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# The 13th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures

Editors:
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Maria Lopez de Murphy, William J. Gold

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American Concrete Institute
Always advancing

# The 13th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures

Sponsored by Committee 440

The Concrete Convention and Exposition
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Anaheim, CA, USA

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The papers in this volume have been reviewed under Institute publication procedures by individuals expert in the subject areas of the papers.



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## Preface

Fiber-reinforced polymer (FRP) composite materials been widely used in civil engineering new construction and repair of structures due to their superior properties. FRP provides options and benefits not available using traditional materials. The promise of FRP materials lies in their high-strength, lightweight, noncorrosive, nonconducting, and nonmagnetic properties. ACI Committee 440 has published reports, guides, and specifications on the use of FRP materials for may reinforcement applications based on available test data, technical reports, and field applications. The aim of these document is to help practitioners implement FRP technology while providing testimony that design and construction with FRP materials systems is rapidly moving from emerging to mainstream technology.

The first International Symposium on Fiber-Reinforced Polymer Reinforcement or reinforced Concrete Structures (FRPRCS) conference was sponsored by the American Concrete Institute (ACI) and held in conjunction with ACI Spring convention in Vancouver, British Columbia, Canada in 1993. Since 1993, FRPRCS has become a prestigious and reputable international conference, and the symposia have been held in Ghent, Belgium (1995); Sapporo, Japan (1997); with ACI in Baltimore, USA (1999); Cambridge, England (2001); Singapore (2003); with ACI in Kansas City, USA (2005); Patras, Greece (2007); Sydney, Australia (2009); with ACI in Tampa, USA (2011); Guimarães, Portugal (2013); and Nanjing, China (2015).

FRPRCS continued the success of the previous conferences and the 13th International Symposium on Fiber-Reinforced Polymer Reinforcement of Concrete Structures (FRPRCS-13) was organized by ACI Committee 440 and held on October 14 and 15, 2017 at the ACI Fall 2018 convention in Anaheim, CA, USA. FRPRCS-13 attracted interest from researchers, practitioners, and manufacturers involved in the use of fiber-reinforced polymers (FRPs) as reinforcement for concrete masonry structures. This includes the use of FRP reinforcement in new construction and FRP for strengthening and rehabilitation of existing structures. The papers/presentations not only emphasized the experimental, analytical, and numerical validations of using FRP composites but also aimed at providing insights needed for improving existing guidelines. New frontiers of FRP research were explored that provide information on emerging materials, systems, and applications for extreme events such as fire and earthquakes. The technical papers also featured discussions on sustainability, novel applications, new technologies, and long-term field data that will result in greater acceptance and use of FRP composites technology by practitioners. Attendees were able to:

a) Understand many of the critical topics of research related to the use of FRP reinforcement in new construction and FRP systems for strengthening and rehabilitating existing structures.
b) Develop knowledge on existing international codes and guidelines on these materials and systems.
c) Exposure to new FRP material technologies as they relate to reinforcing and strengthening concrete and masonry structures.
d) Learn practical aspects of FRP reinforcement materials and systems in field applications for new construction and rehabilitation of existing concrete and masonry structures.

This Special Publication consists of a total of 54 accepted papers out of 63 submissions from 18 countries. 65 presentations were presented over made two days in sixteen special technical sessions. These sessions provided a worldwide state-of-the-art forum for researchers, civil/structural engineers, contractors, consultants, practitioners, and regulatory authorities to exchange recent advances in both research and practice, and to share information, experience, and knowledge in the implementation of FRP technology. The technical papers presented at the sessions and published in this volume included the most recent analytical and experimental research work as well as selected field applications, design, and construction guidelines. The sessions were well attended and generated substantial technical discussion and exchange of new technology. The sessions held included:

FRPRCS A1 —Bond and Anchorage of FRP Bars, Grids, and Laminates to Concrete -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of the bond and anchorage behavior of FRP bars, plates, and tendons to concrete.

FRPRCS B1—Strengthening of Concrete Structures Using FRP Systems -> 5 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP composites for the strengthening of reinforced concrete structures.

FRPRCS A2 —Bond and Anchorage of FRP Bars, Grids, and Laminates to Concrete -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of the bond behavior of different FRP-concrete systems.

FRPRCS B2—Testing of FRP Material Characteristics -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of FRP material characteristics.

FRPRCS A3—Emerging FRP Systems -> 5 Presentations
This session emphasized the experimental, analytical, and numerical validations of using emergent FRP systems in concrete infrastructure.

FRPRCS B3—Strengthening of Concrete Structures Using FRP Systems-> 5 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP composites for the strengthening of reinforced concrete structures.

FRPRCS A4—Global Codes and Standards -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP-reinforced or -strengthened concrete structures and will be aimed at providing insights needed for improving existing design guidelines.

FRPRCS B4—Advances in Uses of FRP in Concrete and Masonry -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP in concrete and masonry structures.

FRPRCS A5—Seismic Resistance of Concrete Structures Using FRP Materials -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP composites in seismic structural applications.

FRPRCS B5—Strengthening of Concrete Structures Using FRP Systems -> 4 Presentations

This session emphasized the experimental, analytical, and numerical validations of using FRP composites for the strengthening of reinforced concrete structures.

FRPRCS A6—FRP Reinforcement of Concrete and Masonry Walls -> 3 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP composites for the reinforcement of concrete and masonry walls.

FRPRCS B6—Field Applications and Case Studies -> 4 Presentations
This session emphasized field applications and case studies of using FRP composites for internal reinforcement of concrete.

FRPRCS A7—Effects of Extreme Events on FRP-Reinforced/Strengthened Structures -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of extreme events on FRP-reinforced or -strengthened concrete.

FRPRCS B7—Effect of Environment on Durability -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of the effects of the environment on the durability of FRP-reinforced or –strengthened concrete structures.

FRPRCS A8—Design and Performance Under Long-Term Loading and Environmental Exposure -> 3 Presentations
This session emphasized the experimental, analytical, and numerical validations of FRP-reinforced or strengthened concrete structures under long term loading and environmental exposure.

FRPRCS B8—Advances in Uses of FRP in Concrete and Masonry -> 4 Presentations
This session emphasized the experimental, analytical, and numerical validations of using FRP composites for concrete and masonry structures.

In accordance with the standard review procedures established by ACI, all papers were reviewed by at least two experts in the subject area and approved for publication. All submitted papers were given serious consideration before a decision regarding publication was made.

This volume represents the thirteen in the symposium series and could not have been put together without the help, dedication, cooperation, and assistance of many volunteers and ACI staff members. First, we would like to thank the authors for meeting our various deadlines for submission, providing an opportunity for FRPRCS-13 to showcase the most current work possible at the symposium. Second, the International Scientific Steering Committee, consisting of many distinguished international researchers, including chairs of past FRPRCS symposia, many distinguished reviewers and members of the ACI Committee 440 who volunteered their time and carefully evaluated and thoroughly reviewed the technical papers, and whose input and advice have been a contributing factor to the success of this volume.

**Editors of this volume and chairs of the FRPRCS-13 international Symposium**
Raafat El-Hacha
Lijuan (Dawn) Cheng
Maria Lopez de Murphy
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