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12th ACI/RILEM International
Conference on Cementitious
Materials and Alternative
Binders for Sustainable Concrete

SP-362

Editor:
Arezki Tagnit-Hamou



American Concrete Institute
Always advancing

12th ACI/RILEM International Conference
on Cementitious Materials and Alternative
Binders for Sustainable Concrete
(ICCM2024)

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Editor:
Arezki Tagnit-Hamou



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PREFACE

In July of 1983, the Canada Centre for Mineral and Energy Technology of Natural Resources Canada (CANMET), in association with the American Concrete Institute (ACI) and the U.S. Army Corps of Engineers, sponsored a 5-day international conference in Montebello, Quebec, Canada, on the use of fly ash, silica fume, slag, and other mineral by-products in concrete. The conference brought together representatives from industry, academia, and government agencies to present the latest information on these materials and to explore new areas of needed research. Since then, eight other such conferences have been held around the world (Madrid, Trondheim, Istanbul, Milwaukee, Bangkok, Madras, Las Vegas, and Warsaw). The 2007 Warsaw Conference was the last in this series.

In 2017, due to the renewed interest in alternative and sustainable binders and supplementary cementitious materials, a new series was launched by Sherbrooke University (Professor Arezki Tagnit-Hamou), American Concrete Institute (ACI), and the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM)—in association with a number of other organizations in Canada, the United States, and the Caribbean—sponsored the 10th ACI/RILEM International Conference on Cementitious Materials and Alternative Binders for Sustainable Concrete (ICCM2017). The conference was held October 2-4, 2017, in Montréal, Canada. The conference proceedings, containing 50 reviewed papers from more than 33 countries, were published as ACI SP-320.

In 2021, UdeS, ACI, and RILEM, in association with Université de Toulouse and a number of other organizations in Canada, the United States, and Europe, sponsored the 11th ACI/RILEM International Conference on Cementitious Materials and Alternative Binders for Sustainable Concrete (ICCM2021). The conference was scheduled to take place in Toulouse, but due to COVID, it was held online June 7-10, 2021. The conference proceedings, containing 53 reviewed papers from more than 21 countries, were published as ACI SP-349.

In 2024, the conference was finally held in-person in Toulouse from June 23 to 26, 2024, with the support of UdeS, ACI, and RILEM in association with Université de Toulouse (Martin Cyr) and a number of other organizations in Canada, the United States, and Europe. The purpose of this international conference was to present the latest scientific and technical information in the field of supplementary cementitious materials and novel binders for use in concrete. The new aspect of this conference is to highlight advances in the field of alternative and sustainable binders and supplementary cementitious materials for the transition to low carbon concrete. The conference proceedings, containing 78 reviewed papers from more than 25 countries, have been published as ACI SP-362.

Thanks are extended to the members of the International Scientific Committee who reviewed the papers. The cooperation of the authors in accepting the reviewers' suggestions and revising their manuscripts accordingly is greatly appreciated. The involvement of the steering committee and the organizing committee is gratefully acknowledged. Special thanks go to Chantal Brien (Université de Sherbrooke) for the administrative work associated with the conference and for processing the manuscripts for both the ACI proceedings and the supplementary volume.

Arezki Tagnit Hamou, Editor
Chairman, 12th ACI/RILEM International Conference on Cementitious Materials and
Alternative Binders for Sustainable Concrete (ICCM2024).
Sherbrooke, Canada, 2024

TABLE OF CONTENTS

SP-362—1

Interface Properties Between Reactive Magnesia Cement Matrix
and GFRP Rebar..... 1-17
Authors: Bo Wu and Jishen Qiu

SP-362—2

The Influence of TiO₂ Nanoparticles on the Smart Properties
of Alkali-Activated Materials..... 18-37
Authors: Denny Coffetti, Elena Crotti, Simone Rapelli, and Luigi Coppola

SP-362—3

Experimental Study on a Low-Carbon Pervious Concrete Based on
Alkali-Activated Binder and Recycled Aggregates..... 38-48
Authors: Denny Coffetti, Simone Rapelli, and Luigi Coppola

SP-362—4

Multiscale Mechanical Investigation of Ternary Binders Incorporating
Calcined Clay and Slag 49-63
Authors: Imane Bekrine, Benoît Hilloulin, and Ahmed Loukili

SP-362—5

Effect of Supplementary Cementitious Materials (SCMS) on the Structural Build-Up
of Cement Pastes..... 64-80
Authors: Youssef El Bitouri and Eric Garcia-Diaz

SP-362—6

Structural Geopolymer Mortars with Maximum Amounts of Construction
and Demolition Wastes 81-96
Authors: Gultekin Ozan Ucal, Hocine Siad, Mohamed Lachemi, Obaid Mahmoodi,
and Mustafa Sahmaran

SP-362—7

It's Not Rocket Science – Multiple SCM Blends Give High Durability AND
Low Carbon 97-107
Author: Robert Lewis

SP-362—8

Rheology of Stabilized Earth-Based Paste..... 108-126
Authors: Mojtaba Kohandelnia and Ammar Yahia

SP-362—9

Improving Sulfate Resistance in Alkali-Activated Self-Compacted Concrete:
Utilizing Precursor Combinations and Dry-Powder Activators as a Novel Approach
for Enhanced Durability 127-146
Author: Dima Kanaan

SP-362—10

Workability of Low-Clinker Mortars with Recycled Fine Aggregates
and Different Polymers as Superplasticizer 147-163
Authors: Mareike Thiedeitz, Noah Tarrab Maslaton, and Thomas Kränkel

SP-362—11

Mechanical Performance and Microstructural Investigation of Binary
and Ternary Lime Binders with Silica Fume and Metakaolin 164-178
Authors: Luca Penazzato, Rogiros Illampas, Ioannis Rigopoulos, Ioannis Ioannou,
and Daniel V. Oliveira

SP-362—12	
Control of Physical Deterioration of Foamed Geopolymers Exposed to High Temperature.....	179-188
Author: Zhuguo Li	
SP-362—13	
Replacement of Natural Sand with Manufactured Sand While Maintaining Packing Density.....	189-201
Authors: Barbara Aboagye, Ryan Gosselin, and William Wilson	
SP-362—14	
Formulation of Self-Compacting Concrete with Limestone Tuff and Study of the Parameters Influence on the Responses.....	202-214
Authors: Boulkhiout M., Benna Y., Bali A., Benyoussef E.H., and Silhadi K.	
SP-362—15	
Evaluation of the AC Conductivity and the Percolation State in Cementitious Materials Based on Alumina Slag.....	215-239
Authors: José Luis Ochoa M., Stephani Voelger S., and Adrián R., Arias P.	
SP-362—16	
Influence of the Polymer Structure on the Rheology of Portland Cement and LC ³ Pastes Containing Superplasticizers.....	240-248
Authors: Torben Gädt and Simon Nickl	
SP-362—17	
Machine Learning Models for Predicting Rheological Properties of Self-Consolidating Concrete (SCC).....	249-267
Authors: Abdelhamid Hafidi, Ilhame Harbouz, Benoit Hilloulin, Ahmed Loukili, and Ammar Yahia	
SP-362—18	
Effects of Si/Al Molar Ratio on the Structure and Properties of Metakaolin-Based Alkali Activated Binders.....	268-282
Authors: Jessica Lohmann and Frank Schmidt-Döhl	
SP-362—19	
Hydration Mechanism of MgO-Nesquehonite Blends.....	283-291
Authors: Paula Montserrat-Torres, Barbara Lothenbach, and Frank Winnefeld	
SP-362—20	
Effect of Milling on the Reactivity of Mixed Recycled Aggregate Powder as an SCM.....	292-301
Authors: Jingwen Liu, Pieter Rauwoens, and Özlem Cizer	
SP-362—21	
Linking Water Demand and Surface Area of Calcined Palygorskite.....	302-312
Authors: Valentin Roux, William Wilson, Dimitri Deneele, Michael Paris, and Arezki Tagnit-Hamou	
SP-362—22	
Rheological Evaluation of High Filler – Low Water Ternary Slag Cement Concrete with Low Binder Intensity.....	313-320
Authors: Matthew Cruickshank, Erisa Myrtja, Roberta Alfani, Laurent Frouin, and Mohend Chaouche	

SP-362—23

Investigating the Potential of Limestone and Calcined Clay as a Substitute for Fly Ash in Strain-Hardening Cementitious Composites (SHCC)..... 321-330
Authors: Ameer Hamza Ahmed, Marco Liebscher, Cesare Signorini, and Viktor Mechtcherine

SP-362—24

Performance of Calcium Nitrate as Accelerator for Cement Blended with Blast Furnace Slag..... 331-343
Authors: Harald Justnes, Tobias Danner, Elise Marie Rong Anfinson, Aleksandra Marie Høye, Margrethe Munch-Ellingsen, and Mehrdad Torabzadegan

SP-362—25

Feasibility of Using Natural Pozzolan-Limestone-Based Cement Composite for 3D Printing..... 344-357
Authors: Haodao Li, Alfred Addai-Nimoh, and Kamal H. Khayat

SP-362—26

Solid Phase Analysis of Hydrated MgO/Nesquehonite Pastes with Silica or Metakaolin Addition..... 358-365
Authors: Zeyu Zhou, Ellina Bernard, and Barbara Lothenbach

SP-362—27

Remediated Thermal-Treated Soil and Tar-Containing Asphalt as Secondary Filler and Sand in Self-Compacting Concrete..... 366-375
Authors: Shizhe Zhang, Jeroen Lenderink, Marc Brito van Zijl, Vincent Twigt, and Rob Bleijerveld

SP-362—28

Early Age Shrinkage, Hydration Kinetics and Workability of Mortars Containing Metakaolin and Limestone Powder 376-392
Authors: Alban Metallari, Mirco Wahab, and Thomas A. Bier

SP-362—29

Direct and Delayed Dosing: A New Approach to Quantify Ineffective Superplasticizers 393-411
Authors: Shengnan Sha, Moghul Sirajuddin, and Robert J. Flatt

SP-362—30

Quantitative Analysis of Fly Ash Hydration Products Formed in Sulfate Environment..... 412-431
Authors: Rajaram Dhole, Michael D.A. Thomas, Kevin J. Folliard, and Thanos Drimalas

SP-362—31

Assessing Fly Ash Beneficiation's Process Effect on Concrete Performance 432-443
Authors: Rennan Medeiros and Leandro. F. M. Sanchez

SP-362—32

Utilization of Electric Arc Furnace Slag for CO₂ Storage in Mortar using Pressurized CO₂ Curing Condition 444-452
Authors: Indong Jang, Namkon Lee, Hoon Moon, Gijoon Park, Gumsung Ryu, and Jungjun Park

SP-362—33

Predicting the Microstructure Stabilization Time from Electrical Resistivity Measurements 453-460
Authors: Thomas Bernard and William Wilson

SP-362–34	
Ternary Cement Mixtures and Marble and Granite Waste in Self-Compacting Concrete: An Evaluation of Fresh and Carbonation Properties	461-473
Authors: Mara M. L. Pereira, Arthur A. Palma e Silva, and Valdirene M. S. Capuzzo	
SP-362–35	
Combined Effect of Polycarboxylate Ether and Phosphonated Superplasticizers in Limestone Calcined Clay Cement	474-486
Authors: Sirajuddin Moghul, Sruthi Sreeram, Shengnan Sha, Franco Zunino, and Robert J. Flatt	
SP-362–36	
Hardening and Shrinkage Kinetics of Geopolymers	487-498
Authors: Hugo Thuilliez, Christophe Lanos, Annabelle Phelipot-Mardelé, and Gérard Mauvoisin	
SP-362–37	
A Novel Clinker-Free Binary Paste with Biomass Fly Ash and Slag.....	499-506
Authors: Xuhui Liang and Guang Ye	
SP-362–38	
Valorization of Harbour Dredging Sediments as Supplementary Cementitious Materials	507-519
Authors: Manassée Foksou Tchilia, Victor Brial, and Claudiane Ouellet-Plamondon	
SP-362–39	
Hydration Properties and Physical Characteristics of Belite Cements	520-534
Authors: Antonio Telesca, Milena Marroccoli, Neluta Ibris, Fulvio Canonico, and Daniela Gastaldi	
SP-362–40	
Particle Interaction in Metakaolin Suspensions.....	535-546
Authors: Sergio Real, Laura González-Panicello, Francisca Puertas, and Marta Palacios	
SP-362–41	
On the Formation of Al/Fe-AFm Solid Solutions During Hydration of Fe-Rich Binders	547-557
Authors: Aurore Lechevallier, Mohend Chaouche, Jérôme Soudier, and Guillaume Renaudin	
SP-362–42	
Upcycling Basic Oxygen Furnace (BOF) Slag into a Carbon-Negative Supplementary Cementitious Material (SCM) through Mineral Carbonation	558-569
Authors: Hadi Kazemi Kamyab, Peter Nielsen, Bert Riems, and Liesbeth Horckmans	
SP-362–43	
Low-Carbon Concrete Achieved through Rheology Modification	570-584
Authors: Lesley Ko, Jeffery Bury, and Charles Nmai	
SP-362–44	
Development Of Bauxite Residue and Class F Fly Ash-Based Geopolymer Concrete	585-593
Authors: Dena Shalaby, Émilie Garneau, Mathieu Fiset, Joao Augusto Lago Araujo Seixas, and Ahmed Rahem	
SP-362–45	
Leaching of Magnesium Phosphate Cement Pastes: Influence of the Mg/P Molar Ratio.....	594-609
Authors: Laura Diaz Caselles, Ganaël Bon, Céline Cau Dit Coumes, Pascal Antonucci, Angélique Rousselet, Adel Mesbah, and Valérie Montouillout	

SP-362—46	
Rheology and Early-Age Reactivity of Calcined Kaolinite	610-614
Authors: Yannick Demeusy, Sandrine Gauffinet, and Christophe Labbez	
SP-362—47	
Effect of Carbonation on Mechanical Properties and Microstructure of One-Part Geopolymer Based on Thermo-Mechanical-Synthesis Sediments Fly Ash Mix	615-629
Authors: Elie Mahfoud, Khadim Ndiaye, Walid Maherzi, Salima Aggoun, Nor-Edine Abriak, and Mahfoud Benzerzour	
SP-362—48	
Influence of Calcination Temperature on the Properties of Clay.....	630-638
Authors: Mehnaz Dhar and Shashank Bishnoi	
SP-362—49	
Marine Dredged Sediments as a Partial Alternative to Sand in Cementitious Systems using Particle Packing Optimization.....	639-650
Authors: Parisa Heidari, William Wilson, and Patrice Rivard	
SP-362—50	
High Initial Strength Low Clinker Ternary Binders for Walls with Integrated Formwork	651-670
Authors: Lucas Mosser, Eric Garcia Diaz, Patrick Rougeau, and François Jacquemot	
SP-362—51	
Clay Calcination Methods and Composition Impacts on Calcined Clay Properties.....	671-681
Authors: Anastasia Koutsouradi, Anne J. Damø, Wilson R. Leal da Silva, Mehnaz Dhar, and Peter A. Jensen	
SP-362—52	
Use of High SO ₃ Coal Ash as Supplementary Cementitious Materials in Concrete	682-700
Authors: Gopakumar Kaladharan, Moe (Mohammadreza) Sharbaf, and Farshad Rajabipour	
SP-362—53	
Experimental-Numerical Studies of Moisture-Toluene Buffering Capacity of HLC	701-719
Authors: Anh Dung Tran Le, Jianshun S Zhang, Zhenlei Liu, Fathia Dahir Igue, Bing Beverly Guo, Jérôme Lasne, Marie Verrielle, and Frédéric Thevenet	
SP-362—54	
Early Reactivity Assessment of Calcined Clays and the Impact of Secondary Phases	720-732
Authors: Tafadzwa Ronald Muzenda, Fabien Georget, and Thomas Matschei	
SP-362—55	
Insights into Phase Assemblage in MgO-Al ₂ O ₃ -(SiO ₂)-CO ₂ Systems.....	733-737
Authors: H. Nguyen, E. Bernard, and P. Kinnunen	
SP-362—56	
Enhancing Reactivity of Calcined Clays for Sustainable Cement Production through Optimization of Rotary Kiln Parameters	738-762
Authors: Abdelmoujib Bahhou, Yassine Taha, Yasmine Rhaouti, Mohamed El Amal, Rachid Hakkou, Mostafa Benzaazoua, and Arezki Tagnit-Hamou	
SP-362—57	
Chloride Diffusion in Geopolymers Containing Phase Change Materials	763-773
Authors: Bouha El Moustapha, Stéphanie Bonnet, and Abdelhafid Khelidj	

SP-362—58

Durability of Concretes with Low Environmental Emissions Based on Ternary Binders: Corrosion Resistance and Positioning with Respect to the Performance Approach..... 774-782
Authors: Thomas Pernin, Suzanne Le Thierry, Jonathan Mai-Nhu, François Jacquemot, Lucas Mosser, and Patrick Rougeau

SP-362—59

Assessing Pozzolanic Reactivity of Reclaimed Fired Clay Roof Tiles and Bricks in Presence of Ground Limestone 783-793
Authors: Bernadin Guillaume, Théodore Serbource, Sandrine Gauffinet, Marie-Noëlle de Noirfontaine, and Laurent Izoret

SP-362—60

Impact of the Type of Binder on the Properties of Deep Soil Mixing Materials..... 794-812
Authors: Clément Bideux, Javad Eslami, Anne-Lise Beaucour, Albert Noumowe, Fabrice Mathieu, and Philippe Gotteland

SP-362—61

Effect of Sorghum Shives & Wheat Straw on the Properties of Compressed Earth Blocks 813-827
Authors: Imane Gharbage, Ferhat Benmahiddine, and Nassim Sebaibi

SP-362—62

Investigations of Ettringite Morphology with the Use of Different Retarders in CSA/OPC Blends..... 828-840
Authors: Tristana Duvallet, Robert Rathbone, Robert Jewell, and Christopher Moore

SP-362—63

Valorization of Primary Aluminum Industry By-Product in Cement Materials..... 841-853
Authors: Victor Brial, Laurent Birry, and Claudiane Ouellet-Plamondon

SP-362—64

Utilization of Waste CO₂ Generated Vaterite in Blended Cements 854-870
Authors: Ying Wang, Jesus Gonzalez, and Craig W. Hargis

SP-362—65

Study on Use of MSWI Fly Ash with Mainstream Supplementary Cementitious Materials 871-886
Authors: Kwangwoo Wi, Oguzhan Sahin, Kejin Wang, and Yunsu Lee

SP-362—66

Resistance to Chloride Ingress of Eco-Efficient Concrete Proportioned through Particle Packing Models (PPMs) 887-900
Authors: M.T. de Grazia, L.F.M. Sanchez, and A. Leemann

SP-362—67

Enhancing the Journey Towards Concrete Net Zero: The Role of Eco-Efficient Concrete, Particle Packing Models, and Limestone Fillers 901-915
Authors: M.T. de Grazia and L.F.M. Sanchez

SP-362—68

Efficiency of Using Recycled Coarse Aggregate for Internal Curing of Blended Cement Concretes 916-929
Authors: Troian Viacheslav, Gots Volodymyr, Bruno Alex, Panek Rafał, and Flatt Robert J.

SP-362—69

Comparative Study of the Mechanical and Durability Performance of Low Carbon Concrete Matrices with Alternative SCMS 930-940
Authors: Eliana Soldado, Hugo Costa, Ricardo do Carmo, and Eduardo Júlio

SP-362–70

Harvested Fly Ash for Supplementary Cementitious Materials 941-952
Authors: Nader Ghafoori, Ariful Hasnat, and Aderemi Gbadamosi

SP-362–71

Investigation of the CO₂ Sequestration by Accelerated Carbonation as a Function of the Composition, Origin, Production Process, and Age of Recycled Concrete Aggregates 953-965
Authors: Sandrine Braymand and Sébastien Roux

SP-362–72

Metals in Mine Tailings and Prospects for Use in Cementitious Materials 966-975
Authors: Anne Mette Tholstrup Bagger, Stefanie Lode, Wolfgang Kunther, and Pernille Erland Jensen

SP-362–73

Effect of Superplasticizer on Water Availability and Rheological Properties of Cement Paste Containing Calcined Clay 976-985
Authors: L. Ferrari, V. Bortolotti, N. Mikanovic, M. Ben-Haha, and E. Franzoni

SP-362–74

Mechanical Behavior of Concrete Based on Aquaculture Co-Products 986-997
Authors: Camille Martin--Cavallé, Alexandra Bourdot, Olivier Rateau, Malo L'helguen, Nassim Sebaibi, and Rachid Bennacer

SP-362–75

Data Mining Heidelbergmaterials Database: Portland Cement – Limestone Systems Optimization with Machine Learning 998-1005
Authors: Alexandre Ouzia and Mohsen Ben Haha

SP-362–76

Chemical Reactivity Assessment of Glass Powder in R³ Method Synthetic Concrete Pore Solution by Accelerated Solubility Testing 1006-1019
Authors: Wena de Nazaré do Rosario Martel, Josée Duchesne, and Benoît Fournier

SP-362–77

Effect of Biochar on the Microstructure and Mechanical Response of Cement Paste 1020-1032
Authors: Renata Lorenzoni, Alexander Mezhov, Tobias Fritsch, Wolfram Schmidt, and Sabine Kruschwitz

SP-362–78

Mechanical Properties and Freezing and Thawing Behavior of 3D Printing Concrete Containing Recycled Fine Aggregates from Construction and Demolition Waste 1033-1051
Authors: Yeakleang Muy, Luc Courard, Xavier Garnavault, David Bulteel, Sébastien Rémond, Maria Taleb, and Julien Hubert

Interface Properties Between Reactive Magnesia Cement Matrix and GFRP Rebar

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ABSTRACT

Reactive magnesia cement (RMC) is an emerging class of low-alkaline and CO₂-sequestering binder, which can mitigate the deterioration of GFRP reinforcements induced by a high-alkaline environment, e.g., in Portland cement. This study investigated the slip behavior of GFRP rebar embedded in RMC composite, which varies with carbonation depth significantly. The variation of the interfacial bond was determined by a specially designed push-out test of the GFRP core; the variation of the carbonation degree and microstructure was examined by SEM-EDX, XRD, TGA, and acid digestion tests. Both properties demonstrated a similar trend, decreasing rapidly with increasing depth. A new finite element model that considers the depth-dependency of the matrix compositions and the rebar-to-matrix interfacial bond is established. It can predict the constitutive bond-slip behavior of a long GFRP rebar embedded in an RMC composite with non-uniform carbonation.

Keywords: glass fiber reinforced polymer (GFRP), reactive magnesia cement (RMC), bond-slip behavior, non-uniform carbonation, CO₂ sequestration.

INTRODUCTION

Reactive magnesia cement (RMC) is low-carbon binder, which can be manufactured by calcining minerals at a lower temperature than Portland cement (PC) (700-1000 °C vs. 1450 °C) [1]; it can chemically sequester CO₂ from the ambient air in two steps – first the cement grains react with water to form Brucite (Mg(OH)₂), which contributes little to strength development; second, the Brucite further react with the extra water and the dissolved CO₂ to form various hydrated magnesium carbonates (HMCs) [2, 3]. The formation of HMCs is essentially a process of solid volume expansion, which densifies the microstructure and provides a high strength of RMC matrix [1, 4, 5]. Furthermore, at a low calcination temperature (700 °C), the HMCs have the potential to be fully decomposed into RMC, which can be used for making new concretes [6, 7]. However, the RMC-based composites have an intrinsic problem, i.e., their relatively low alkalinity (pH = 9 to 10 after carbonation [8]) does not allow the steel bars to be used as internal reinforcement. This is because under a pH lower than 11.5, the passive layer of the steel rebar will be consumed quickly, and early-age rebar corrosion will appear [9, 10].

Glass fiber-reinforced polymer (GFRP) is a class of high-strength composites that are widely used in structural strengthening and retrofitting; it is promising to use the GFRP bars as the internal reinforcements for the RMC-based concrete, because it contains no metal elements and can be free from corrosion [11]. A recent study has demonstrated that the mechanical degradation of GFRP rebar is indeed largely alleviated when the high-pH PC is replaced by the more neutral RMC [12]. After being exposed to hot water (40 °C) for 90 days, the strength retention is 73.6% in the PC concrete, while it is 90.4% in the RMC-based composites. However, RMC-based composites are heterogeneous – the microstructure and strength vary significantly with the carbonation degree, which is governed by CO₂ diffusion and decreases with the increasing distance to the surface [13, 14]. Such heterogeneity suggests that the rebar-to-matrix interfacial strength is likely to vary with the depth, especially when the rebars are aligned perpendicular to the surface (e.g., the anchorage rebars for slope stability). As a result, the traditional pull-out test [15, 16] is unable to characterize the interface properties between RMC and GFRP at varying depths.

This work investigated the effect of depth-dependent carbonation on the bond-slip behavior of a GFRP rebar embedded in RMC-based composites. Besides the traditional long-rebar pull-out test to characterize the overall interfacial behavior, a new push-out test was carried out to the GFRP-RMC discs sliced from different depths to characterize the local interfacial behavior. The microstructure and chemical composition of the RMC discs were analyzed with various material characterization technologies to study the carbonation dependency on depth. Finite element (FE) models, which use the depth-dependent local interfacial properties as input, were developed to predict the overall bond-slip curve of GFRP-RMC composites. The models were validated by the experimental results.