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Fiber Reinforced Concrete for Sustainable Structures

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American Concrete Institute
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Preface

Fiber Reinforced Concrete for Sustainable Structures

In recent years, human sustainability has been increasingly associated with the integration of economic, social and environmental spheres. The cement-based materials industry is committed to minimizing any negative impact it may contribute to the natural environment. The papers included in this special publication discuss some of the sustainability aspects of using fibers in a chopped and textile form in concrete structures, including the role of fiber reinforcement in enhancing durability, optimized structure size, reduced weight, reduced footing dimensions and recyclability, lessons learned from real life situations and lay the foundation for Life Cycle Engineering Analysis with fiber reinforced concrete.

Recognizing the sustainability aspects of using fibers in cement-based materials, ACI Committee 544 Fiber Reinforced Concrete, together with 549 Thin Reinforced Cementitious Products and Ferrocement and 130 Sustainability of Concrete sponsored a technical session entitled Advances in Fiber Reinforced Concrete for Sustainable Structures at the Fall 2012 ACI Convention in Toronto and two technical sessions on the same topic at the Fall 2013 ACI Convention in Phoenix. Papers were presented by invited international experts from Belgium, Brazil, Canada, Italy, Israel, Turkey and the United States of America.

This Symposium Publication (SP) contains eight papers which provide insight on the state of the art of the topic in the academia, in the industry and in real life applications. The topics of the papers cover sustainability aspects of using fiber reinforced concrete ranging from durability and interface mechanisms of natural fiber reinforced concrete (FRC), evaluation of eco-mechanical performance of FRC, reducing carbon dioxide emissions of concrete, as well as applications of fiber reinforcement for self-consolidating concrete, bridge link slabs, extruded prefabricated elements, slab systems and fabric-reinforced cementitious matrix systems for strengthening unreinforced masonry walls. The papers included in this publication have been peer reviewed by international experts in the field according to the guidelines established by the American Concrete Institute.

On behalf of ACI Committee 544 Fiber Reinforced Concrete, and committees 549 Reinforced Cementitious Products and Ferrocement and 130 Sustainability of Concrete, the editors would like to thank all the authors for their contributions and the reviewers for their assistance, valuable suggestions and comments.

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On the Durability and Interface Mechanisms of Natural FRC: A Material for the Sustainable Construction Industry

by Flávio de Andrade Silva, João de Almeida Melo Filho, Saulo Rocha Ferreira and Romildo Dias Toledo Filho

Synopsis: The durability performance and interface transition zone of natural fiber reinforced concrete has always been a major concern. Natural fibers due to its hydrophilic nature present a high volume variation which may cause degradation in the fiber-matrix interface. Furthermore, natural FRC may undergo an enhanced aging process, while submitted to a humid environment during which they may suffer a reduction in ultimate strength and toughness. This paper presents how the use of a matrix with low content of calcium hydroxide can mitigate the embrittlement process of natural fibers. The durability performance of the composite systems is examined and the mechanisms for the significant delay in the fiber degradation when the total amount of calcium hydroxide is reduced from the matrix discussed. Furthermore, it is shown how the repeated wetting and drying cycles affects the fiber-matrix interface. Pull-out tests were performed in sisal fiber cement composite systems to study the mechanisms that influence the fiber-matrix bond. The results showed that the use of a matrix with low amount of calcium hydroxide improved the composite durability and that the wetting and drying process reduced the water absorption capacity of the fiber and increased the fiber-matrix bond.

Keywords: cement based composites, natural fibers, sisal, durability, interface, microstructure.

ACI member **Flávio de Andrade Silva** is an Assistant Professor in the Department of Civil Engineering at the Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), Brazil. He is a voting member of ACI Committee 544 (fiber reinforced concrete), secretary of RILEM TC 240 FDS (A framework for durability design of fiber reinforced strain-hardening cement-based composites (SHCC)) and a member of RILEM TC CMS (thermal cracking of massive concrete structures). His research interests include fiber-reinforced cement composites, innovative cement based composites, concrete durability and natural fibers.

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INTRODUCTION

In the line of development of materials reinforced with natural fibers, many researches have been carried out on cementitious and polymeric matrix composites and promising results have been achieved, showing an improvement in durability, strength and ductility [1-5]. The use of natural fibers as reinforcement shows to be beneficial in many aspects, including sustainability, availability, low cost and low energy consumption. Natural fiber reinforced composites have the potentiality to become the ultimate green material option, minimizing the use of natural resources and overall lifetime impact.

Sisal as well as other natural fiber cement based composites produced with ordinary Portland cement (OPC) matrices undergo an enhanced aging process, while submitted to a humid environment during which they may suffer a reduction in ultimate strength and toughness. The aging process is due to fiber mineralization and results in a reduction of the tensile strength of fibers and a decrease of the fiber pull-out ligament after fracture. This mineralization process is a result of migration of hydration products (mainly $Ca(OH)_2$) to the fiber structure [1,3]. Several works found in the literature discussed the durability problem of natural fibers when used in a cement based matrix and some of them presented counter-measures to avoid the fiber mineralization process [6-18]. The most promising treatment is the partial substitution of Portland cement by pozzolanic materials in order to reduce the amount of calcium hydroxide in the matrix.

Toledo and co-workers [9] evaluated sisal and coir fiber reinforced cement composites durability by means of accelerated aging processes. Counter-measures to avoid fiber degradation such as carbonation of the matrix in a CO_2-rich environment, immersion of fibers in slurried silica fume prior to incorporation in the ordinary Portland cement matrix, partial replacement of OPC matrix by undensified silica fume or blast-furnace slag and a combination of fiber immersion in slurried silica fume and cement replacement was investigated. Regarding to the tests in specimens with partial cement replacement by pozzolanic materials the results obtained indicate that the treatment of the matrix with undensified silica fume was an effective means of slowing down the strength loss and embrittlement of the composites. The specimens incorporating slag were quite sensitive to the cycles of wet and dry and presented a strong deterioration with time.

The previous works [13,14] performed by the authors confirmed that the partial cement replacement by pozzolanic materials in order to complete the consumption of the calcium hydroxide produced during the cement hydration process is the most promising treatment resulting in a composite with increased durability. Results have shown that continuous sisal fiber cement-based composites produced with a