RECLAMATION
Managing Water in the West

TiO_2 Cement for Green Construction

Research and Development Office
Science and Technology Program
Final Report 2014-01-7846
Technical Memorandum MERL-2014-84

Jessica Torrey

Research and Development Office
Bureau of Reclamation
U.S. Department of the Interior

September 2014

Mission Statements

The U.S. Department of the Interior protects America’s natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

REPORT DOCUMENTATION PAGE						*Form Approved* *OMB No. 0704-0188*
T1. REPORT DATE MONTH YEAR		**T2. REPORT TYPE** Research				**T3. DATES COVERED** 10/13-09/14
T4. TITLE AND SUBTITLE TiO_2 Cement for Green Construction						**5a. CONTRACT NUMBER** 14XR0680A1-RY1541EN201427846
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER 1541 (S&T)
6. AUTHOR(S) Jessica Torrey, 303-445-2376, jtorrey@usbr.gov						**5d. PROJECT NUMBER** 7846
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER 86-68180
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Jessica Torrey, U. S. Bureau of Reclamation, Denver, CO						**8. PERFORMING ORGANIZATION REPORT NUMBER** TM-MERL-2014-84
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Research and Development Office U.S. Department of the Interior, Bureau of Reclamation, PO Box 25007, Denver CO 80225-0007						**10. SPONSOR/MONITOR'S ACRONYM(S)** R&D: Research and Development Office BOR/USBR: Bureau of Reclamation DOI: Department of the Interior
						11. SPONSOR/MONITOR'S REPORT NUMBER(S) 2014-01-7846
12. DISTRIBUTION / AVAILABILITY STATEMENT Final report can be downloaded from Reclamation's website: https://www.usbr.gov/research/						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT *(Maximum 200 words)* Two titanium dioxide nanoparticle-based "green" cement products were tested. The i.active coating and TX Active cement products were exposed to cyclic weathering and freeze-thaw conditions. Testing and analysis is ongoing. In addition to the research performed at USBR, two collaborations were established with Colorado Precast Concrete and the U.S. Army Corps of Engineers Environmental Laboratory. Work for FY15 includes refinement of the initial experiments, field testing, and nanoparticle release testing in conjunction with our research partners.						
15. SUBJECT TERMS titanium dioxide, green materials, concrete, coating						
16. SECURITY CLASSIFICATION OF: U			**17. LIMITATION OF ABSTRACT**		**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Jessica Torrey
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	**U**		10	**19b. TELEPHONE NUMBER** 303-445-2376

S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

PEER REVIEW DOCUMENTATION

Project and Document Information

Project Name: TiO_2 Cement for Green Construction WOID: X7846

Document: MERL-2014-84

Document Author(s): Jessica Torrey Document date: 9/2014

Peer Reviewer: John Bret Robertson

Review Certification

Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer Bret Robertson Date reviewed 9/29/14
(Signature)

Executive Summary

In 2008, the DOI issued the Department of the Interior Sustainable Buildings Implementation Plan (SBIP). Reclamation has committed to the vision of the SBIP "to reduce the negative economic, social, and environmental impacts of its buildings through sustainable planning, acquisition, siting, design, construction, operation, maintenance, leasing, and decommissioning." Additionally, the 2011 U.S. Green Building Initiative challenged new construction to be designed with more energy and resource efficiency. Goals were to reduce greenhouse gases and contribute to a healthier environment for the community through better building practices.

This research represented a unique opportunity for Reclamation to collaborate on the evaluation of two TiO_2 nanoparticle-based photocatalytic green cement products: i.active coating and TX Active cement. The Italian manufacturer of these products, Italcementi Group, has cited several instances where buildings in both the United States and, primarily, Europe have used this product as part of a green building plan for LEED certification. It has been shown in the literature to purify air from pollutants such as volatile organic compounds (VOCs), particulate matter (PM10), nitrogen oxides (NOx), and sulfur oxides (SOx). Studies in pollutant abatement have been reported by the manufacturer and others and cite 45-91% abatement of NO_x and 20-80% abatement of PM10, depending on test conditions. In addition, it is marketed as a self-cleaning product that helps to reduce maintenance costs and improve cosmetic appearance of structures. Reclamation is often asked to provide architectural concrete to meet the aesthetic needs of new and existing building projects. This product may be able to satisfy those needs with an additional benefit of improving air quality in the vicinity of the structure. It could be used broadly across all Reclamation regions to comply with the SBIP guiding principles. However, while the TX Active cement product has been employed in several locations in the eastern USA, there is little data available on the i.active coating and how it may perform in the wet-dry, freeze-thaw conditions that Reclamation routinely services.

In FY14, collaboration was cemented with Colorado Precast Concrete (CPC), based in Loveland, CO. They are contracted to install this product on concrete pillar caps at Denver International Airport. CPC has invited USBR to participate in the testing of the product at DIA, and provided the i.active and TX Active cement raw materials for testing in the MERL laboratories.

FY14 experiments focused in two key areas: ability of the product to resist nanoparticle leaching under various environmental exposure conditions and mechanical durability of the product under freeze-thaw conditions. Laboratory weathering tests are currently underway, with the experimental set-up exposing panels to cyclic "rain" and light/dark conditions (Figure 1). Panels measuring 8 x 8 x 1 inch were made with three compositions: ordinary Portland cement (OPC) concrete control samples, OPC concrete panels with an i.active coating applied with a stucco sprayer and troweling, and concrete panels using the TX Active cement product (Figure 2). Samples were cured for a minimum of 28 days under 100% relative humidity before being placed in the weathering chambers. Three chambers were designed and built to apply “rain” in six-hour cycles and either dark, visible light, or UV-light exposure on 12-hour cycles continuously for six

weeks. Samples are being collected bi-weekly for testing of nanoparticle release. Collaboration was established with the US Army Corp of Engineers Environmental Laboratory for analysis of the nanoparticle release. They have chosen TiO_2 as a target material to develop recommendations for testing and toxicity studies and are interested in using the TiO_2-cement products as a case study. Samples of water taken after six weeks of weathering of the iActive coating panels have been sent to USACE-EL for analysis.

Freeze-thaw exposure tests, according to ASTM C 666, were conducted on control OPC concrete, i.active coated-OPC concrete, and TX Active concrete bars. The bars measured 3 x 3 x 16 inches, and were made with and without the addition of entrained air. Samples were tested in the freeze thaw machine, which applies freeze-thaw conditions in 3 hour cycles for 300 cycles or until specimen failure, whichever occurs first. The i.active coating showed very poor durability under freeze-thaw conditions (Figure 3). However, it is hypothesized that the sample geometry and test conditions were extremely harsh for coated samples; this set-up is typically used for testing solid concrete blocks. For FY15, we have proposed a new experimental set-up using a temperature- and humidity-controlled chamber that accommodates the panel geometry more conducive to testing cementitious coatings. This set-up would still follow ASTM standard practice, yet it should yield more accurate results for freeze-thaw exposures of cementitious coatings.

In addition for FY15, due to delays in installation at DIA and limited access for monitoring, we have proposed the installation of several test panels on the Denver Federal Center. A request has been made to GSA building managers to install i.active-coated cement board panels on a south-facing wall on the roof of Building 56. We would also install an air quality and solar insolation monitoring station. This would allow easy access to a long-term monitoring site with real-world environmental exposure. The weathering box testing will be finalized, and the remaining samples will be sent to the USACE-EL lab for testing. We will continue to work with the research staff there to analyze the results of the nanoparticle release tests and develop a plan for additional work or final recommendations.

Figure 1.Weathering test experiments running TX Active concrete samples. From L to R: no light, visible light exposure, ultraviolet light exposure.

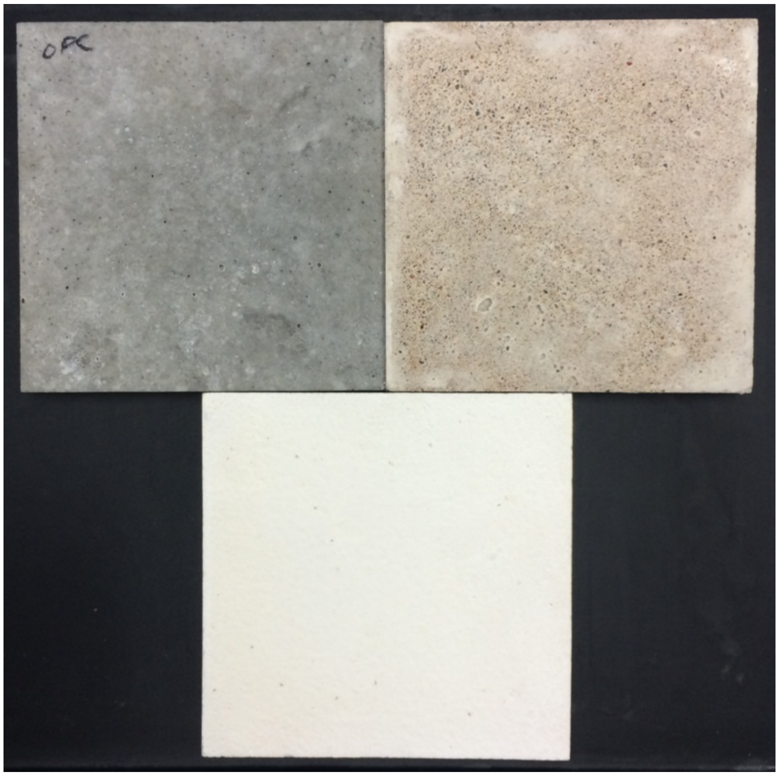

Figure 2. 8x8 inch sample panels for weathering test: OPC control concrete (top left), TX Active concrete (top right), and i.active COAT applied to OPC concrete (bottom)

Figure 3. i.active-COAT on an OPC concrete sample after freeze-thaw testing. Note the cracking, delamination, and spalling of the coating.

Point of Contact: Jessica Torrey, Materials Engineer, USBR-TSC-MERL, jtorrey@usbr.gov, 303-445-2376

Keywords: titanium dioxide, green materials, concrete, coating

Approximate total size of all files: 1776 KB