# Recent Advances in Concrete Technology and Sustainability Issues

Proceedings
Fifteenth International Conference
Milan, Italy

July 2022

Denny Coffetti
Luigi Coppola
Terence C. Holland

American Concrete Institute

SP-355

# Recent Advances in Concrete Technology and Sustainability Issues--Conference Proceedings

Sponsored by
ACI Committees 130, 201, 209, 212

Fifteenth International Conference
Milan, Italy
July 13-15, 2022

Editors:
Denny Coffetti,
Luigi Coppola, and
Terence Holland

American Concrete Institute
*Always advancing*

SP-355

First printing, June 2022





Editorial production: Susan Esper and Ryan Jay

ISBN-13: 978-1-64195-184-5

## Preface

The Canada Centre for Mineral and Energy Technology (CANMET) of Natural Resources of Canada, Ottawa, ON, Canada, has played a significant role for more than 40 years in the broad area of concrete technology in Canada. In recent years, CANMET has become increasingly involved in research and development dealing with supplementary cementitious materials, high-performance normalweight and lightweight concretes, and alkali-aggregate reactions. As part of CANMET's technology transfer program, an international symposium on Advances in Concrete Technology was sponsored jointly with the American Concrete Institute (ACI) and other organizations in Athens, Greece, in May 1992. In June 1995, CANMET, in association with ACI and other organizations in Canada and the United Staes, sponsored the Second CANMET/ACI Symposium on Advances in Concrete Technology in Las Vegas, NV, USA. For the Athens symposium, the CANMET publication "Advances in Concrete Technology," constituted the proceedings of the symposium. The proceedings from the Las Vegas symposium were published by ACI as SP-154.

In August 1997, CANMET, in association with ACI and other organizations in Canada and New Zealand, sponsored the Third CANMET/ACI Symposium on Advances in Concrete Technology in Auckland, New Zealand. The main purpose of the symposium was to bring together representatives from industry, universities, and government agencies to present the latest information on concrete technology, and to explore new areas of research and development. Thirty-three refereed papers from 15 countries were presented and distributed at the symposium. The proceedings were published as ACI SP-171.

In June 1998, CANMET, in association with ACI, Japan Concrete Institute (JCI), and several other organizations in Canada and Japan, sponsored the Fourth CANMET/ACI Conference on Recent Advances in Concrete Technology in Tokushima, Japan. More than 80 papers from 20 countries were received and reviewed in accordance with the policies of ACI. Sixty-one refereed papers were accepted for presentation at the conference and for publication as ACI SP-179. In addition to the refereed papers, more than 30 papers were presented and distributed at the conference.

In July-August 2001, CANMET, in association with ACI and several organizations in Singapore, sponsored the Fifth CANMET/ACI Conference on Recent Advances in Concrete Technology in Singapore. More than 100 papers from 25 countries were received and reviewed in accordance with the policies of ACI. Forty-six refereed and more than 25 additional papers were accepted for presentation at the conference. The proceedings of the conference were published as ACI SP-200.

In June 2003, CANMET, in association with ACI and several organizations in Romania, sponsored the Sixth CANMET/ACI Conference on Recent Advances in Concrete Technology in Bucharest, Romania. More than 40 papers presented at the conference were distributed "as received," and no formal ACI special publication was published.

In May 2004, CANMET, in association with ACI and several other organizations in the United States, sponsored the Seventh CANMET/ACI Conference on Recent Advances in Concrete Technology in Las Vegas, NV. Seventeen refereed papers from more than 10 countries were presented and distributed at the conference. The proceedings of the conference, consisting of the refereed papers, were published as ACI SP-222. In addition to the refereed papers, 20 additional papers were presented and distributed at the conference.

In May 2006, CANMET, in association with ACI and several other organizations in Canada and the United States, sponsored the Eighth CANMET/ACI Conference on Recent Advances in Concrete Technology in Montreal, QC, Canada. The proceedings of the conference, consisting of 17 refereed papers, were published as ACI SP-235. In addition to the refereed papers, more than 30 additional papers were presented and distributed at the conference.

In May 2007, CANMET, in association with ACI and several other organizations in Canada, Europe, and the United States, sponsored the Ninth CANMET/ACI Conference on Recent Advances in Concrete Technology in Warsaw, Poland. The proceedings of the conference consisting of 10 refereed papers, were published as ACI SP-243. More than 20 additional papers were presented and distributed at the conference.

In October 2009, ACI, in association with several organizations in Canada, Europe and the United States, sponsored the Tenth ACI Conference on Advances in Concrete Technology in Seville, Spain. The proceedings of the conference, consisting of 20 refereed papers, were published as ACI SP-261. In addition to the refereed papers, more than 20 additional papers were presented at the conference and published in a supplementary papers volume.

In May 2010, the Committee for the Organization of International Conferences (COIC) (formerly CANMET/ACI Conferences), in association with the Chinese Ceramics Society (CCS) and several other organizations in China, sponsored the Eleventh International Conference on Advances in Concrete Technology and Sustainability Issues in Jinan, China. More than 40 papers were presented at the conference. The proceedings of the conference were published by the CCS, Beijing, China.

In October 2012, the COIC, in association with ACI, sponsored the Twelfth International Conference on Advances in Concrete Technology and Sustainability Issues in Prague, Czech Republic. The proceedings of the conference, consisting of more than 30 refereed papers, were published as ACI SP-288. In addition to the refereed papers, more than 40 other papers were presented at the conference and published in a supplementary papers volume.

In July 2015, the COIC, in association with ACI, sponsored the Thirteenth International Conference on Advances in Concrete Technology and Sustainability Issues in Ottawa, ON, Canada. The proceedings of the conference, consisting of 28 refereed papers, were published by ACI as SP-303. In addition to the refereed papers, more than 40 other papers were presented at the conference and published in a supplementary papers volume.

In October 2018, the CCS and the China Academy of Building Research (CABR), Beijing China, in association with the COIC sponsored the Fourteenth International Conference on Recent Advances in Concrete Technology and Sustainable Issues in Beijing, China. The proceedings of the conference, consisting of 19 refereed papers, were published by ACI as SP-330. In addition to the refereed papers, more than 52 other papers were presented at the conference and published in a supplementary papers volume.

In July 2022, after a postponement for the COVID-19 pandemic, the ACI Italy Chapter and the University of Bergamo, Italy, sponsored the Fifteenth International Conference on Recent Advances in Concrete Technology and Sustainable Issues in Milan, Italy.

The proceedings of the conference, consisting of 44 refereed papers, were published by ACI as SP-355. In addition to the refereed papers, about 20 other papers were presented at the conference and published in a supplementary papers volume.

The main topics of the papers presented at the conference include: the deterioration of concrete structures; the corrosion of metallic reinforcement; the repair techniques of damaged concrete structures by using shrinkage-compensating cement-based mixtures; the protection of concrete structures by special materials to obtain watertight concrete; the reduction of the damage caused by alkali-silica reaction; the use of mineral additions such as fly ash, silica fume, and ground-granulated blast-furnace slag to improve the durability of concrete structures; and the production of concrete by reducing gas emissions and energy consumption such as the use of binders alternative to portland cement (alkali-activated materials, geopolymers, sulphoaluminate cement) and recycling of wastes coming from different sources.

Thanks are extended to the reviewers for the valuable efforts in reviewing all the manuscripts published in the conference proceedings and in the supplementary volume.

The guidance from Dr. V. M. Malhotra and Prof. M. Collepardi, the Honorary Chairpersons of the conference, is sincerely appreciated.

Also, acknowledged is the support the American Concrete Institute for the publication of the proceedings (ACI SP-355).

The Editors
Dr. Denny Coffetti
Prof. Luigi Coppola
Dr. Terence Holland

## TABLE OF CONTENTS

# Low-Carbon Durable Concrete for the New Genoa's San Giorgio Bridge

Gilberto Artioli, Anna Bravo, Stefano Broggio, Giorgio Ferrari,
Francesco Santonicola, Francesco Surico, Luca Torelli,
Luca Valentini, Andrea Zecchini

**Synopsis**: The new San Giorgio bridge replaced the Polcevera viaduct, built between 1963 and 1967 and collapsed during a storm in summer 2018. The new bridge was designed by Renzo Piano and is made by 19 steel spans supported by 18 concrete pillars. Beside the architectural aspects, special attention was devoted to the mix-design of the pillars, to ensure the production of durable concrete in the marine environment. The use of slag cement combined with limestone filler and polycarboxylate superplasticizers allowed to cast flowable concrete associated with low water to cement ratio and high final compressive strength. A new generation accelerating admixtures, working on the homogeneous nucleation technology, was used to accelerate the cement hydration and gain early compressive strength to speed-up the elevation of the pillars. In the present paper, the advantage of using the new admixture is discussed both in terms of early strength development and microstructure of the cement paste. Beside the improvement of the early strength development, the new admixture reduced the water permeability and the chloride diffusion and improved the resistance to carbonation of the concrete used for the pillars, with further advantages for the durability of this structure.

**Keywords:** carbonation, chloride penetration, durability, homogeneous nucleation, microstructure, PCE-nanocomposites, water permeability.