R. (Rusty) Morgan, and David Graham—updated article originally published in Shotcrete Magazine, Volume 21, Number 3, Summer 2019

Lice Harbor Lock and Dam was constructed in 1956 and is located along the Snake River near the confluence with the Columbia River, approximately 19 km east of Pasco, Washington, USA. The dam is a concrete gravity run of the river dam operated by the U.S. Army Corps of Engineers (USACE) and provides electrical power through six (6) turbines for electrical distribution through the Bonneville Power Administration in the State of Washington.

Accelerated silica fume modified wet-mix shotcrete with 59 kg/m³ (100 lb/cu.yd.) of steel fibres was applied overhead up to 1.8m (6 ft.) thick, as part of structural modifications made to draft tube ceilings downstream of Turbine Unit No. 2 in 2017 and Turbine Unit No. 3 in 2020. This shotcrete application posed challenges for the contractor performing the work. Rigorous shotcrete specifications were developed by USACE for this work. This article details the shotcrete work for construction in Unit No. 3 in 2020, including:

- Shotcrete application procedures developed during the preconstruction mockups;
- Construction sequencing and challenges to overcome while shooting the real work; and
- Construction monitoring and quality control testing results.

The draft tube is 30.5 m (100 ft) below the surface, based on measuring the distance between the draft tube floor at the downstream exit door and the Tailrace Deck located at the surface. The draft tube is 27.9 m (91.5 ft) long and is split into two sections (Barrels A and C) by a concrete pier nose. Barrel A and Barrel C are each 10.4 m (34.1 ft) wide at the stop logs (furthest downstream). The structural modification was completed to the ceiling from the location of the draft tube exit doors and upstream to approximately 11.2 m (36.7 ft) away from the exit doors.



Fig. 1: Nozzleman shooting the final lift of the full-scale mock-up (Ref. 2)

DESIGN, SPECIFICATIONS AND MIX DESIGNS

The U.S. Army Corps of Engineers (USACE) designed structural modifications to the turbine draft tube to improve hydraulic conditions for fish passage and electrical power generating efficiency. This required the ceiling at the draft tube (furthest downstream) to drop by approximately 1.8 m (6 ft), while maintaining an overall slope of 22° in Barrel A and 23° in Barrel C, until the shotcrete terminated at a 65 mm (2.5 in) cut notch which was to be built out flush with the existing ceiling. The design included the drilling of 25.4 mm (1 in) diameter (Type 1) and 12.7 mm (0.5 in) diameter (Type 2) anchors into the existing ceiling concrete and installing 15M (No. 5) reinforcing steel positioned 65 mm (2.5 in) from the concrete substrate and 30M (No. 9) reinforcing steel positioned approximately 100 mm (4 in) from the final finished shotcrete surface.

USACE specified shotcrete performance as follows:

- A minimum specified shotcrete compressive strength of 35 MPa (5000 PSI) at 28 days and a minimum bond

strength to the prepared concrete substrate of 0.7 MPa (100 PSI).

- Demonstrate that the specification requirements could be achieved by constructing large full-scale mock-ups 2.4 m long x 1.8 m wide (7.9 ft long x 5.9 ft wide) and varying in thickness from 1.2 to 1.9 m (3.9 to 6.2 ft); one for each nozzleman proposed to shoot on the job. The mock-ups were used to prequalify the mixture designs, accelerator dosage, nozzleman technique and shooting procedures. These mock-ups were constructed and successfully shot by three nozzlemen for structural modification of Turbine Unit No. 2 in 2017 (Ref. 2).

The shotcrete mixture design was proportioned with the following materials and designed to meet the following performance requirements:

- Coarse aggregate comprised of 10 mm (3/8 in) maximum size meeting the ACI 506 Grading No. 2 requirements;
- 59 kg/m³ steel fibre (100 lb/cu. yd.) or 0.75 percent by volume;
- ASTM Type I normal Portland cement
- 8.3 percent fly ash and 9 percent silica fume;
- 180-230 mm (7-9 in) slump at discharge into the shotcrete pump;
- 7-10 percent air content as-batched and 2-5 percent air content as-shot.

PRECONSTRUCTION MOCKUPS

Full-scale mockups were constructed for each nozzleman as part of the prequalification process using the reinforcing details specified for the work (Fig. 1). The shotcrete mix selected was trial shot and tested for preconstruction qualification. Initial set, final set, early and later age compressive strength, and boiled absorption and volume of

permeable voids were tested to qualify the mix. Shotcrete inspectors and quality control testing technicians/engineers were also qualified for the project. Shotcrete was supplied, applied, inspected, and tested only by the qualified entities and individuals. Detailed information about mockup and testing is included in Ref. 2.

CONSTRUCTION

Pump, slick line, and scaffold setup

The wet-mix shotcrete pump, dry-mix gun, and air compressor were set up on the surface. Steel slick lines were used to pump shotcrete down, through a vertical shaft and egress access, around 15-23 m (50-75 ft.) to the draft tube (Fig. 2a). The slick line contained several turns and 90-degree elbows to reach the bottom of the draft tube from the power house. Approximately 61 m (200 ft.) of slick line and rubber hoses were used to feed the shotcrete to the nozzleman in the draft tube where the end of slick line transitioned into a 50 mm (2 in) rubber hose at the shotcrete work area. The shotcrete work area had several levels of scaffold decks supported by a sloped floor. The scaffold decks were adjusted up or down so that the nozzleman could apply shotcrete overhead while shooting in a predominantly upright position where possible. Nozzlemen found that shooting in a crouching position was at times necessary to enable a suitable shooting angle during application to the sloped ceiling (Fig. 2b).

Concrete Surface Preparation

The existing concrete ceiling surfaces of the draft tubes located in barrels A and C were generally found to be in good condition based on visual inspection of the concrete surfaces. Abrasive blasting using silica glass was used to provide an ICRI CSP 7³ surface roughness profile (Fig. 3a and 3b). Visual inspection and hammer sounding techniques were completed by the QA Engineer/Technician to ensure a sound and clean surface was provided. Surfaces were brought to a saturated surface dry (SSD) condition prior to shotcrete application.

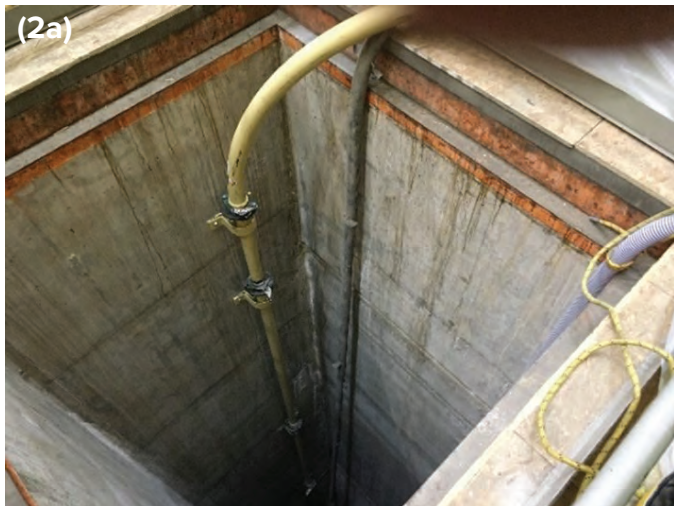


Fig. 2a) Slick line entering the draft tube from the power house; 2b) Nozzleman shooting overhead on a scaffold platform in a crouching position maintaining suitable shooting angle and distance to the receiving surface and building out shotcrete to the shooting wires.

Reinforcing Steel and Anchors

The reinforcing steel was inspected for size, spacing, and for being secure prior to shotcrete application. Positioning of anchors into the concrete ceiling required some offsetting due to encountering existing rebar following ground penetrating radar scanning. Anchor Types 1 and 2 were required to be drilled at 1 m (3 ft.) O.C. and 0.450 m (18 in) O.C., respectively with tolerance of +/- 100 mm (4 in.) spacing for anchors. The 15M (No. 5) and 30M (No. 9) reinforcing steel were required to be spaced at 300 mm (12 in) O.C. E.W. (Figs. 4a and 4b, and Figs. 5a and 5b).

All reinforcing steel was inspected to verify that it met design requirements in the structural drawings and was secure for overhead shotcrete application. In addition, the anchors were protected from overspray by plastic wrap (Fig 6a).

Placement Sequence

The concrete substrate was cleaned using a 20 MPa (3000 psi) pressure washer to remove any dust and debris that had accumulated on the surface, which was then allowed to dry back to a SSD condition prior to shotcrete applica-

tion. A compressed air fed blow pipe was used to accelerate drying of the surfaces, where necessary.

Shotcrete nozzlemen began shooting the prepared concrete substrate behind the 15M (No. 5) rebar by “picture framing” the edge of the work. Nozzlemen would fill in behind the rebar and wrap the bars with shotcrete by manipulating the nozzle in a side-to-side motion adjusting the angle of the nozzle so that shotcrete fully encapsulated the rebar. After the edge of the work was shot, the nozzleman would work away from the edge, using the same sequencing as described above (Fig. 5a).

Anchor rod extensions were installed and protected with plastic wrap and shotcrete was built out in maximum 100 mm (4 in) layers beyond the 15M (No. 5) bars. Shooting wires installed at 1 m (3.2 ft.) O.C. provided guidance to the nozzlemen on how thick the work should be built out in a single pass (Fig. 5b) and provide uniform layers of ceiling shotcrete thickness (Fig 6a). Each morning before application of the next layer of shotcrete, the hardened shotcrete surface was cleaned using a 20 MPa (3000 psi) pressure washer and allowed to dry back to a SSD condition (Fig.



Fig. 3a): ICRI CSP 7 surface roughness profile; 3b): Substrate concrete surface and No. 5 bars measured to be approximately 12" O.C. E.W.



Fig. 4a) Permanent steel form; 4b) Ceiling slope, concrete substrate, 254 mm (1 in) anchors and 15M (No. 5) rebar installed for shotcrete application

6b). Nozzlemen were observed to generally shoot at 90 degrees to the receiving surface, manipulating the nozzle in a side-to-side movement with a small circular motion to fully encapsulate rebar and anchors. (Figs. 7a, 7b, and 8a). A compressed air fed blow pipe was used during shotcrete application to enable removal of overspray from the rebar (Fig. 8b).

Nozzlemen were required to wait until the shotcrete had reached final set prior to shooting the next layer of shotcrete, as confirmed by testing for initial and final set times. Surfaces of shotcrete were also evaluated to the touch prior to applying the next layer of shotcrete. 30M (No. 9) bars were installed when the build-out of shotcrete was at approximately 250 mm (10 in) from the final finish grade. The nozzlemen applied shotcrete in the sequence described above when shooting through the 15M rebar but were able to work carefully around the more congested No. 9 bars and provide full encapsulation of this larger diameter rebar (Figs. 7b and 8a).

Nozzlemen applied dry-mix microsynthetic fiber reinforced shotcrete (without accelerator) to the final shooting wires

to provide the 100 mm (4 in) specified cover to the No. 9 rebar. The shotcrete was trimmed to the wires with a cutting screed, troweled, and wood float finished (Fig 9a and 9b). The final finish was a broom finish and satisfied the specification tolerance requirement of 50 mm (2 in) over a 3.050 m (10 ft.) straight edge (Fig. 11).

Thickness Control: Guide wires installed 1.0 m (3 ft.) O.C. and were offset approximately 100 mm (4 in) from the surface of the preceding layer of shotcrete to control line and grade.

Curing: Sprinklers were set up on the scaffold deck to apply water to cure the freshly applied shotcrete overnight. The high relative humidity, as well as no exposure to any sun or wind and the ambient temperatures in the hoarded shotcrete work area being generally greater than 55°F made the climatic conditions for curing the shotcrete in the draft tube favorable.

Challenges Encountered

Cold ambient temperature encountered during construction between February 10 and March 14, 2020 (tempera-



Fig. 5a): Formwork, 12.7 mm (0.5") anchors, 15M rebar and nozzleman shooting to prepared concrete substrate; 5b) 254 mm (1 in) diameter anchor and a shooting wire to control thickness



Fig. 6a): Profile of ceiling following shotcrete application to 15M rebar, anchor extensions, and steel form; 6b) high pressure water blasting shotcrete surface to clean the surface prior to shotcrete application of succeeding layers.

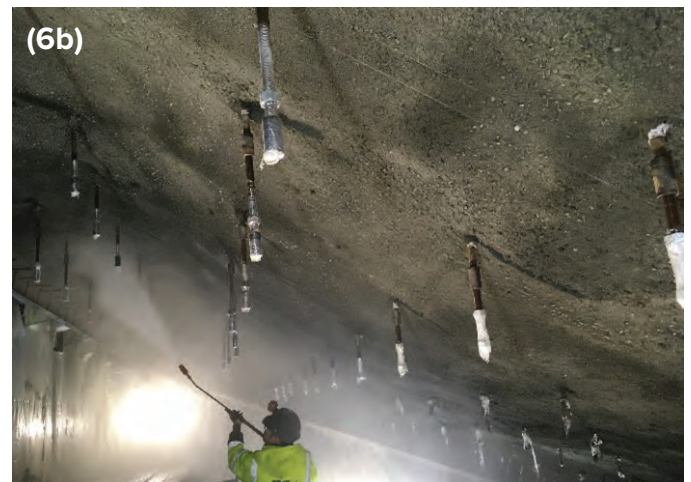




Fig. 7a): Nozzleman shooting in an upright position adjacent to steel form to achieve 90° shooting angle to receiving surface 7b): Nozzleman shooting to the 30M rebar at high impacting velocity



Fig. 8a) Inspecting quality of shotcrete around 30M rebar. 8b) using blow pipe to remove overspray from rebar



Fig. 9a): Dry-mix shotcrete to the finish line, cut and screed, and wood float finishing. 9b): A close up of the final broom finish appearance.

tures were recorded as low as -7°C (19°F) early in the morning) posed a challenge for achieving the required initial and final set times and adequate early age compressive strength development, particularly between 2 hours and 4 hours. It is well known that shotcrete tunneling in the winter poses challenges for early age strength development due to a combination of factors including: ambient air temperature, ready-mix supplied shotcrete temperature, cement type and composition, and accelerator temperature. These factors can all have an effect on the necessary accelerator dosage to achieve suitable initial and final set times and early age compressive strength development so that shotcrete will stick overhead and not sag or fall off. Also, the hydration stabilizers dosage can also affect the amount of accelerator required to be added at the nozzle to wake the shotcrete up when it is cold. This situation was made better by ensuring the tote that stored the accelerator was at the minimum required temperature of 23°C (74°F) for the accelerator to be effective. Therefore, the tote was wrapped with a heating blanket and the temperature of the accelerator inside the tote was measured daily to ensure that the heating system was working properly, and the accelerator temperature was greater than the minimum required temperature of 74°F (23°C). Initial and final set times and early age compressive strength development was measured regularly to check that suitable addition rate of accelerator was being provided by the accelerator dosing pump so that shotcrete would stick overhead without any sags or fall outs at the targeted maximum thickness of 4 in. (100 mm). On a spot check basis, accelerator consumption was measured from the accelerator tote to verify accelerator addition rates.

Balls or clumps of material were sometimes observed coming off the truck chute. These clumps were occasionally observed to plug the slick line at the reducer where the slick line transitions to a rubber hose. This issue was corrected by adjusting the silica fume and steel fibre material addition techniques at the batch plant.

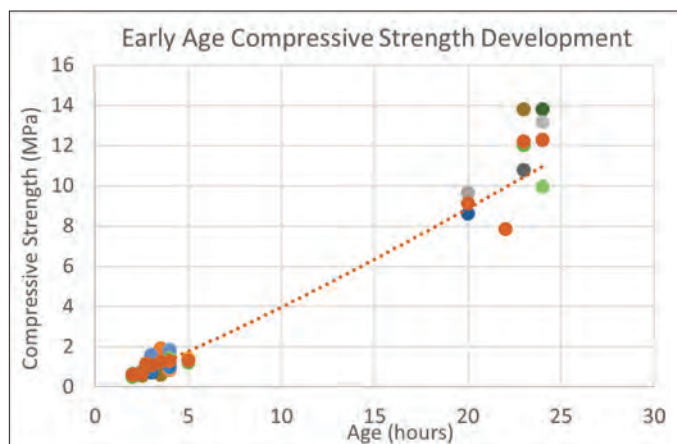


Fig. 10 Early Age Compressive Strength during construction.

Blockages in the lines sometimes occurred during pumping the shotcrete through the slick lines and rubber hoses into the work area. Regular maintenance of opening the slick lines and rubber hoses at the connections and checking the inside of the slick lines for any buildup of mortar was completed. Any buildup of mortar observed along the insides of the lines was removed prior to reconnecting the lines and clamping the lines shut. In addition, after each truck the nozzle assembly was disconnected, and the nozzle air ring was immersed in a bucket of cleaning vinegar as regular maintenance to ensure that air rings were clear of any shotcrete blockages. A new nozzle assembly was connected to the rubber hose for continued shooting.

Fall outs were occasionally observed when the nozzle-man attempted to shoot at thicknesses greater than the target maximum 100 mm (4 in) in a single layer. When fall outs occurred, the fall out area was prepared for re-application with shotcrete by using a compressed air blow pipe to remove any loosely bonded shotcrete or carefully scraping any loose shotcrete around the perimeter of the fallout area with a steel trowel. Shotcrete was required to achieve initial set before re-shooting in the fall-out area.

Entry into the draft tube was designated as a confined space and this required all personnel who entered the draft tube to follow USACE safety regulations for confined space entry. Lockouts and reporting on sign in/out documents were required to ensure that everyone inside the draft tube was accounted for.

QUALITY CONTROL During Construction

At the start of each day, initial and final set times were tested to confirm that the accelerator addition rate was correct for shotcrete overhead application. Beam molds were shot to test for early age compressive strength at 2, 4, 6, 8, and 24 hours. A square test panel was shot, from which cores were extracted to test for compressive strength at 7, 28 and 56 days, and boiled absorption and volume of permeable voids to ASTM C-642 at 28 days.



Fig. 11. Re-profiled draft tube

Early age compressive strength development

Fig. 10 shows the early age compressive strength development during construction. Shotcrete generally reached 0.5 MPa (72.5 psi) at 2 hours and 1.0 MPa (145 psi) around 3 hours, allowing the shotcrete to be applied in two layers per day. Shotcrete reached 8–14 MPa (1160–2030 psi) and above after 20 hours which proved that the shotcrete developed compressive strength properly. Early age compressive strength development for wet-mix shotcrete is dependent on the mixture design, accelerator dosage, and application procedure. Accelerator addition at the nozzle is key to early age compressive strength development up to 24 hours. Increasing the dosage of accelerator will increase the early age compressive strength up to 24 hours, but will reduce compressive strength at 7 and 28 days relative to a shotcrete with no accelerator addition at the nozzle. The dosage of accelerator needs to be strictly controlled to develop the required early and later age compressive strengths.^{2,3}

The contractor shot one production test panel for every 38 m³ (50 cu.yd.) of shotcrete placed, or once per day, whichever occurred more frequently. Cores were extracted from these test panels to determine:

- Compressive strength at 7, 28, and 56 days
- Boiled Absorption and Volume of Permeable Voids to ASTM C-642 at 28 days

The contractor performed bond pull-off testing to determine the shotcrete bond strength to the prepared concrete substrate. Bond strength testing was conducted after the shotcrete bonded to the original prepared concrete substrate had cured for a minimum of 7 days. Bond strength tests were also performed to measure bond between shotcrete layers.

Compressive Strength

Cores from the wet-mix shotcrete test panels reached an average of 47.9 MPa (6945 psi) for both Barrel C and Barrel

Table 1. QC Test Results for Compressive Strength, Boiled Absorption, and Volume of Permeable Voids of Shotcrete Cores

Process for Both Barrel C & A	Average 28 Days Compressive Strength	Boiled Absorption	Volume of Permeable Voids
Wet-Mix	47.9 MPa	7.8%	17.1%
Dry-Mix	48.5 MPa	5.8%	12.9%
Specified:	Min. 34.5 MPa	Max. 9.0%	Max. 18.0%

Table 2. Bond Pull-off Testing

Bond Strength (MPa)		
	Unit No. 3 Barrel A	Turbine Unit No. 3 Barrel C
Test No.	Age at 30 Days	Age at 180 Days
1	0.80	1.16
2	1.05	2.32
3	1.30	0.92
4	0.97	1.98
Mean	1.03	1.59
Std Dev	0.21	0.66
Specs	Min. 0.7	Min. 0.7
ACI 506	Min. 1.0	Min. 1.0

A. Cores from the dry-mix shotcrete test panels reached an average of 48.5 MPa (7030 psi) for both Barrel C and Barrel A. As shown in Table 1, the 28-day compressive strength test results well exceeded the specified minimum compressive strength requirement of 34.5 MPa (5000 psi) at 28 days.

Boiled Absorption and Volume of Permeable Voids

For wet-mix shotcrete applied in both Barrel C and Barrel A, the average boiled absorption tested at 28 days was 7.8 percent and the average volume of permeable voids tested at 28 days was 17.1 percent.

For dry-mix shotcrete applied in both Barrel C and Barrel A, the average boiled absorption tested at 28 days was 5.8 percent and the average volume of permeable voids tested at 28 days was 12.9 percent.

While the USACE specification did not have a requirement to test the shotcrete to ASTM C-642 for Boiled Absorption and Volume of Permeable Voids⁵, it has been found to be a very good test to evaluate the inherent durability of concrete and shotcrete.¹ ACI 506R-05⁶ states, “Typical Boiled Absorption values are 6-9 percent and volume of permeable voids values are 14-18 percent.” All the wet-mix shotcrete test results (with one exception) were within this range and test results for the non-accelerated dry-mix shotcrete were even lower, as shown in Table 1. Table 1 shows that dry-mix shotcrete, with lower values of BA and VPV, can be applied to produce durable shotcrete. This good performance is dependent on the nozzleman’s skills, including controlling water content, rebound, and overspray. Table 1 also shows higher BA and VPV results for wet-mix shotcrete. This is likely due to the fact that more accelerator was added to wet-mix shotcrete to improve the shootability (resistance to sloughing and fallout) and early age compressive strength development.

Bond Testing

Shotcrete bond strength to the prepared concrete substrate was tested in the laboratory (Fig. 12) after 30 days in Barrel A. Bond strengths tested ranged between 0.80 MPa (116 psi) to 1.30 MPa (189 psi) and averaged 1.03 MPa (149 psi) in Barrel A. Due to the pandemic situation, bond strength at Barrel C could not be conducted until 180 days later. Shotcrete bond strength to the prepared concrete substrate was tested in situ at 180 days in Barrel C. Bond strengths ranged between 0.92 MPa (134 psi) and 2.32 MPa (336 psi), and averaged 1.59 MPa (231 psi) in Barrel C.

As shown in Table 2, the bond strength test results exceeded the specified minimum shotcrete bond strength requirement of 0.7 MPa (100 psi).

Construction Schedule

Shotcrete construction at Unit No. 2 lasted about 3 months during 2017 due to it being a learning experience for both contractors and engineers. Shotcrete construction of Unit

#3 started on Feb 10, 2020, and was completed by March 17, 2021, when the 2020 COVID-19 pandemic started. This work benefited from the experience gained from construction of Unit No. 2 in 2017, and lasted 6 weeks, which was a great improvement in the construction schedule.

SUMMARY

Construction of Unit No. 2 (2017) and Unit No. 3 (2020) proved that a high quality, accelerated, wet-mix, steel fiber reinforced, silica fume shotcrete up to 1.8m (6 ft.) thick overhead can be applied successfully. Careful attention to the shotcrete mixture design, selection of the accelerator brand and addition rate and dosing system, and calibration of the accelerator addition rate were important aspects of a successful project; also important were prequalification of the shotcrete mix, equipment, nozzlelemen, and crew in full-scale preconstruction mock-ups and rigorous QA monitoring and QC testing during construction.


There were logistical, access, and scaffolding challenges in the full-scale work, but the shotcrete subcontractor successfully overcame these challenges and completed the reshaping of the draft tube to the satisfaction of the USACE. This is the second of three draft tubes to be reshaped on the Ice Harbour Lock and Dam and it is expected that the same products and processes will be used for reshaping the next draft tube. 



Fig. 12 Bond pull-off test at the laboratory

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- FRC Industries: Steel fibre supplier
- TCC Materials: Dry-mix shotcrete supplier
- Wood Environment & Infrastructure Solutions: Steel fibre reinforced accelerated wet-mix shotcrete mix design development, technical submittal reviews, inspection and monitoring of the shotcrete preconstruction mockups, and shotcrete application inside the draft tube
- LZhang Consulting and Testing: Shotcrete monitoring and testing, accelerator dosing pump calibration and shotcrete quality testing for the preconstruction mockups and for the draft tube application



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REFERENCES

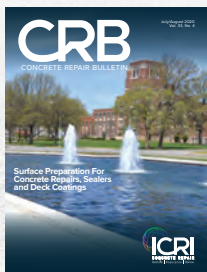
1. Zhang L., Morgan D.R., Mindess S., *Comparative Evaluation of the Transport Properties of Shotcrete Compared to Cast-In-Place Concrete*, ACI Materials Journal, May-June, 2016, pp. 373-384.
2. Radomski S., Morgan D.R., Zhang L., Graham D., *Structural Modifications to Hydroelectric Turbine Draft Tube Ceiling*, Shotcrete magazine, Summer 2019, pp 22-34
3. Lihe (John) Zhang, *Accelerator Dosing Pump Calibration and Verification*, Shotcrete Magazine, Summer 2012, pp 42-44.
4. ICRI 310.2R, *Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair*, International Concrete Repair Institute, St. Paul, MN, 2013.
5. ASTM C642 *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete* ASTM International, West Conshohocken, PA, 2017
6. ACI 506R-05 *Guide to Shotcrete* American Concrete Institute, Farmington Hills, MI, 2005.



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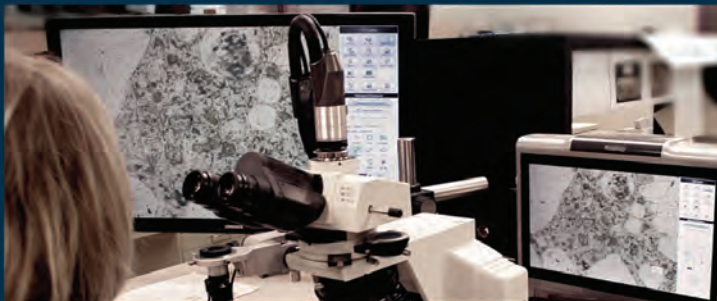
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Shotcrete for Repair—Not Your Father's Gunitite

by Charles Hanskat, American Shotcrete Association



Fig. 1: Original shotcrete dual-chamber gun



Fig. 2: Cement Gun Company "Bulletin"

Though many think shotcrete is a recent development, in fact it is a process well over 100 years old. And as with concrete construction, as well as repair materials and processes, we've seen a massive improvement in shotcrete materials, equipment, and placement techniques over the decades.

WHERE WE CAME FROM

A brief history. The initial shotcrete process was invented in 1907 by Carl E. Akeley, a well-known explorer and naturalist with the Field Museum of Natural History in Chicago. These were exciting times for the development of materials and equipment in the concrete industry. Akeley patented the shotcrete equipment in the United States in 1911 (Fig. 1). The first ready-mix concrete truck didn't appear until 1916 so the shotcrete process predates centrally-batched concrete.

Soon after Akeley patented the process, the Cement Gun Company saw the potential for the placement system and purchased the rights to produce the equipment and qualify contractors to use their cement guns for concrete placement. The company registered the tradename "Gunitite" in 1912 for any product shot out of their "Cement Gun" equipment (Fig. 2). The term "gunitite" is still used today in many venues, though the American Railway Engineering Association (AREA now AREMA) in the 1930s adopted

the generic, non-proprietary name "shotcrete." In 1951 the American Concrete Institute (ACI) published the standard *Recommended Practice for the Application of Mortar by Pneumatic Pressure* (ACI 805-51)¹ that also adopted the term "shotcrete" that we use today. ACI Committee 506 on Shotcrete was formed in 1960 and has continually developed and revised technical documents that have facilitated adoption of shotcrete placement for concrete in a wide variety of applications.

WHAT IS SHOTCRETE?

In the most basic terms, shotcrete is simply a placement method for concrete. ACI Concrete Terminology (CT-21)² defines shotcrete as "concrete placed by a high-velocity pneumatic projection from a nozzle." The definition has two key aspects that differentiate shotcrete from other concrete placement methods. First, "pneumatic projection" means that the flow of compressed air is used to convey concrete materials from the nozzle through the air to the receiving surface. Second, "high velocity" is key to shotcrete placement. Research shows that concrete is accelerated to between 60 to 80 mi/hr (100 to 130 km/hr) with current shotcrete equipment. This high velocity is required to compact and consolidate low-slump concrete in-place vertically or even overhead. Shotcrete is not the same as low-velocity sprayed mortar systems.

Shotcrete materials are concrete materials. We are simply placing concrete. Shotcreted concrete has the same fire resistance, cover requirements, and reinforcing designs as conventionally-placed concrete. However, the concrete mixture must be designed to allow conveying the concrete materials through relatively small diameter delivery lines, usually 1.5 to 2 in. (38 to 50 mm), over long distances (often hundreds of feet), and then having a consistency to allow placement without sagging in the vertical or overhead application. This usually limits our coarse aggregate sizes to ½ in (13 mm) or less. Concrete mixtures will typically be cementitious paste-rich to enhance pumpability. This also gives shotcrete a lower w/cm, with increased strength and improved durability as compared to concrete cast in form-and-pour applications.

There are two different shotcrete processes—dry-mix and wet-mix. Dry-mix pushes dry concrete materials from the gun through the delivery line with a high flow of compressed air and then adds water to the mixture at the nozzle (Fig. 3). Water mixes with the dry materials within the

nozzle, as the spray is conveyed from the nozzle through the air, and then at the receiving surface. In effect, dry-mix isn't making concrete until water is added at the nozzle. The nozzleman controls the water addition at the nozzle so they can continuously maintain the proper consistency of the concrete for consolidation and encapsulation of embedded reinforcing without sagging or dropouts. Thus, the dry-mix process creates concrete that is as fresh as possible and eliminates any issues with delays in delivery.

The dry-mix process can use site-batched dry concrete materials but increasingly uses sophisticated prebagged mixtures that can include almost anything that can routinely be used in concrete (Fig. 4). This includes but isn't limited to steel or synthetic fibers, air-entraining admixtures, supplementary cementitious materials (SCMs), accelerators, corrosion inhibitors, alternative binders, and rapid-set cements.

Wet-mix shotcrete placement takes premixed concrete with water already added; using a concrete pump, it

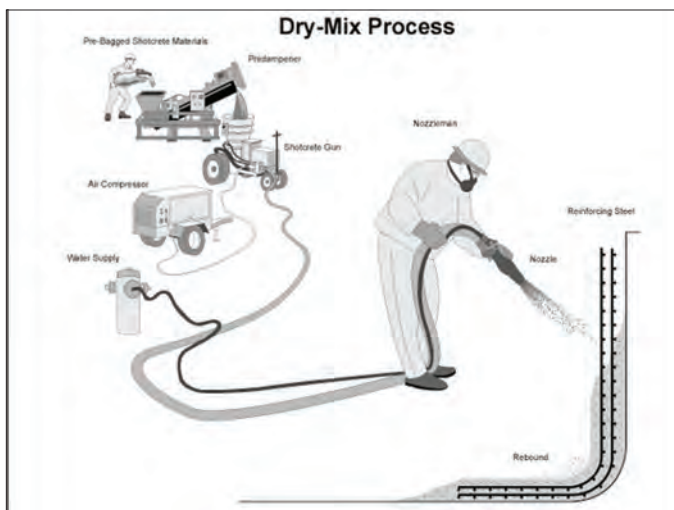


Fig. 3: Dry-mix shotcrete process



Fig. 4: Dry-mix equipment with supersack prebagged concrete materials

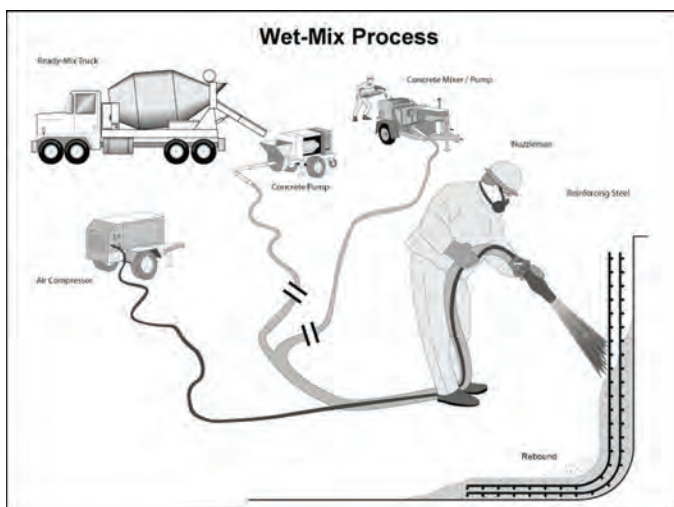


Fig. 5: Wet-mix shotcrete process



Fig. 6: Wet-mix equipment – small line concrete pump with ready-mix truck

pushes the flowable concrete through the delivery line to the nozzle (Fig. 5). Compressed air flow is added at the nozzle to accelerate the concrete mixture to the high velocity required for shotcrete placement. The large majority of wet-mix shotcrete contractors use small concrete pumps with positive displacement hydraulic cylinders and a swing tube for pushing concrete through the lines. Using premixed concrete, usually plant-batched and delivered in a ready-mix truck, allows close control of the concrete mixture design, and the ability to place more volume of concrete in a given time span (Fig. 6).

COMPARING DRY-MIX AND WET-MIX

Dry-mix was the predominant shotcrete process until the 1960s. Thus, the prevalence of the old tradename “gunite” that we still see today. You’ll often see real estate listings with gunite pools as a sales feature of a property. In the 1950s and 1960s, concrete pump designs got much more robust and, with increased reliability, could be expected to run throughout the construction day. Because the wet-mix delivery line is full of concrete the rule-of-thumb is that the wet-mix process can place four times the volume of concrete in a given time as compared to dry-mix. Thus, wet-mix has become the predominant shotcrete process today, especially in thick structural sections and ground support.

Though having a lower production rate, dry-mix does have significant benefits. Water is only added immediately before concrete placement. There are no issues with ready-mix trucks stuck in traffic or with long haul times that can mean the concrete may be delivered with less time allowable for placement and finishing. Dry-mix can start and stop immediately, being advantageous where placements are spread out across the project, as may often be the case with concrete repair jobs. Also, there isn’t a ready-mix truck full of concrete that needs to be placed within approximately 90 minutes from batching (if not using retarder or hydration control). In repair projects requiring thinner layers of concrete, dry-mix may allow more precise placements, and more time with fresh concrete to produce the desired finish.

A disadvantage of dry-mix is certainly the lower production rate when shooting thicker sections. A 2 to 3 ft (0.6 to 0.9 m) thick reinforced wall would certainly take much longer to place with dry-mix. Dry-mix also tends to have more rebound and dust as the water has just been added to the concrete materials in the nozzle. However, recent developments in equipment and materials have significantly reduced the potential for dust and rebound so that dry-mix may soon be equivalent to wet-mix.

A big advantage of wet-mix is certainly the higher production. Wet-mix nozzling, unlike dry-mix, doesn’t require the nozzleman to constantly adjust the water—so takes less nozzling expertise. Wet-mix also provides closer control of the concrete w/cm.

Disadvantages of wet-mix include potential issues with concrete delivery, especially in metropolitan areas that may have traffic issues that can cause unexpected delays. Wet-mix equipment including concrete pumps and delivery lines (pipe and hose) are more expensive than dry-mix shotcrete equipment. Also, wet-mix equipment produces much higher delivery line pressures that need more attention to safety issues when line plugs occur.

We are seeing several shotcrete contractors using volumetric batching rigs for producing concrete on the job site. These can be used for batching dry-mix materials or a fully mixed concrete for wet-mix. This eliminates the delivery issues with wet-mix and ready-mix trucks but may also limit the production rate. However, there is a distinct benefit of having fresh concrete made at the site to give maximum time to place and finish that may well offset the reduced production rate. This may be especially applicable for repair jobs that aren’t as thickly placed as in new construction.

SHOTCRETE FOR REPAIR

Shotcrete has been used for repair since its initial development. It was reported that the first practical use of the cement gun developed by Carl Akeley was the covering of the façade of the old Field Museum with a coat of gypsum stucco. The Cement Gun Company bulletins from the 1920s include numerous examples of gunite used to repair brick and concrete structures. A 1928 Cement-Gun Co. Bulletin related:

The positive adhesion is proven by numerous tests made under official supervision, but none more clearly shows it than one described in ENGINEERING NEWS RECORD of January 22, 1925, where a test made by the University of California to determine the adhesion of “Gunite” to concrete surfaces was described. In this test it was clearly brought out that the adhesion was much stronger than the shear value in the concrete itself, and could with safety be estimated at more than 600 pounds per sq. in. ultimate value.

Shotcrete placement inherently produces excellent bond to existing concrete or when placed in layers. Placement of shotcrete in bonding to an existing concrete surface or building out in layers has sometimes been equated to casting concrete with cold joints as experienced in cast-in-place concrete construction. ACI’s CT-21² defines a cold joint as:

cold joint—a joint or discontinuity resulting from a delay in placement of sufficient duration to preclude intermingling and bonding of the material, or where mortar or plaster rejoin or meet.

In form-and-pour concrete construction or repair, internal vibration is the most common method for providing adequate consolidation of the placed concrete. In form-

and-pour work, a cold joint is formed when an initial lift of concrete becomes too stiff for penetration by the vibrator used to consolidate a subsequent lift (Fig. 7). This is also the case of casting fresh concrete against an existing concrete substrate. This thus precludes the “intermingling” of material in the definition. However, ACI 309R-05 *Guide for Consolidation of Concrete*³ indicates that if bond is obtained between cast sections, a cold joint is avoided. ACI 309R-05 Section 7.2 states:

When the placement consists of several layers, concrete delivery should be scheduled so that each layer is placed while the preceding one is still plastic to avoid cold joints. If the underlying layer has stiffened just beyond the point where it can be penetrated by the vibrator, bond can still be obtained by thoroughly and systematically vibrating the new concrete into contact with the previously placed concrete; however, an unavoidable layer line will show on the surface when the form is removed.

Shotcrete does not use internal vibration for consolidation of the concrete. Instead, shotcrete provides thorough consolidation and densification by high velocity impact of fresh concrete material on the receiving surface. It is well proven in laboratory testing that properly placed shotcrete is very well consolidated and provides excellent strength and durability. The high velocity, 60 to 80 mi/hr (100 to 130 km/hr) impact of shotcrete on a hardened, previous shot layer or existing concrete surface provides a strong abrasive blast to open up the surface, and then provides an immediate exposure of that hardened surface to fresh cement paste. Also, the initial layer of shotcrete against a hard surface (like a concrete substrate) has more rebound of the coarse aggregate. This leaves a more paste-rich layer right at the interface between the substrate and the fresh concrete mixture (Fig. 8). As a result, shotcrete exhibits excellent bond to concrete and previously shot surfaces.

A study on shotcrete bond to concrete repair surfaces that included work on multi-layer shotcrete bond was conducted at Laval University (Beaupré 1999).⁴ The study looked at bond with multiple layers of shotcrete shot 4 hours, 1 day and 28 days apart with four levels of surface finishing (no surface finishing, scratched with steel trowel, scratched and finished with wood trowel, rough broom finish). Table 1 shows the results from Beaupré’s report. The report concluded that “it can be seen that, for the waiting period and

the types of finish studied, there is no significant influence of these parameters on bond strength” and “With respect to the multi-layer bond strength of shotcrete, the presence of shotcrete/shotcrete interfaces does not seem to create a large reduction in shotcrete quality in terms of mechanical bond if no curing compound is used.” Specified shotcrete bond strength for shotcrete to properly prepared



Fig. 7: Form-and-pour wall with cold joint



Fig. 8: Demonstration of thin paste-rich shotcrete layer at substrate

	Type of finish between layers (result with no curing compound)			
Time	None	Scratch	Scratch + Wood	Roughen w/Broom
4 hours	2.1 (300)	1.8 (206)	2.1 (300)	1.9 (275)
1 day	n/a	2.1 (300)	2.1 (300)	n/a
28 days	n/a	1.8 (260)	n/a	2.0 (290)

Table 1. Multi-layer bond strength in MPa (psi) (Beaupré 1999)

concrete substrates generally range from 100 to 150 psi (0.7 to 1.0 MPa).

As in all repair applications, in shotcrete construction surface preparation of the substrate or between layers to provide full bond is important. ACI 506.2-13 *Specification for Shotcrete*⁵ specifically addresses this in the requirements of Sections 3.4.2.1 and 3.4.2.2 that:

3.4.2.1 When applying more than one layer of shotcrete, use a cutting rod, brush with a stiff bristle, or other suitable equipment to remove all loose material, overspray, laitance, or other material that may compromise the bond of the subsequent layer of shotcrete. Conduct removal immediately after shotcrete reaches initial set.

3.4.2.2 Allow shotcrete to stiffen sufficiently before applying subsequent layers. If shotcrete has hardened, clean the surface of all loose material, laitance, overspray, or other material that may compromise the bond of subsequent layers. Bring the surface to a saturated surface-dry condition at the time of application of the next layer of shotcrete.

When shooting onto existing concrete sections the surface must be properly prepared and then shotcreted with proper shotcrete materials, equipment, and placement techniques. This will produce a construction joint that acts monolithically and not be a “cold” joint. Shotcrete placed onto an existing concrete surface will provide an excellent bond **if** the following conditions are met:

- Make sure the surface is roughened and clean. The amplitude of the roughness is recommended to be +/- 1/8th in. (3 mm) or more.
- A high-pressure water blaster (5000 psi [34 MPa] or more) or abrasive blasting can help to roughen and clean the surface.
- Bring the concrete surface to saturated surface dry (SSD) condition. This means the surface feels damp, but water is not picked up on a hand.
- Make sure the shotcrete placement is properly executed with high velocity placement and quality materials.
- The shotcrete should have a minimum 28-day compressive strength of 4000 psi (28 MPa).
- Be sure the shotcrete contractor is using an air compressor able to produce at least 250 ft³/min (7 m³/min) for wet-mix and 385 ft³/min (11 m³/min) for dry-mix (gunite) of air flow at 120 psi (0.83 MPa).
- Use of an ACI-certified shotcrete nozzleman is recommended.
- No bonding agent should be used. It will interfere with the natural bonding characteristics of shotcrete placement.
- A minimum thickness of no less than ½ in. is recommended.

Thus, shotcrete placed against an existing substrate or in layers does not produce a “cold joint” as defined by ACI, because it produces excellent bond between the layers. This has been confirmed by visual inspection of numerous cores taken through multiple layers of shotcrete where it is often impossible to identify where one layer stops and the other starts, unlike cold joints in form-and-pour work where the difference between lifts is readily apparent.

CURRENT SHOTCRETE REFERENCES

As previously mentioned, ACI Committee 506 specifically develops and maintains documents on shotcrete. Current ACI 506 documents include:

- ACI PRC-506.1-21: *Fiber-Reinforced Shotcrete - Guide*
- ACI PRC-506.4-19: *Guide for the Evaluation of Shotcrete*
- ACI PRC-506.5-09: *Guide for Specifying Underground Shotcrete*
- ACI PRC-506.6-17: *TechNote: Visual Shotcrete Core Quality Evaluation Technote*
- ACI PRC-506-16 *Guide to Shotcrete*
- ACI SPEC-506.2-13 *Specification for Shotcrete* (Reapproved 2018)


ACI PRC-506-16 *Guide to Shotcrete* is a non-mandatory document that is a great primer for those interested in learning more about shotcrete. ACI SPEC-301 *Specifications for Concrete Construction* and ACI SPEC-563 *Specification for Repair of Concrete in Buildings* both reference ACI SPEC-506.2 for inclusion of shotcrete. ACI CODE-318-19 also directly includes shotcrete as a placement method for structural concrete.

Two ICRI Committees also directly address shotcrete in their documents. These include:

- 320.1R-2019—*Guideline for Selecting Application Methods for the Repair of Concrete Surfaces*
- 320.2R-2018—*Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces*
- 320.5R-2013—*Pictorial Atlas of Concrete Repair Equipment*
- 110.1-2016—*Guide Specifications for Structural Concrete Repair*

SUMMARY

Shotcrete has been used in concrete construction for well over a century. Over the decades, we have refined materials, improved equipment, and quantified proper placement techniques. These improvements have led to shotcrete being used to place high quality, durable concrete in a wide variety of concrete applications. Concrete repair has always been a significant market for shotcrete. Quality shotcrete placement requires an experienced contractor who has the correct and well-maintained shotcrete equip-

ment, can select the proper concrete mixtures, uses experienced ACI-certified nozzlemen, provides proper surface preparation and commits to full curing and protection of the shotcreted concrete sections. Done correctly, shotcreted repair sections will provide many decades of low-maintenance performance in extending the life of all types of concrete structures. 

REFERENCES

1. ACI 805-51 *Standard Recommended Practice for the Application of Mortar by Pneumatic Pressure*, American Concrete Repair Institute, Farmington Hills, MI, 1951
2. ACI CT-21 *Concrete Terminology*, American Concrete Institute, Farmington Hills, MI, 2020
3. ACI 309R-05 *Guide for Consolidation of Concrete*, American Concrete Institute, Farmington Hills, MI, 2005
4. Beaupré, Denis, Bond Strength of Shotcrete Repair, *Shotcrete Magazine*, May 1999, American Shotcrete Association
5. ACI SPEC-506.2-13 *Specification for Shotcrete*, American Concrete Institute, Farmington Hills, MI, 2018



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CONCRETE REPAIR CALENDAR

JULY 20-21, 2022

ICRI Concrete Slab Moisture Testing
Sacramento, CA
Website: www.icri.org

AUGUST 2, 2022

ICRI Webinar
*Understanding Traffic-Bearing
Waterproof Membranes*
Website: www.icri.org

AUGUST 3-4, 2022

ICRI Concrete Slab Moisture Testing
Chicago, IL Area
Website: www.icri.org

AUGUST 18, 2022

ICRI Concrete Surface Repair Technician
Live Performance Exam
Raleigh, NC
Website: www.icri.org

AUGUST 22-23, 2022

ICRI Concrete Slab Moisture Testing
Denver, CO
Website: www.icri.org

AUGUST 24, 2022

ICRI Concrete Surface Repair Technician
Live Performance Exam
Denver, CO
Website: www.icri.org

OCTOBER 23-27, 2022

ACI Concrete Convention
Dallas, TX
Website: www.concrete.org

OCTOBER 25-26, 2022

ICRI Concrete Slab Moisture Testing
Dallas/Ft. Worth, TX Area
Website: www.icri.org

NOVEMBER 7-9, 2022

2022 ICRI Fall Convention
Atlanta, GA
Website: www.icri.org

DECEMBER 7, 2022

ICRI Concrete Surface Repair Technician
Live Performance Exam
Dallas, TX
Website: www.icri.org

JANUARY 16-19, 2023

World of Concrete
Las Vegas, NV
Website: www.worldofconcrete.com

JANUARY 31—FEBRUARY 2, 2023

The International Surfaces Event
Las Vegas, NV
Website: www.intlsurfaceevent.com

INTERESTED IN SEEING YOUR CONCRETE INDUSTRY EVENT OR NEWS LISTED HERE?

Events and News can be emailed to editor@icri.org. Content for the September/October 2022 issue is due by August 1, 2022, and content for the November/December 2022 issue is due by October 1, 2022.



INDUSTRY NEWS

COBOD MAKES INTERNATIONAL IMPACT WITH CONCRETE 3D PRINTER

GE Renewable Energy announces minority investment in COBOD International

GE Renewable Energy has announced a minority investment in COBOD International, the company providing the 3D printer used at the Bergen research facility. Officials from both companies said the investment will build on an existing relationship with COBOD International, a leading player in 3D construction printing solutions, first undertaken in 2019. COBOD is experiencing double digit growth and the global market leader within 3D construction printing with more than 50 3D construction printers sold world-wide.

3DCP Group, COBOD's Danish customer, 3D printed a 37 m² tiny house, first of its kind in Europe

- DCP Group, COBOD's Danish customer, 3D printed a 37 m² tiny house, first of its kind in Europe. The house is a masterpiece in terms of creating a fully livable house on as few square meters as possible.
- To drive down cost the walls, roof and the foundation were 3D printed using low-cost real concrete (not mortar)—

with an innovative new method for making the roof.

- Renowned and visionary Danish architects Saga Space Architects designed the building.

COBOD International signs on Fortex as new distributor to bring state-of-the-art 3D construction printing technology to Australia

- COBOD announces distribution agreement with Australian company Fortex (Melbourne) to bring world class 3D multifunctional construction robots to Australia.
- With Australian company Fortex as a distributor, COBOD now have customers across six continents.
- COBOD is further strengthening its focus on Asia-Pacific by now opening a new office in Kuala Lumpur, Malaysia, which will serve customers in the region.

Largest 3D printed building in Africa paves the way for affordable housing

- Power2Build finished their second and largest 3D printed building yet in Angola with the BOD2 construction printer.

- 140 m² house printed 4.5 times faster than the first 3D printed building Power2Build made.
- D.fab concrete solution from COBOD International and CEMEX enabling cost-saving up to 90% - first shown in Angola, now spread all over the world.
- COBOD completely dominates the 3D construction printing market in Africa with the six 3D printed buildings, all done with COBOD technology.

COBOD partners with nidus3D for distribution of 3D printing technology in Canada

- COBOD announces distribution agreement with nidus3D (Ontario, Canada) to bring multifunctional construction robots based on 3D printing to Canada.
- nidus3D recently built Canada's first 3D printed multi-unit residential building, fully permitted for occupancy, and North America's first 3D construction project to use real concrete.

For more information on these news items visit www.cobod.com.

ASSOCIATIONNEWS

CENTER OF EXCELLENCE FOR CARBON NEUTRAL CONCRETE ANNOUNCES EXECUTIVE DIRECTOR

NEU: An ACI Center of Excellence for Carbon Neutral Concrete has hired Dr. Andrea Schokker as Executive Director. Dr. Schokker will lead all NEU activities along with recruiting partners willing to assist in mitigating the concrete industry's carbon footprint.



Dr. Schokker was previously Professor and Head of Civil Engineering at the University of Minnesota Duluth, where she also served as Provost and Dean. Alongside actively chairing several code committees of the American Concrete Institute (ACI), she was the founding chair of ACI Committee 130, Sustainability of Concrete; is a LEED AP; and registered Professional Engineer in the state of Minnesota. Dr. Schokker received the ACI Joe W. Kelly Award for "invaluable service in promoting green concrete and developing sustainability into one of the areas of greater interest within ACI" in 2012. She received her PhD in Structural Engineering from the University of Texas at Austin.

For more information visit www.neuconcrete.org.

AMERICAN CONCRETE INSTITUTE OPENS NEW MIDWEST RESOURCE CENTER IN ILLINOIS

The American Concrete Institute (ACI) has opened a second Resource Center, located in the Chicago Metropolitan Area, to serve Midwest communities in the concrete industry. This new ACI Resource Center – Chicago/Midwest, will help meet the increased demand for ACI knowledge through hands-on training, educational offerings, and on-demand access to ACI Certification Programs.

ACI's Resource Centers offer a diverse array of custom training programs designed to communicate required skills and demonstrate test methods in order to achieve certification. In addition to custom training programs, the new Chicago/Midwest Resource Center offers education programs on popular industry topics such as design, fundamentals, repair, slabs, and more.

For more information visit concrete.org/midwestresourcecenter.

ACI FOUNDATION ANNOUNCES NEW FELLOWSHIP HONORING JOANNE K. AND CECIL L. JONES

The ACI Foundation has established the JoAnne K. and Cecil L. Jones Carolinas Fellowship through generous funding by the ACI Carolinas Chapter. The ACI Carolinas Chapter created both fellowships to use chapter resources to support the young men and women who will enter and shape the future of the concrete industry, and to engage more students in ACI and industry activities by establishing more student chapters in the Carolinas. The chapter named the new fellowship in honor of JoAnne and Cecil because of their tremendous dedication to the concrete community and the Carolinas Chapter of ACI.

The new Fellowship will be awarded annually to students who are either undergraduate, Master's, or PhD students in construction, design, education, or materials programs during the year of the award.

To learn more visit ACIFoundation.org

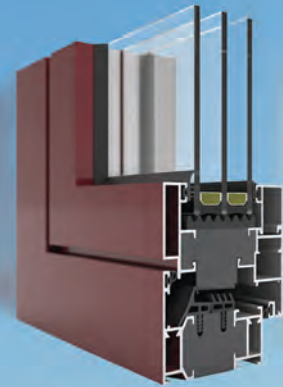
FICEM AND ACI EXPAND PARTNERSHIP WITH JOINT EFFORT

The Federacion Interamericana Del Cemento (FICEM) and the American Concrete Institute (ACI) recently completed an addendum to their International Partner Agreement which calls for a joint effort to achieve carbon neutrality in the concrete/cement sector.

The efforts of FICEM and ACI will be propelled through NEU: An ACI Center of Excellence for Carbon Neutral Concrete (NEU), whose mission is to provide access to technologies and the knowledge needed to effectively and safely produce and place carbon neutral concrete in the built environment. The expanded agreement will encourage cooperation in areas of joint events, industry partnerships, research, technology acceleration, technical committees, and other related activities.

In 2019, FICEM and ACI completed an International Partner Agreement to exchange the technical expertise of each organization through publications, meet-

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ings, conferences, internet links, committee membership, certification activities, and other activities.

To learn more about FICEM and ACI, visit ficem.org and concrete.org, respectively.

ACI FOUNDATION FUNDS 10 NEW RESEARCH PROJECTS

The ACI Foundation's Concrete Research Council (CRC) selected 10 research projects to receive grants this year. The ACI Foundation seeks concrete research projects that further the knowledge and sustainability of concrete materials, construction, and structures.

- *Alternative Supplementary Cementitious Materials from Local Agricultural Products*—Ohio State University
- *Damage Classification of Reinforced Concrete Structures for Fire: Rebar Temperature*—University at Buffalo
- *Development of a Phase Change Material-Based Heat-Absorbing Surface Covering for Concrete Pavements/Bridge Decks*—Texas State University
- *Evaluation of Early-Strength Development in Tension-Driven High Strength Concrete Formulations*—Illinois Institute of Technology and University of Illinois at Urbana-Champaign
- *Fatigue Behavior of FRP Bars Embedded in Concrete*—Western Reserve University
- *How Much Consolidation Energy is Really Required to Create Concrete Specimens?*—Missouri University of Science and Technology and University of Florida
- *Maximum Reinforcing Ratio for Reinforced UHPC Beams: Towards Slender Elements*—University of California, Berkeley
- *Multiscale Reinforcement of Hybrid Steel Fiber Reinforced Concrete*—Texas State University and Texas A&M University
- *Reliable Measurement and Specification of Sulfur in Concrete Aggregates*—RJ Lee Group
- *Shear Behavior of Ultra-High Performance Concrete (UHPC) Considering Axial Load Effects*—University of Houston

For more information visit ACIFoundation.org/research.

CENTER OF EXCELLENCE FOR CARBON NEUTRAL CONCRETE ANNOUNCES FULL TIME EXECUTIVE DIRECTOR



NEU: An ACI Center of Excellence for Carbon Neutral Concrete—a uniquely positioned center providing access to technologies and the knowledge needed to effectively and safely produce and place carbon neutral concrete in the built environment—has seen rapid growth in membership which has led to an expansion of the staff needed to serve NEU's mission. With this increase, the board of directors has determined the need for a full-time executive director and has hired Drew Burns, CAE to serve as the Executive Director of NEU.

Dr. Andrea Schokker, the founding Executive Director, has provided invaluable expertise in setting up NEU, developing its activities and recruiting partners. She will continue to work with NEU, focusing on the technical aspects of activities, as the Senior Technical Consultant and Board Advisor.

As this new endeavor expands NEU's reach, both Burns and Dr. Schokker will be working together with the board to meet membership needs and set strategic goals for the organization. To learn more, visit www.neuconcrete.org.

ACI FOUNDATION ESTABLISHES MEMORIAL SCHOLARSHIP TO HONOR BERNARD ERLIN

A generous donor made it possible for the ACI Foundation to establish the Bernard Erlin Memorial Scholarship in memory of ACI Honorary Member Bernard Erlin. The scholarship was established to honor Erlin's many contributions to the concrete industry and ACI.



Erflies with him.

Erlin served on many ACI committees and, in 2018, he was recognized as a 50-year member of ACI. During the ACI 2012 Fall Concrete Convention, Erlin gave the Katharine and Bryant Mather Lecture, in which he talked about Bryant's interest in lepidopterology and told a story about collecting moths and butterflies with him.

Erlin organized, chaired, or co-chaired many ACI sessions, and authored or co-authored over 120 papers dealing with petrographic examinations and other aspects of construction materials. He was a co-editor of several books that are compilations of papers from ACI and ASTM International sessions.

The Bernard Erlin Memorial Scholarship will provide tuition assistance to deserving students studying in a concrete materials-related degree program. For more information visit www.acifoundation.org

REGISTRATION OPEN FOR ACI FOUNDATION'S 2022 TECHNOLOGY FORUM

The ACI Foundation's Concrete Innovation Council (CIC) will host its next Technology Forum on August 30–September 1, 2022, in St. Paul, MN. This is the first in-person forum in two years and will include four technology showcases, over ten different presentations, and a debate.

Technology Showcases:

- *Carbon Dioxide Utilization and Machine Learning Deliver Low-Carbon Concrete*—Gaurav N. Sant
- *Concrete Sensors for Curing*—Jim Cairns and Kevin A. MacDonald
- *Novel Method for Producing Cement & SCMs*—Cody Finke
- *Ultra-High Performance Concrete and its Carbon Footprint*—Peter W. Weber

Presentations:

- *3D-Printed Topology Optimized UHPC Walls with Superior Ductility*—Siham S. Al Shanti
- *A Contractor's Experience with the Evolution of Sustainable Mix Designs*—Eric S. Peterson
- *Early Concrete Performance Extremes*—Tim Cost
- *Integration of Alternative Cements into Building Codes*—Lawrence L. Sutter
- *Legal Issues in Concrete Construction: Responsibility with New Technology*—Jeffery W. Coleman

ASSOCIATION NEWS

- *Structural Polymer Concrete for Accelerated Bridge Construction and Other Infrastructure Applications*—Mahmoud Reda Taha
- *The New FRP Bar Code*—Carol K. Shield
- *The Minnesota DOT Test Road “MNRoad”*—Bernard I. Izevbekhai
- *Understanding the “What, Why and How” when Specifying Permeability-Reducing Admixtures*—Shashiprakash (Prakash) Surali

A debate titled, Alternatives to Cylinder Breaks for Acceptance Testing, will be moderated by Rex A. Donahey. Participants will discuss if the industry could/should develop more rapid and reliable acceptance criteria based, for example, on multivariate analyses of fresh concrete properties and data from non-destructive tests and sensors.

For information visit acifoundation.org/technology.

INTERESTED IN SEEING YOUR NEWS IN THIS COLUMN?

Email your 150-200 word association news to editor@icri.org. Content for the September/October 2022 issue is due by August 1, 2022, and content for the November/December 2022 issue is due by October 1, 2022. ICRI reserves the right to edit all submissions..

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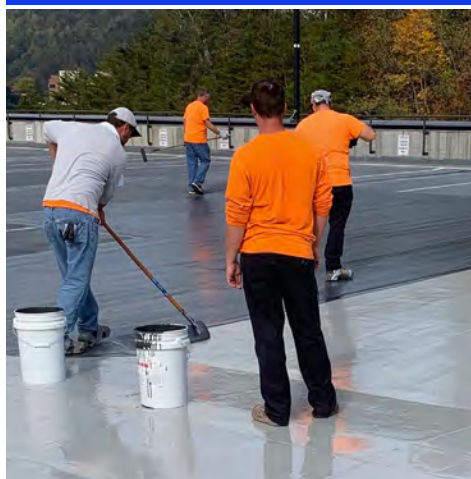
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ICRI CHAPTER NEWS

CHAPTER CALENDAR

ICRI Chapters are starting to host events again in 2022. Be sure to check with individual chapters by visiting their chapter pages to determine if they have made any plans after this publication was published.

CHICAGO

September 22, 2022
CHAPTER DINNER MEETING
Westwood Tavern
Schaumburg, IL

CINCINNATI

July 20, 2022
CHAPTER SUMMER SOCIAL
TopGolf West Chester
West Chester, OH

September 21, 2022
CHAPTER GOLF OUTING
Winton Woods, Mill Creek Course
Forest Park, OH

DELAWARE VALLEY

September 16, 2022
ANNUAL CORNHOLE TOURNAMENT
Location: TBD

GREAT PLAINS

July 14, 2022
ANNUAL SUMMER SHOOT
Power Creek Shooting Park
Lenexa, KS

GULF SOUTH

July 20, 2022
JOINT MEETING WITH AMPP
AGC Building
Irondale, AL

INDIANA

July 14, 2022
CHAPTER TECHNICAL MEETING
Topic: Parking Garage Repairs
Tavern on South
Indianapolis, IN

September 8, 2022
GOLF OUTING
Plumb Creek Golf Club
Carmel, IN

FLORIDA WEST COAST

August 3, 2022
MEETING ON FLORIDA BUILDING SAFETY
ACT
Red Mesa Cantina
St. Petersburg, FL

MINNESOTA

July 19, 2022
CHAPTER GOLF OUTING
Bunker Hills Golf Club
Minneapolis, MN

NEW ENGLAND

September 14, 2022
CHAPTER GOLF OUTING
Shaker Hills Country Club
Harvard, MA

NORTHERN OHIO

July 2022
CHAPTER BREAKFAST MEETING
Crown Plaza Cleveland South
Independence, OH

September 2022
CHAPTER GOLF OUTING
Bunker Hill Golf Course
Medina, OH

OKLAHOMA

August 23, 2022
CHAPTER MEETING
Topic: Post Tension Repairs
Cynergy Offices
Tulsa, OK

ROCKY MOUNTAIN

August 15, 2022
ANNUAL CHAPTER GOLF TOURNAMENT
The Club at Pradera
Douglas County, CO

VIRGINIA

September 15, 2022
FALL SYMPOSIUM
Colonial Heritage
Williamsburg, VA

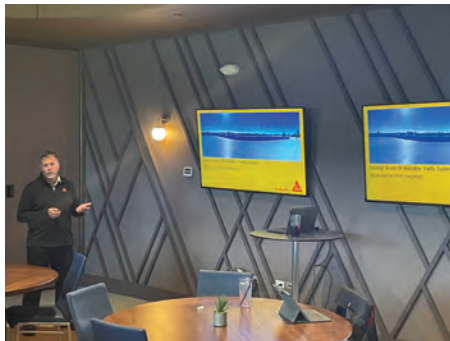
ICRI CHAPTER NEWS

CHAPTER ACTIVITIES

NORTHERN OHIO MEETS AT TOPGOLF



The ICRI Northern Ohio Chapter hosted their first meeting of 2022 at TopGolf in Cleveland



Local member Mike Childress gave a presentation at the May 18, 2022, meeting on "Making Sense of Available Traffic Systems"



Gathering with friends and colleagues, plus learning something new; all with decent view



Join your local chapter! Visit www.icri.org

CHAPTER ACTIVITIES

NORTH TEXAS CHAPTER HOSTS 8TH ANNUAL CLAY SHOOT

On the balmy Friday morning of May 13, 2022, the North Texas Chapter hosted their eighth annual Sporting Clay Classic. This year, the event was held at a new venue—Elm Fork Shooting Sports in Dallas, Texas. The 18 teams that competed enjoyed the new venue and the new challenge of Shotgun Golf—a “closest to the pin” competition where a golf ball is propelled by the shooters’ gunshots! The event was a great success for the chapter and raised more than \$3,000 for their scholarship funds. The chapter thanks all of their sponsors, participants, and volunteers for another great clay shoot.

The 1st place team from Master Construction & Engineering included Don Weempe P.E., RW Smith, George O’Reilly, and Lucas Eddy. In 2nd place was the team from Master Builders Solutions that included Patrick Jorski, Glen Turner,

Jeremy Birdwell, and Jeff Lungrin. Finally, 3rd place was awarded to Team Farris—Royce Farris, Ray Dickerson, BW Briscoe, and Andy Malis. Top individual shooter awards went to George O’Reilly—1st place, Scott Grissom—2nd, and a tie for 3rd between Don Weempe and Jeff Lungrin. The Shotgun Golf Winner for this tournament was Andrew Malis.



1st place team from Master Construction & Engineering (from left to right): Lucas Eddy, Don Weempe, George O’Reilly, and RW Smith



A great day for shootin’ at Elm Fork



Great weather in Texas at Elm Fork Shooting Sports for the 8th Annual clay shoot

BALTIMORE-WASHINGTON HOSTS CFRP RESEARCH PROGRAM

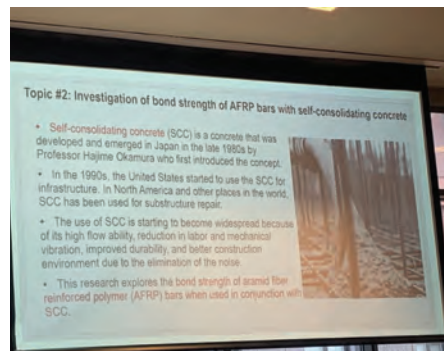
Members of the ICRI Baltimore-Washington Chapter convened for their 2022 second quarter dinner meeting on Thursday, May 12. The meeting was hosted at Pinstripes in Bethesda, Maryland. The night’s events included drinks, dinner, and bowling. A very special thanks to Joe Wilcher, with Walker Consultants, and the Facilities Committee for organizing the event at one of the premier establishments at the new Pike and Rose development in Bethesda.

During dinner, a technical presentation was provided by Dr. Mehdi Shokouhian, assistant professor at Morgan State University in Baltimore, MD. Dr. Shokouhian is an active member of the American Society of Civil Engineers and has been at Morgan State since 2015. His research is focused on performance-based design and stability of structures made of high performance materials. Dr. Shokouhian presented

his ongoing research of one such high performance material, reviewing his practical experiments of structural strengthening applications of carbon-fiber reinforced polymers (CFRP). CFRP is very useful in the field of concrete repair, in particular for strengthening applications associated with change-of-use of existing structures. The seminar was very informative about the CFRP applications being studied by Dr. Shokouhian and was well-received by those in attendance.



Dr. Shokouhian presenting his research at a recent Baltimore-Washington Chapter meeting



Overview of previous strengthening research outlined by Dr. Shokouhian



Dinner attendees discussing the presentation

CHAPTER ACTIVITIES

OKLAHOMA CHAPTER GETS BACK TO IN-PERSON MEETINGS →

The ICRI Oklahoma Chapter stepped back into meetings with a small gathering on April 29. A group of seven dedicated professionals met to hear local presenter Rob Cordova with Master Builders Solutions give a presentation on "The Importance of Concrete Curing."



FLORIDA WEST COAST HOSTS DEMO DAY

On April 1, 2022, the Florida West Coast Chapter held its annual Demo Day with an excellent turnout. Even with some rain early in the day, the sun came out and everyone enjoyed a beautiful day. Attendees showed a great deal of interest and participated with all the demonstrations. They provided some great feedback and overall thankfulness for a great event and a great way to gather again as a chapter. The event brought in almost 70 attendees.

Those providing demonstrations to the crowd included: MAPEI showcasing its vertical and overhead repair mortar; 3M with its safety equipment demo; Accessa with Ransburg Equipment offering a hands-on application of electrostatic coating on aluminum; Master Builders Solutions

offered attendees a demo on sealant fundamentals and field testing; Milwaukee Tools brought new tools and accessories to demonstrate; and Sika Corporation provided a demonstration on membrane penetration detailing and balcony membrane applications.

The chapter brought in morning doughnuts and coffee then lunch from M-N-M BBQ. This year's demo was hosted at Tom White Painting and Restoration in St. Petersburg, Florida. Booths where attendees could view the latest and greatest innovations in materials and services included: MAPEI, Master Builders Solutions, Milwaukee Tools, Coastal Construction, Beacon, P&R, Accessa/Ransburg, Sherwin Williams, Graco, Pectora, Florida Paints, and General Caulking.



More than 60 members and guests gathered for the Florida West Coast Demo Day in April



Along with the guests came 7 live demonstrations and more than a dozen booths



One of the demonstrations showed electrostatic coatings for aluminum



Once the sun came out, guests got some shade and were able to wander the tent area where they could network with local vendors

SOUTH CENTRAL TEXAS MEETS IN AUSTIN

The South Central Texas Chapter hosted their first and long awaited in-person event since 2020. The social event started with an informative presentation at the Terracon office in Austin, Texas. 2022 Chapter President Allison Lea introduced the chapter board members, committee chairs, and upcoming event schedule. The 2022 Chapter Vice President (and 2022 ICRI's 40under40) Kandace Thompson shared her key takeaways from attending the ICRI Spring Convention in Baltimore, encouraging members to actively participate in their local chapter, to attend the Fall Convention in Atlanta, and join a technical committee. Featured speaker Natalie Faber, President of the ICRI Rocky Mountain Chapter and founder of 3C (Careers in Concrete Construction), hosted an overview and Q&A session on the 3C program. This session kicks off one of the South Central Texas Chapter's 2022 priorities—piloting the 3C program in their area. After the presentation, everyone headed just a few steps away to a brewery where they enjoyed food truck tacos and local brews. Everyone had a grand time reconnecting, catching up, and networking. Thank you to all who attended; we look forward to seeing you at our next educational event on July 21, 2022.



Friends of the South Central Texas Chapter gather for their first in-person meeting in 2022



Guest speaker Natalie Faber prepares to dive deep into her Careers in Concrete Construction program that she is spearheading in Colorado and across the country

CHAPTER ACTIVITIES

FLORIDA WEST COAST GATHERS FOR COMMUNITY PROJECT

The ICRI Florida West Coast Chapter participated in a community volunteer project in April 2022. A special thanks goes out to local chapter member Tom White for his assistance as guys from his company prepared and primed the building the day before this volunteer event. The group lead by Tom White also painted the second floor portions prior to the arrival of the chapter volunteers in order to allow those volunteers to finish the work on the lower portions by the end of the day. The chapter volunteers gathered at the non-profit St. Petersburg City Theatre.

The chapter welcomed 30 or so volunteers throughout the day.

St. Petersburg City Theatre, located at 4025 31st Street S. in Saint Petersburg, Florida is the oldest operating theater in the area, turning 100 in 2025. In 1925 it was originally named The Players Club until changed to The Saint Petersburg City Theatre in 2011. The theatre was also originally located in downtown Saint Petersburg until 1957 when it was moved to its current location. This theatre has seen quite a bit of history as it was founded during the Roaring Twenties, hosted troops stationed in Florida during WWII, and

entertained during Prohibition. It continues to this day with new youth programs encouraging the arts on a local level.

A lunch of Jersey Mike's subs was provided by the chapter and the theatre provided dessert from a local bakery! Paint for the project was donated by Florida Paints. This was an excellent demonstration of community coming together to assist with a need. the Chapter wished to whole-heartedly thank all those who were able to show true generosity in making this event a success!



Before photos



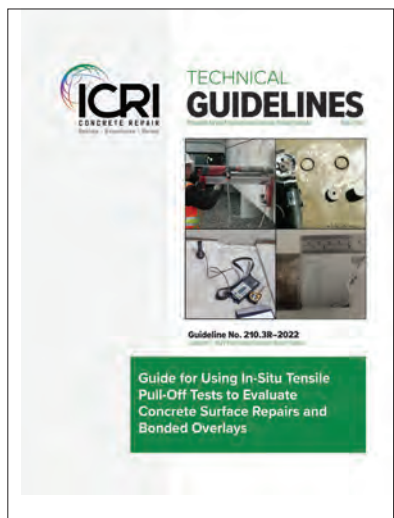
During the work to paint and revitalize the outside of the theatre before a performance scheduled that same evening!



After the volunteers finished their work



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Guide for Using In-Situ Tensile Pull-Off Tests to Evaluate Concrete Surface Repairs and Bonded Overlays

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ICRI CHAPTER NEWS

CHAPTER ACTIVITIES

NORTH TEXAS HOSTS A FEW APRIL IN-PERSON GATHERINGS

The North Texas Chapter was pleased to host its first in-person membership meeting since the beginning of the COVID-19 pandemic on Thursday, April 21, 2022! North Texas Chapter members and guests joined together at Las Colinas Corporate Center in Irving for great networking and a technical presentation over a spread of BBQ provided by Baker's Ribs. The technical presentation provided by Robert Hendricks, PhD, of Terracon dove into the details of Light Detection and Ranging (LiDAR) technology. Dr. Hendricks' wealth of knowledge and expertise provided the group with a comprehensive understanding of LiDAR technology and its many capabilities and applications. Dr. Hendricks covered applications of LiDAR as it pertains to concrete repair, nondestructive evaluation, and even threw in a few mentions of geophysics!

LiDAR is a versatile remote sensing method that can be used to generate millions of 3D data points in a quick, single scan, replacing many of the manual methods of investigation we all use today. LiDAR can even be used in conjunction with other emerging technologies, such as drones, photogrammetry, and ground penetrating radar (GPR)! Thank you, Robert, for showing the North Texas Chapter where LiDAR fits into the work that we all do!

Next, members and guests of the North Texas Chapter gathered for a social happy hour at Longhorn Icehouse on Northwest Highway in Irving on April 28, 2022. Longhorn provided great food, plenty of cold beverages, and a great atmosphere. The chapter would like to thank all who attended.



The North Texas Chapter hosted Dr. Robert Hendricks to discuss LiDAR at the April Membership meeting



The NTX Chapter enjoyed cold drinks at Longhorn Icehouse during a Chapter Happy Hour



ICRI has 39 chapters, including two student chapters, in metropolitan areas around the world. Chapters hold technical presentations, educational meetings, symposia, and local conventions on repair-related topics.

Chapters also provide an outstanding opportunity to meet and build relationships with repair specialists in your area. In addition to the technical meetings, chapters also host golf outings, social evenings, dinner cruises, and other networking events.

CHAPTERS COMMITTEE CHAIR'S LETTER



MICHELLE NOBEL
Chapters Chair

Well, summer is in full force! The beaches, roads, and restaurants are booming in Florida. It's nice to see things getting back to normal. In the observant words of Ernest Hemingway, *"Night is always darker before the dawn and life is the same, the hard times will pass, everything will get better and sun will shine brighter than ever."*

If you missed the convention in Baltimore, you missed a good one! The ICRI Baltimore-Washington Chapter pulled out all the stops and delivered a fantastic ICRI Spring Convention. Unfortunately, my flight got delayed due to weather and I missed Monday sessions and events. I did make the Sagamore Whiskey Spirit Event. It was incredible! Fabulous food, friendly and knowledgeable tour staff, and an outstanding band! The Baltimore-Washington Chapter also paid to extend the fun and live music for an extra hour. We didn't get off the dance floor! The 2022 ICRI Spring Convention Technical sessions are available on the ICRI.org website in the archive section. So, if you missed it, you still have a chance to see them.

We recently had an ICRI Virtual Chapter Roundtable on June 2, 2022. We had several polls to determine what everyone from around the country and Canada has been experiencing since COVID. There was a common theme among everyone—things have improved. ICRI Staff will be dissecting the information and continue to help find ways to support the chapters as much as possible. We hope to have an in-person Chapter Roundtable in the New England area in the Fall. Details about this event are coming soon, so keep an eye out for email updates.

We also learned that Mexico and Panama want to be a part of ICRI. Chris Lippmann headed up the ICRI International Membership Committee that has worked with people in these countries that want to start a chapter in their country. Chris has also spoken with people from Australia who want to have an ICRI chapter in Australia. ICRI is trying to expand its footprint around the world.

I know I keep saying this, but The Women in ICRI Committee is looking for like-minded women to join its distinguished group of talented women. We'd love you to join this group of women working in the concrete repair industry. We highlight the accomplishments of women from all around the world. If you would like to join this group, please reach out to Tara Toren-Rudisill at TToren-rudisill@ThorntonTomasetti.com, Monica Rourke at MRourke@mapei.com, or me at mnobel@mapei.com.

Have you looked at the Certification and Education tab on the ICRI.org website lately? It has information about the CSMT/CSRT programs, webinars, and the ICRI Learning Center. Did you know that your chapter can receive rebates? Host an event at your chapter and you'll receive rebates if the participant identifies the chapter as the promotional source. These programs have been taking off!

In the rebate program, chapters receive a 15% rebate of the paid member/nonmember registration fees for all participants who register for the CSMT/CSRT programs solely due to the chapter's marketing and promotion. For the chapter to receive the rebate, the participant (during registration) must indicate that they heard

about the CSMT/CSRT program from the chapter as the promotional source and then identify the specific chapter name in the appropriate drop-down menu. The rebates apply to all ICRI CSMT/CSRT program courses and categories that the chapter promotes and gets registrants to identify the chapter as the promotional source (excludes registration fees for CSMT classes where registration is handled by others, like World of Concrete, TISE-Surfaces, and partner events). If a private partner program includes open registration and the chapter is asked to promote to fill the class, the chapter does receive the rebate if the participant identifies the chapter as the promotional source. So, host a CSMT/CRST event and receive rebates for your chapter! It's educational and a fundraiser at the same time! Take advantage of this program for your chapter!

Dates to mark on your calendar are:

- 2022 ACI Concrete Convention—October 23-27, Dallas, Texas
- 2022 ICRI Fall Convention—November 7-9, Baltimore, Maryland
- 2023 World of Concrete—January 16-19, Las Vegas, Nevada
- 2023 The International Surfaces Event—Jan 31-Feb 2, Las Vegas, Nevada
- 2023 ACI Concrete Convention—April 2-6, San Francisco, California
- 2023 ICRI Spring Convention—April 17-19, Vancouver, British Columbia

I have to say thank you to everyone that has sent information to Dale Regnier. I write these articles and look at the ICRI.org website for upcoming events. It's full of events from local ICRI Chapters!! It's a great resource if you're traveling and you want to see what's happening in the area you're visiting. So, please send your events to Dale Regnier at daler@ewald.com so he can post them on the ICRI website and in the *Concrete Repair Bulletin*. Check out the ICRI calendar to find out more! Some of my best friends belong to this great organization!

Here's a link to the calendar on the ICRI website for more information: https://www.icri.org/events/event_list.asp

The Executive Committee, Region and At-Large Directors, local leaders at your ICRI chapters, and ICRI staff are here for you. Don't hesitate to reach out!

Travel safe, be kind, and I will see you in Atlanta or sooner!

Sincerely,

Michelle Nobel
2022 ICRI Chapters Committee Chair
MAPEI Corporation

INTERESTED IN SEEING YOUR CHAPTER NEWS & EVENTS LISTED HERE?

Chapter News & Event Deadlines

SEPTEMBER/OCTOBER 2022
Deadline: July 10, 2022

NOVEMBER/DECEMBER 2022
Deadline: September 10, 2022

Send Chapter News and Event dates by the deadlines above to
Program Manager Dale Regnier at daler@icri.org.

PRODUCT INNOVATION

INTRODUCING AMP-UPTM RB - A NEW GENERATION OF REBAR COATING

AMP-UP™ RB is a single component, self-healing, hybrid epoxy coating designed and optimized to protect reinforcing & structural steel before, during, and after application of concrete. AMP-UPTM RB offers contractors increased ease of application, scheduling flexibility, and drastically extended repair open times.



Coating rebar for corrosion protection is common practice in the concrete repair & restoration process. Many products require mixing & measuring of multiple components and give contractors a narrow window to apply the repair mortar after the rebar has been coated.

AMP-UPTM RB offers contractors & engineers the best of both worlds: higher performing corrosion protection & easier application. AMP-UPTM RB is one component, low VOC rebar coating that gives contractors the flexibility to extend open times on repairs. Using its patented self-healing technology, AMP-UPTM RB responds to any physical damage during the repair open time without the need for manual intervention or touchups. AMP-UPTM RB makes coating & protecting rebar simple for everyone involved, it's an easy choice.

For more info visit www.noco.tech/product/amp-up-rb.html

GENERAL EQUIPMENT COMPANY'S M-SERIES SURFACE GRINDER LINE DESIGNED FOR MAGNETACH® TOOLING SYSTEM

General Equipment Company's new M-Series surface grinders, which feature a convenient, versatile magnetic tooling system, are designed for use by both contractors and homeowners alike. These low-speed surface grinders are compatible with a wide range of industry-standard magnetic type attachments, including those in General's MAGNETACH® Tooling System or attachments utilizing the Lavina®/EDCO® magnetic mount tooling.

The M-Series line includes five different single- and dual-head grinders and offer

the same reliable performance and extreme durability of General's long-established line of Legacy Series grinders, but use magnetic retention for quickly and easily switching attachments, instead of the traditional wedge system.



For more information visit www.generalequip.com.

SURFACE APPLIED TACTILE REDIMAT™ MESHES ADDED STRENGTH & DURABILITY

Detectable Warning Systems (DWS) developed the original RediMat™ in 1994 as the forebearer of their complete line of ADA compliant tactile warning products for visually impaired pedestrians. Now a part of the proprietary product family of Mar-Bal, Inc. (Mar-Bal: Chagrin Falls, OH), DWS has advanced the innovative, flexible RediMat's to include mesh reinforcement for added strength and increased durability. This 'next-level' addition of adding engineered mesh strengthens its advanced properties ensuring a secure installation with longer-term durability.



Constructed of extremely durable, UV protected, mesh reinforced polyurethane material, the flexible RediMat is surface applied on a variety of surfaces (including both asphalt and concrete) and features a proprietary, pre-applied, peel-and-stick technology adhesive system.

For more information visit www.detectable-warning.com

MCCANN INDUSTRIES NOW CARRIES KOBELCO EXCAVATORS

McCann Industries, Inc. now represents the full line of Kobelco excavators. In addition to offering their specialty, compact, mid size, and large machines, McCann will also add them to their rental fleet and

provide Kobelco parts and service. They will represent the product line in Cook, DuPage, Ford, Grundy, Iroquois, Kane, Kankakee, Kendall, Lake, Livingston, McHenry, and Will counties in Illinois.

Kobelco builds an excavator for nearly any job that contractors, earthmoving, or construction crews will face in Northern Illinois. Their mini and short rear swing excavators are compact with light footprints, perfect for urban or residential projects. Kobelco conventional excavators cover the requirements of the largest digging, grading, and demolition jobs, with a large variety of attachment options, and they feature 360° sightlines. Plus, they have specialty long reach models and excavators designed specifically for building demolition.

For more information visit www.McCannOnline.com.

HOW TO AVOID MUD CRACKING WHEN APPLYING ANTICORROSION COATINGS

The solution for preventing mud cracking is extremely simple: follow the manufacturer's recommendations for coating thickness. The coating manufacturer already knows how the coating will behave and usually provides both a wet film thickness (WFT) and a dry film thickness (DFT) recommendation on the product data sheet. To avoid mud cracking, the coating applicator simply needs to apply the recommended WFT, measuring coating thickness with a WFT gauge to make sure it is correct.

If only the DFT is listed, the painter can figure out the proper WFT based on the recommended DFT and the percent volume of solids. This percentage tells how much of the coating will remain after the volatiles have evaporated. For example, an approximately 50% volume solids coating such as VpCI®-395 will lose about half of its WFT by the time it dries. To get 3 mils (75 µm) DFT, the coating will need to be applied at 6 mils (150 µm) WFT. A coating such as EcoShield® VpCI®-386 with a 31% volume of solids will lose a little more than two-thirds of WFT by the time it dries, meaning 9.6 mils (240 µm) WFT are needed to achieve 3 mils (75 µm) DFT.

For more information visit <https://www.cortecoatings.com/contact-us-2/>

PRODUCT INNOVATION

CORTEC® LAUNCHES NEW IMPROVED MCI®-2039 HORIZONTAL CONCRETE REPAIR MORTAR!

Because concrete repairs are time and labor intensive, it is important to do them in a way that will extend structural service life as much as possible. Cortec's new, improved line of MCI® repair mortars is designed to help contractors reach that goal, starting with the release of MCI®-2039 High Performance Horizontal Repair Mortar.

MCI®-2039 is a single-component, fast-setting, high-strength, cement-based repair mortar enhanced with Migrating Corrosion Inhibitors (MCI®). These inhibitors form a molecular protective layer on the surfaces of rebar, increasing the quality and extending the service life of the repair and surrounding structure. Once

applied and hardened, MCI®-2039 provides a high level of adhesion and durability, as well as resistance to water and carbonation attack. High early strength allows for fast repairs and quick return of traffic. MCI®-2039 can be applied indoors or outdoors in a wide temperature range, from 20 to 100 °F (-6 to 38 °C). The mortar can be extended up to 60% by weight for repairs greater than 2" (51 mm) deep. Minimize the Ring-Anode/Halo Effect

MCI®-2039 can minimize the counterproductive ring-anode/halo effect as Migrating Corrosion Inhibitors in the repair mortar travel to adjacent concrete to even out the corrosion potential and help the repair last longer.

By following MCI® HPRS® guidelines, concrete contractors can maximize the

durability of the patch and thus delay time to the next repair, substituting MCI®-2039 for standard repair mortar to enhance protection wherever a horizontal concrete repair is needed.

To learn more visit <https://www.cortecmci.com/product/mci-2039/>

INTERESTED IN SEEING YOUR NEW PRODUCT IN THIS COLUMN?

Email your 150-200 word news to editor@icri.org. Content for the September/October 2022 issue is due by August 1, 2022, and content for the November/December 2022 issue is due by October 1, 2022. One (1) high resolution product photo may be included. ICRI reserves the right to edit all submissions.

NEW MEMBERS

COMPANY MEMBERS

Alen Construction Group, Inc

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United States
Enrique Larrazabal

Armor Shield Concrete Coatings

Gifford, Illinois
United States
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Capital Restoration & Waterproofing

Raleigh, North Carolina
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ICON Floor Prep

Loveland, Colorado
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New York, New York
United States
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Performance Sealants and Waterproofing, LLC

Montgomery, Alabama
United States
Brian Ward

Tremco Canada

Saint Jerome, Quebec
Canada
Patrick Le-Pain

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Naples, Florida
United States

Paula Espinosa

Watson Bowman Acme
Amherst, New York
United States

Adam Pankonien

ARDEX Americas, Inc.
Rowlett, Texas
United States

ADDITIONAL INDIVIDUALS FROM COMPANY MEMBERS

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Sealy, Texas
United States

Suzanne Aultman

Metromont Corporation
Greenville, South Carolina
United States

John Bronco

ICON Floor Prep
Loveland, Colorado
United States

Derek Gilbert

Simpson Strong-Tie Company, Inc.
Columbus, Ohio
United States

Tom Johnson

Complete Property Services, LLC
Tampa, Florida
United States

Scott Kaiser

Sherwin Williams
Keizer, Oregon
United States

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Chicago, Illinois
United States

NEW MEMBERS

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Mexico

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Mexico

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Williamsburg, Virginia
United States

Matthew Namy

San Francisco, California
United States

Robert Nittinger

New Castle, Pennsylvania
United States

Sarvesh Patil

Trevose, Pennsylvania
United States

INDEX OF ADVERTISERS

American Engineering	29
Aquajet	29
Azon	37
Coastal One Construction Products	11
Euclid Chemical Company	10
Evonik Corporation	Inside Front Cover
Gary Carlson Equipment	10
Lymtal International, Inc.	39
MAPEI	Inside Back Cover
Miracote	3
National Waterproofing Supply	39
Quikrete	9
Sika Corporation	Back Cover
Simpson Strong-Tie	5



INTERNATIONAL CONCRETE REPAIR INSTITUTE

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